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Cancer Chemotherapy  
Drug Manual  
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# Physicians' Cancer Chemotherapy Drug Manual 2008

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## Preface

The development of effective drugs for the treatment of cancer represents a significant achievement beginning with the discovery of the antimetabolites and alkylating agents in the 1940s and 1950s. The success of that effort can be attributed in large measure to the close collaboration and interaction between basic scientists, synthetic organic chemists, pharmacologists, and clinicians. This tradition continues to flourish, especially as we now enter the world of pharmacogenomics and the rapid identification of new molecular targets for drug design and development.

In this, our eighth edition, we have condensed and summarized a wealth of information on chemotherapeutic and biologic agents in current clinical practice into a reference guide that presents essential information in a practical and readable format. The primary indications, drug doses and schedules, toxicities, and special considerations for each agent have been expanded and revised to take into account new information that has been gathered over the past year. We have included four new agents that have recently been approved by the FDA.

This drug manual is divided into five chapters. Chapter 1 gives an overview of the key principles of chemotherapy that have helped to guide cancer drug development and provides an overview of the growing literature showing a strong linkage between cell cycle control, intracellular signaling pathways, and chemosensitivity. Chapter 2 reviews individual chemotherapeutic and biologic agents that are in current clinical use; these agents are presented in alphabetical order according to their generic name. In this chapter, specific details are provided regarding drug classification and category, key mechanisms of action and resistance, critical aspects of clinical pharmacology and pharmacokinetics, clinical indications, special precautions and considerations, and toxicity. Chapter 3 includes recommendations for dose modifications that are required in the setting of myelosuppression and/or liver and renal dysfunction. Additionally, relevant information is provided highlighting the teratogenic potential of various agents. Chapter 4 presents a review of the combination drug regimens and selected single-agent regimens for solid tumors and hematologic malignancies that are used commonly in daily clinical practice. This section is organized alphabetically by specific cancer type. Finally, Chapter 5 reviews individual agents used to treat chemotherapy-induced nausea and vomiting, a significant toxicity observed with many of the anticancer agents in current practice, and commonly used antiemetic regimens.

It remains our hope that this book will continue to serve as both an in-depth reference and an immediate source of practical information that can be used by physicians and other healthcare professionals actively involved in the daily care of cancer patients. This drug manual continues to be a work in progress, and our goal is to continue to update it on an annual basis and to incorporate new drugs and treatment strategies that reflect the rapid advances in the field of cancer drug development.

Edward Chu, MD  
Vincent T. DeVita, Jr., MD

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Edward Chu, MD

# *Principles of Cancer Chemotherapy*

Vincent T. DeVita, Jr. and Edward Chu

## **Introduction**

The development of chemotherapy in the 1950s and 1960s resulted in curative therapeutic strategies for patients with hematologic malignancies and several types of advanced solid tumors. These advances confirmed the principle that chemotherapy could indeed cure cancer and provided rationale for integrating chemotherapy into combined modality programs with surgery and radiation therapy in early stages of disease so as to provide clinical benefit. The principal obstacles to the clinical efficacy of chemotherapy have been toxicity to the normal tissues of the body and the development of cellular drug resistance. The development and application of molecular techniques to analyze gene expression of normal and malignant cells at the level of DNA, RNA, and/or protein has helped to identify some of the critical mechanisms through which chemotherapy exerts its antitumor effects and activates the program of cell death. This modern-day technology has also provided insights into the molecular and genetic events within cancer cells that can confer chemosensitivity to drug treatment. This enhanced understanding of the molecular pathways by which chemotherapy exerts its cytotoxic activity and by which genetic change can result in resistance to drug therapy has provided rationale for developing innovative therapeutic strategies in which molecular, genetic, and biologic therapies can be used in combination to directly attack these novel targets. As we now move forward in this new millennium, the implementation of such novel treatment approaches provides an important paradigm shift in which therapy is administered. The long-term goal of these intense research efforts is to improve the clinical outcome of cancer patients undergoing treatment, especially in those with cancers that have been traditionally resistant to conventional chemotherapy.

# The Role of Chemotherapy in the Treatment of Cancer

Chemotherapy is presently used in four main clinical settings: (1) primary induction treatment for advanced disease or for cancers for which there are no other effective treatment approaches, (2) neoadjuvant treatment for patients who present with localized disease, for whom local forms of therapy, such as surgery and/or radiation, are inadequate by themselves, (3) adjuvant treatment to local methods of treatment, including surgery and/or radiation therapy, and (4) direct instillation into sanctuary sites or by site-directed perfusion of specific regions of the body directly affected by the cancer.

Primary induction chemotherapy refers to drug therapy administered as the primary treatment for patients who present with advanced cancer for which no alternative treatment exists.<sup>1,2</sup> This has been the mainstay approach to treat patients with advanced, metastatic disease, and in most cases, the goals of therapy are to palliate tumor-related symptoms, improve overall quality of life, and prolong time to tumor progression (TTP) and survival. Studies in a wide range of solid tumors have clearly shown that chemotherapy in patients with advanced disease confers survival benefit when compared to supportive care, providing sound rationale for the early initiation of drug treatment. Cancer chemotherapy can be curative in a relatively small subset of patients who present with advanced disease. In adults, these curative cancers include Hodgkin's and non-Hodgkin's lymphoma, germ cell cancer, and choriocarcinoma, while the curative childhood cancers include acute lymphoblastic leukemia, Burkitt's lymphoma, Wilms' tumor, and embryonal rhabdomyosarcoma.

Neoadjuvant chemotherapy refers to the use of chemotherapy for patients who present with localized cancer for which alternative local therapies, such as surgery, exist but are less than completely effective.<sup>3</sup> For chemotherapy to be used as the initial treatment of a cancer, which would be partially curable by either surgery or radiation therapy, there must be documented evidence for its clinical efficacy in the advanced disease setting. At present, neoadjuvant therapy is most often administered in the treatment of anal cancer, bladder cancer, breast cancer, esophageal cancer, laryngeal cancer, locally advanced non-small cell lung cancer, and osteogenic sarcoma. For some of these diseases, such as anal cancer, gastroesophageal cancer, laryngeal cancer, and non-small cell lung cancer, optimal clinical benefit is derived when chemotherapy is administered with radiation therapy either concurrently or sequentially.

One of the most important roles for cancer chemotherapy is as an adjuvant to local treatment modalities such as surgery and/or radiation therapy, and this has been termed adjuvant chemotherapy.<sup>4</sup> The development of disease recurrence, either locally or systemically, following surgery and/or radiation is mainly due to the spread of occult micrometastases. Thus, the goal of adjuvant therapy is to reduce the incidence of both local and systemic

recurrence and to improve the overall survival (OS) of patients. In general, chemotherapy regimens with clinical activity against advanced disease may have curative potential following surgical resection of the primary tumor, provided the appropriate dose and schedule are administered. Several well-conducted, randomized phase III clinical studies have documented that adjuvant chemotherapy is effective in prolonging both disease-free survival (DFS) and OS in patients with breast cancer, colon cancer, gastric cancer, non-small cell lung cancer, Wilms' tumor, and osteogenic sarcoma. There is also evidence to support the use of adjuvant chemotherapy in patients with anaplastic astrocytomas. Patients with primary malignant melanoma at high risk of metastases derive benefit in terms of improved DFS and OS from adjuvant treatment with the biologic agent  $\alpha$ -interferon, although this treatment must be given for one year's duration for maximal clinical efficacy. Finally, the anti-estrogen tamoxifen is an effective adjuvant in postmenopausal women whose breast tumors express the estrogen receptor. However, because this agent is cytostatic rather than cytotoxic, adjuvant therapy with tamoxifen must be administered on a long-term basis, with the standard recommendation being five years' duration.

## Clinical Endpoints in Evaluating Response to Chemotherapy

### PRIMARY INDUCTION CHEMOTHERAPY

In induction chemotherapy for patients with advanced cancer and measurable disease, it is possible to assess response. The partial response rate is defined as the fraction of patients who demonstrate at least a 50% reduction in measurable tumor mass. Growing evidence suggests that tumor-related symptoms are improved and that quality-of-life indices are higher in patients who show either a response to therapy or a minimal response than in those receiving supportive care, even when the OS is not improved; however, partial responses are also useful in the evaluation of new drugs or new drug regimens to determine whether a specific experimental approach is worthy of further clinical development.

In general, the most important indicator of the effectiveness of chemotherapy has been the rate of complete response.<sup>5</sup> No patient with advanced cancer has ever been cured without first achieving a complete remission. In support of this concept is the fact that the recent advances in the treatment of advanced colorectal, breast, and non-small cell lung cancer have brought significant improvements in overall response rates and survival, yet have not translated into actual cure for these respective diseases. The reason is that the complete

response rate for even these newer regimens has been uniformly lower than 10%. When new anticancer drugs alone or in combination with other agents consistently produce more than an occasional complete remission, they have invariably been proven to have significant clinical benefit in medical practice. Thus, in clinical trials, complete and partial responses should always be reported separately. The most important indicator of the quality of a complete remission is the relapse-free survival from the time treatment is discontinued.

The OS has been the primary endpoint for clinical studies evaluating new treatment agents and/or regimens; however, with the increasing availability of effective second-line and salvage therapies, including surgical resection, the direct effect of a given treatment on OS has become somewhat blurred. To highlight this point, TTP has now replaced OS as the primary endpoint in clinical trials of metastatic colorectal cancer<sup>6</sup> and should be seriously considered for other tumor types for which there are multiple effective treatment options. TTP satisfies several critical requirements as a surrogate endpoint for OS, which includes the following: (1) provides a strong correlation with OS, (2) directly evaluates change in disease burden using standardized radiographic tumor measurement criteria, whether it be WHO or RECIST criteria, (3) is not confounded by subsequent therapies, and (4) offers a clear method of presentation and straightforward analysis. Finally, and perhaps more importantly, the use of TTP as a primary endpoint conserves valuable patient resources and facilitates the process of drug development. From the perspective of clinical trials design, smaller sample sizes are needed, as is the time to accrue the target number of patients and acquire mature clinical data when TTP is the primary endpoint as compared with OS.

## NEOADJUVANT CHEMOTHERAPY

The unique feature of administering chemotherapy to cancer patients with localized disease before or in place of strictly local treatments such as surgery, radiation therapy, or both is the preservation of the presenting tumor mass as a biologic marker of chemosensitivity. Moreover, this approach has allowed the sparing of vital normal organs, including the larynx, the anal sphincter, and the bladder, as the primary tumor is reduced in size and rendered easier to treat by traditional local modalities, such as surgery. As with induction chemotherapy for patients with advanced cancer, it is possible to determine the potential efficacy of a new treatment program on an individual basis. A good response to chemotherapy identifies a patient who may benefit from further treatment. In contrast, a poor response of the primary tumor to chemotherapy identifies a patient for whom alternative methods of treatment should be seriously considered. Removal of residual tumor masses and histologic examination of the tissue allow determination of the viability and character of the remaining tumor cells. Such an approach could result in the development of treatment programs that are shorter, less morbid, and more effective.

One of the other positive aspects of neoadjuvant chemotherapy is that it may be effective in killing micrometastatic disease that is present locally, systemically, or both. Given this fact, the complete extent of disease may not be entirely clear with respect to locoregional lymph node status when chemotherapy is administered in the preoperative setting, either alone or concurrently with radiation therapy. As in the case of locally advanced rectal cancer and/or breast cancer, additional cycles of chemotherapy are generally required to reduce the incidence of both local and systemic recurrence.

## ADJUVANT CHEMOTHERAPY

The rationale for adjuvant chemotherapy is to treat micrometastatic disease at a time when tumor burden is at a minimum, which thereby enhances the potential efficacy of drug treatment. It was assumed that chemotherapy, when administered at such an early stage, would result in significantly higher cure rates. Unfortunately, because the primary tumor has already been removed, the major indicator of clinical efficacy of a chemotherapy program—the complete remission rate—is absent in the adjuvant setting. Treatment is selected for individual patients based on response rates experienced in an entirely different population, namely that of patients with advanced disease. In adjuvant programs, DFS and OS remain the major end points. The DFS in the adjuvant setting measures time to regrowth to clinically detectable levels of cells unresponsive, partially responsive, or exquisitely sensitive to chemotherapy, and this endpoint is the equivalent of the duration of remission of a combined group of those showing complete response, partial response, and nonresponse. Of note, a retrospective analysis was performed by Sargent et al. on 18 randomized phase III adjuvant clinical studies for early-stage colon cancer conducted in the United States and Europe and included a sample size of over 20,000 patients.<sup>7</sup> This pooled analysis showed that 3-year DFS and 5-year OS were highly correlated within patients and across clinical trials and also showed that the vast majority of relapses occur within the first 3 years after completion of adjuvant therapy. Based on this analysis, the U.S. Food and Drug Administration has now agreed to use 3-year DFS as the primary endpoint in adjuvant clinical trials of early-stage colon cancer.

## Principles of Combination Chemotherapy

With rare exceptions (e.g., choriocarcinoma and Burkitt's lymphoma), single drugs at clinically tolerable doses have been unable to cure cancer. In the 1960s and early 1970s, drug combination regimens were developed based

on known biochemical actions of available anticancer drugs rather than on their clinical efficacy. Such regimens were, however, largely ineffective.<sup>8,9</sup> The era of effective combination chemotherapy began when a number of active drugs from different classes became available for use in combination in the treatment of the acute leukemias and lymphomas. Following this initial success with hematologic malignancies, combination chemotherapy was extended to the treatment of solid tumors.

Combination chemotherapy with conventional cytotoxic agents accomplishes several important objectives not possible with single-agent therapy. First, it provides maximal cell kill within the range of toxicity tolerated by the host for each drug as long as dosing is not compromised. Second, it provides a broader range of interaction between drugs and tumor cells with different genetic abnormalities in a heterogeneous tumor population. Finally, it may prevent and/or slow the subsequent development of cellular drug resistance.

Certain principles have been useful in guiding the selection of drugs in the most effective drug combinations, and they provide a paradigm for the development of new drug therapeutic programs. First, only drugs known to be partially effective against the same tumor when used alone should be selected for use in combination. If available, drugs that produce some fraction of complete remission are preferred to those that produce only partial responses. Second, when several drugs of a class are available and are equally effective, a drug should be selected on the basis of toxicity that does not overlap with the toxicity of other drugs to be used in the combination. Although such selection leads to a wider range of side effects, it minimizes the risk of a lethal effect caused by multiple insults to the same organ system by different drugs and allows dose intensity to be maximized. In addition, drugs should be used in their optimal dose and schedule, and drug combinations should be given at consistent intervals. Because long intervals between cycles negatively affect dose intensity, the treatment-free interval between cycles should be the shortest possible time necessary for recovery of the most sensitive normal target tissue, which is usually the bone marrow. Finally, there should be a clear understanding of the biochemical, molecular, and pharmacokinetic mechanisms of interaction between the individual drugs in a given combination, to allow for maximal effect. Omission of a drug from a combination may allow overgrowth by a cell line sensitive to that drug alone and resistant to other drugs in the combination. Finally, arbitrary reduction in the dose of an effective drug to add other less effective drugs may dramatically reduce the dose of the most effective agent below the threshold of effectiveness and destroy the capacity of the combination to cure disease in a given patient.

One final issue relates to the optimal duration of chemotherapy drug administration. Several randomized trials in the adjuvant treatment of breast and colorectal cancer have generally shown that short-course treatment on the order of six months is as effective as long-course therapy (12 months).<sup>10,11</sup> While progressive disease during chemotherapy is a clear indication to stop

treatment in the advanced disease setting, the optimal duration of chemotherapy for patients without disease progression has not been well-defined. With the development of novel and more potent drug regimens, the potential risk of cumulative adverse events, such as cardiotoxicity secondary to the anthracyclines and neurotoxicity secondary to the taxanes and the platinum analogs, must also be factored in the decision-making process. There is, however, no evidence of clinical benefit in continuing therapy indefinitely until disease progression. A recent randomized study in advanced colorectal cancer comparing continuous and intermittent palliative chemotherapy showed that a policy of stopping and re-challenging with the same chemotherapy provides a reasonable treatment option for patients.<sup>12</sup> Similar observations have been observed in the treatment of advanced, metastatic disease affecting other organ sites, including non-small cell lung cancer, breast cancer, germ cell cancer, ovarian cancer, and small cell lung cancer. However, for such an intermittent treatment approach to be adopted into clinical practice, several issues need to be addressed. First, the induction chemotherapy regimen must be of sufficient clinical efficacy and duration to ensure that the majority of responses are achieved during the treatment period. Second, there must be a good response to the re-initiation of the same chemotherapy or to the administration of an effective salvage chemotherapy regimen. Third, there should be a sufficient time interval between the termination of primary induction chemotherapy and the onset of progressive disease. Finally, patients who are taken off of active chemotherapy must be followed closely to ensure that treatment can be reinstated at the first sign of disease progression.

## The Concept of Dose Intensity

One of the main factors limiting the ability of chemotherapy and/or radiation therapy to achieve cure is effective dosing. The dose-response curve in biologic systems is usually sigmoidal in shape, with a threshold, a lag phase, a linear phase, and a plateau phase. For chemotherapy and radiation therapy, therapeutic selectivity is significantly dependent on the differential between the dose-response curves of normal and tumor tissues. In experimental *in vivo* models, the dose-response curve is usually steep in the linear phase, and a reduction in dose when the tumor is in the linear phase of the dose-response curve almost always results in a loss in the capacity to cure the tumor effectively before a reduction in the antitumor activity is observed. Thus, although complete remissions continue to be observed with dose reduction as low as 20%, residual tumor cells may not be entirely eliminated, thereby allowing for eventual relapse to occur. Although *in vivo* systems may not represent the ideal model for human malignancies, the general principles may be applicable to the clinical setting. Because anticancer drugs are associated with toxicity, it is often appealing for clinicians to avoid acute toxicity by simply

reducing the dose or by increasing the time interval between each cycle of treatment. Such empiric modifications in dose represent a major reason for treatment failure in patients with drug-sensitive tumors who are receiving chemotherapy in either the adjuvant or advanced disease setting.

A major issue facing clinicians is the ability to deliver effective doses of chemotherapy in a dose-intense manner. The concept of dose intensity was put forth by Hryniuk et al.,<sup>13,14</sup> where they defined dose intensity to be the amount of drug delivered per unit of time. Specifically, this was expressed as milligrams per square meter per week, regardless of the schedule or route of administration. The dose intensity of each drug regimen is then determined based on the time period in which the treatment program is administered. Specific calculations can be made for the intended dose intensity, which is the dose intensity originally proposed in the treatment regimen, or the received dose intensity. It is the received dose intensity, rather than intended dose intensity, that is the more clinically relevant issue, as it reflects the direct impact of dose reductions and treatment delays imposed in actual practice. A positive relationship between dose intensity and response rate has been documented in several solid tumors, including advanced ovarian, breast, lung, and colon cancers, as well as in hematologic malignancies, including the lymphomas.

At present, there are three main approaches to deliver chemotherapy in a dose-intense fashion. The first approach is by dose escalation whereby the doses of the anticancer agents are increased. The second strategy is to administer anticancer agents in a dose-dense manner by reducing the interval between treatment cycles, while the third approach involves sequential scheduling of either single agents or of combination regimens. The use of a sequential scheduling should also be considered as a means to deliver chemotherapy in a dose-dense approach.

The growth of most solid tumors follows a pattern of Gompertzian kinetics. In this setting, the growth of cells is significantly faster in the early part of the growth curve than at any other stage in the growth kinetics. For this reason, the initiation of chemotherapy at an earlier stage would be theoretically greater than at a later stage. The log cell kill generated by chemotherapy would, therefore, be greater in tumors of small volume than in those of large volume. In this setting, the regrowth of cancer cells between chemotherapy cycles is more rapid. Thus, the more frequent administration of cytotoxic chemotherapy would represent an attractive strategy to minimize residual tumor burden. In computer simulations, this relatively simple maneuver has, indeed, achieved significantly higher benefit by minimizing the regrowth of cancer cells between cycles of treatment. The clinical relevance of dose-density is supported by a landmark randomized phase III trial comparing dose-dense versus conventionally scheduled chemotherapy in the adjuvant therapy of node-positive primary breast cancer (INT C9741). Citron et al.<sup>15</sup> showed that a dose-dense schedule, in which the anticancer agents doxorubicin, cyclophosphamide, and paclitaxel were administered on an every-2-week schedule rather

than at the conventional 3-week interval, resulted in significantly improved clinical outcomes with respect to DFS and OS. Of note, through concomitant use of the colony-stimulating factor filgrastim, dose-dense therapy was not accompanied by an increase in toxicity. While a dose-dense approach may have its greatest application in the adjuvant setting, there are growing examples where this strategy is also effective in the treatment of metastatic disease. Dose-dense regimens have shown superior clinical activity when compared to standard chemotherapy in metastatic colorectal cancer, extensive-stage small cell lung cancer, and poor-prognosis germ cell cancer.

One of the potential limitations of modern combination chemotherapy is that dose levels of individual drugs are usually reduced in an effort to limit toxicity when used in combination. To address this issue, investigators have administered drug combinations in an alternating sequence to deliver a greater number of different drugs per unit time. This strategy, however, may not allow for enhanced dose intensity; in fact, it may actually compromise clinical benefit. A randomized clinical trial conducted by Bonadonna et al.<sup>16</sup> observed that four 3-week cycles of doxorubicin followed by eight 3-week cycles of CMF in women with high-risk primary breast cancer (four or more positive lymph nodes) was superior in terms of DFS and OS when compared to an alternating schedule of doxorubicin and CMF. Sledge et al.<sup>17</sup> addressed the issue of sequential versus combination therapy in the Eastern Cooperative Oncology Group E1193 randomized phase III trial of sequential single agent therapy with doxorubicin and paclitaxel versus the combination of the two agents in the first-line therapy of metastatic breast cancer. While combination therapy yielded a superior response rate and time to disease progression, this improvement in clinical benefit did not translate into a survival benefit when compared to sequential single-agent therapy. Moreover, combination therapy did not improve patient quality of life. Thus, this clinical study provides support to the notion that sequential chemotherapy represents a reasonable treatment option in patients with metastatic breast cancer. Such sequential strategies are being developed in other solid tumors, including colorectal cancer and ovarian cancer.

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## 2

# *Chemotherapeutic and Biologic Drugs*

Edward Chu, Margit McGowan, Aymen Elfiky, Soonmo P. Kang,  
Laurie J. Harrold, Dawn Tiedemann, and M. Sitki Copur

## **Albumin-Bound Paclitaxel**

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### **Trade Names**

Abraxane

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### **Classification**

Taxane, antimicrotubule agent

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### **Category**

Chemotherapy drug

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### **Drug Manufacturer**

Abraxis

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### **Mechanism of Action**

- Albumin-bound form of paclitaxel with a mean particle size of about 130 nm. Selective binding of albumin-bound paclitaxel to specific albumin receptors present on tumor cells versus normal cells.
- Active moiety is paclitaxel, which is isolated from the bark of the Pacific yew tree, *Taxus brevifolia*.
- Cell cycle-specific, active in the mitosis (M) phase of the cell cycle.
- High-affinity binding to microtubules enhances tubulin polymerization. Normal dynamic process of microtubule network is inhibited, leading to inhibition of mitosis and cell division.

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## Mechanism of Resistance

- Alterations in tubulin with decreased binding affinity for drug.
- Multidrug-resistant phenotype with increased expression of P170 glycoprotein. Results in enhanced drug efflux with decreased intracellular accumulation of drug. Cross-resistant to other natural products, including vinca alkaloids, anthracyclines, taxanes, and VP-16.

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## Absorption

Not orally bioavailable.

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## Distribution

Distributes widely to all body tissues. Extensive binding (<90%) to plasma and cellular proteins.

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## Metabolism

Paclitaxel is metabolized extensively by the hepatic P450 microsomal system. About 20% of drug is excreted via fecal elimination. Less than 10% is eliminated as the parent form with the majority being eliminated as metabolites. Renal clearance is relatively minor with less than 1% of drug cleared via the kidneys. The clearance of abraxane is 43% greater than paclitaxel, and the volume of distribution is about 50% higher than paclitaxel. Terminal elimination half-life is on the order of 27 hours.

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## Indications

FDA-approved for the treatment of breast cancer after failure of combination chemotherapy for metastatic disease or relapse within six months of adjuvant chemotherapy.

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## Dosage Range

1. Recommended dose is 260 mg/m<sup>2</sup> IV on day 1 every 21 days.
2. An alternative regimen is a weekly schedule of 125 mg/m<sup>2</sup> IV on days 1, 8, and 15 every 28 days.

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## Drug Interaction

None well-characterized to date.

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## Special Considerations

1. Contraindicated in patients with baseline neutrophil counts of <1,500 cells/mm<sup>3</sup>.
2. Closely monitor complete blood count (CBC) with differential on a periodic basis.
3. Abraxane has not been studied in patients with hepatic or renal dysfunction. Use with caution in patients with abnormal liver

function, as patients with abnormal liver function may be at higher risk for toxicity.

4. In contrast to paclitaxel, no premedication is required to prevent hypersensitivity reactions prior to administration of abraxane.
5. Abraxane can **NOT** be substituted for or with other paclitaxel formulations as the albumin form of paclitaxel may significantly alter the drug's clinical activity.
6. Closely monitor infusion site for infiltration during drug administration as injection site reactions have been observed.
7. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression with dose-limiting neutropenia and anemia. Thrombocytopenia relatively uncommon.

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#### Toxicity 2

Neurotoxicity mainly in the form of sensory neuropathy with numbness and paresthesias. Dose-dependent effect. In contrast to paclitaxel, abraxane-mediated neuropathy appears to be more readily reversible.

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#### Toxicity 3

Ocular and visual disturbances seen in 13% of patients with severe cases seen in 1%.

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#### Toxicity 4

Asthenia, fatigue, and weakness.

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#### Toxicity 5

Alopecia with loss of total body hair.

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#### Toxicity 6

Nausea/vomiting, diarrhea, and mucositis are the main gastrointestinal (GI) toxicities. Mucositis is generally mild seen in less than 10%. Mild to moderate nausea and vomiting, usually of brief duration.

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#### Toxicity 7

Transient elevations in serum transaminases, bilirubin, and alkaline phosphatase.

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#### Toxicity 8

Injection site reactions.

# A

## Aldesleukin

### Trade Names

Interleukin-2, IL-2, Proleukin

### Classification

Immunotherapy, cytokine

### Category

Biologic response modifier agent

### Drug Manufacturer

Chiron

### Mechanism of Action

- Glycoprotein cytokine that functions as a T-cell growth factor.
- Biologic effect of interleukin-2 (IL-2) is mediated by specific binding to the interleukin-2 receptor (IL-2R).
- Precise mechanism by which IL-2 mediates its anticancer activity remains unknown but appears to require an intact immune system.
- Enhances lymphocyte mitogenesis and lymphocyte cytotoxicity.
- Induces lymphokine-activated (LAK) and natural killer (NK) cell activity.
- Induces interferon- $\gamma$  production.

### Mechanism of Resistance

- Up to 75% of patients may develop anti-IL-2 antibodies.
- Increased expression of counter-regulatory factors, such as glucocorticoids, which act to reduce the efficacy of interleukin-2.

### Absorption

Not available for oral use and is administered only via the parenteral route. Peak plasma levels are achieved in five hours after subcutaneous (SC) administration.

### Distribution

After short intravenous (IV) infusion, high plasma concentrations of IL-2 are achieved followed by rapid distribution into the extravascular space.

### Metabolism

IL-2 is catabolized by renal tubular cells to amino acids. The major route of elimination is through the kidneys by both glomerular filtration and tubular secretion. The elimination half-life is 85 minutes.

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### Indications

1. Metastatic renal cell cancer.
2. Malignant melanoma.

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### Dosage Range

Renal cell cancer: 600,000 IU/kg IV every eight hours for a maximum of 14 doses. Following nine days of rest, the schedule is repeated for another 14 doses, for a maximum of 28 doses per course.

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### Drug Interaction 1

Corticosteroids—May decrease the antitumor efficacy of IL-2 due to its inhibitory effect on the immune system.

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### Drug Interaction 2

Nonsteroidal anti-inflammatory drugs—May enhance the capillary leak syndrome observed with IL-2.

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### Drug Interaction 3

Antihypertensives—IL-2 potentiates the effect of antihypertensive medications. For this reason, all antihypertensives should be stopped at least 24 hours before IL-2 treatment.

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### Special Considerations

1. Use with caution in patients with pre-existing cardiac, pulmonary, central nervous system (CNS), hepatic, and/or renal impairment as there is an increased risk for developing serious and sometimes fatal reactions.
2. Pretreatment evaluation should include CBC; serum chemistries, including liver function tests (LFTs), renal function, and electrolytes; pulmonary function tests (PFTs); and stress thallium.
3. Patients should be monitored closely throughout the entire treatment, including vital signs every 2–4 hours, strict input and output, and daily weights. Continuous cardiopulmonary monitoring is important during therapy.
4. Monitor for capillary leak syndrome (CLS), which begins almost immediately after initiation of therapy. Manifested by hypotension, peripheral edema, ascites, pleural and/or pericardial effusions, weight gain, and altered mental status.
5. Early administration of dopamine (1–5 µg/kg/min) in the setting of CLS may maintain perfusion to the kidneys and preserve renal function.
6. Use with caution in the presence of concurrent medications known to be nephrotoxic and hepatotoxic as IL-2 therapy is associated with both nephrotoxicity and hepatotoxicity.

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7. Use with caution in patients with known autoimmune disease as treatment with IL-2 is associated with autoimmune thyroiditis leading to thyroid function impairment.
8. Allergic reactions have been reported in patients receiving iodine contrast media up to four months following IL-2 therapy.
9. Pregnancy category C.

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## Toxicity 1

Flulike symptoms, including fever, chills, malaise, myalgias, and arthralgias. Observed in all patients.

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## Toxicity 2

Vascular leak syndrome. Usual dose-limiting toxicity, characterized by weight gain, arrhythmias, and/or tachycardia, hypotension, edema, oliguria and renal insufficiency, pleural effusions, and pulmonary congestion.

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## Toxicity 3

Myelosuppression with anemia, thrombocytopenia, and neutropenia.

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## Toxicity 4

Hepatotoxicity presenting as increases in serum bilirubin levels with minimal changes in serum transaminases. Usually reversible within 4–6 days after discontinuation of IL-2 therapy.

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## Toxicity 5

Neurologic and neuropsychiatric findings can develop both acutely and chronically during treatment. Somnolence, delirium, and confusion are common but generally resolve after drug termination. Alterations in cognitive function and impaired memory more common with continuous infusion IL-2.

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## Toxicity 6

Erythema, skin rash, urticaria, and generalized erythroderma may occur within a few days of starting therapy.

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## Toxicity 7

Alterations in thyroid function, including hyperthyroidism and hypothyroidism.

# Alemtuzumab

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## Trade Names

Campath

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## Classification

Monoclonal antibody

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Millenium and Ilex Oncology; Berlex

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## Mechanism of Action

- Recombinant humanized monoclonal antibody (Campath-1H) directed against the 21–28 kDa cell surface glycoprotein CD52 that is expressed on most normal and malignant B and T lymphocytes, NK cells, monocytes, and macrophages.
- CD52 antigen is not expressed on the surface of hematopoietic stem cells and mature plasma cells.
- Immunologic mechanisms involved in antitumor activity, including antibody-dependent cellular cytotoxicity (ADCC) and/or complement-mediated cell lysis.

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## Mechanism of Resistance

None yet defined.

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## Absorption

Alemtuzumab is given only by the IV route.

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## Distribution

Peak and trough levels rise during the first few weeks of therapy and approach steady-state levels by week six. However, there is marked variability, and levels correlate roughly with the number of circulating CD52+ B cells.

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## Metabolism

Metabolism has not been extensively characterized. Half-life is on the order of 12 days with minimal clearance by the liver and kidneys, as has been observed for other monoclonal antibodies used in the clinic.

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### Indications

1. Relapsed and/or refractory B-cell chronic lymphocytic leukemia (B-CLL)—Indicated in patients who have been treated with alkylating agents and who have failed fludarabine therapy.
2. T-cell prolymphocytic leukemia—Clinical activity in patients who failed first-line therapy.

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### Dosage Range

The recommended dose is 30 mg/day IV three times per week for maximum of 12 weeks.

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### Drug Interactions

None known.

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### Special Considerations

1. Contraindicated in patients with active systemic infections, underlying immunodeficiency (HIV-positive, AIDS, etc.), or known type I hypersensitivity or anaphylactic reactions to alemtuzumab or any of its components.
2. Patients should be premedicated with acetaminophen, 650 mg PO, and diphenhydramine, 50 mg PO, 30 minutes before drug infusion to reduce the incidence of infusion-related reactions.
3. Alemtuzumab should be initiated at a dose of 3 mg, administered daily as a 2-hour IV infusion. When this daily dose of 3 mg is tolerated, the daily dose can then be increased to 10 mg. Once the 10 mg daily dose is tolerated, the maintenance dose of 30 mg daily can then be initiated. This maintenance dose of 30 mg/day is administered three times each week on alternate days (Monday, Wednesday, and Friday) for a maximum of 12 weeks. Dose escalation to the 30 mg daily dose usually can be accomplished within seven days. Alemtuzumab should **NOT** be given IV push or bolus.
4. Monitor closely for infusion-related events, which usually occur within the first 30–60 minutes after the start of the infusion and most commonly during the first week of therapy. Pulse, blood pressure, and oral temperature should be measured every 15–30 minutes. Immediate institution of diphenhydramine (50 mg IV), acetaminophen (625 mg PO), hydrocortisone (200 mg IV), and/or vasopressors may be required. Resuscitation equipment should be readily available at bedside.
5. Patients should be placed on anti-infective prophylaxis upon initiation of therapy to reduce the risk of serious opportunistic infections. This should include Bactrim DS, one tablet PO bid three times per week, and famciclovir or equivalent, 250 mg PO bid. Fluconazole



may also be included in the regimen to reduce the incidence of fungal infections. If a serious infection occurs while on therapy, alemtuzumab should be stopped immediately and only reinitiated following the complete resolution of the underlying infection.

6. Monitor CBC and platelet counts on a weekly basis during alemtuzumab therapy. Treatment should be stopped for severe hematologic toxicity or in any patient with evidence of autoimmune anemia and/or thrombocytopenia.
7. Most significant antitumor effects of alemtuzumab are observed in peripheral blood, bone marrow, and spleen. Tumor cells usually cleared from blood within 1–2 weeks of initiation of therapy, while normalization in bone marrow may take up to 6–12 weeks. Lymph nodes, especially those that are large and bulky, seem to be less responsive to therapy.
8. Pregnancy category C. Should be given to a pregnant woman only if clearly indicated. Breast-feeding should be avoided during treatment and for at least three months following the last dose of drug.

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#### Toxicity 1

Infusion-related symptoms, including fever, chills, nausea and vomiting, urticaria, skin rash, fatigue, headache, diarrhea, dyspnea, and/or hypotension. Usually occur within the first week of initiation of therapy.

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#### Toxicity 2

Significant immunosuppressive agent with an increased incidence of opportunistic infections, including *Pneumocystis carinii*, cytomegalovirus (CMV), herpes zoster, *Candida*, *Cryptococcus*, and *Listeria* meningitis. Prophylaxis with anti-infective agents is indicated as outlined above. Recovery of CD4 and CD8 counts is slow and may take over one year to return to normal.

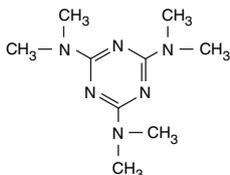
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#### Toxicity 3

Myelosuppression with neutropenia most common, but anemia and thrombocytopenia also observed. In rare instances, pancytopenia with marrow hypoplasia occurs, which can be fatal.

# A

## Altretamine



### Trade Names

Hexalen, Hexamethylmelamine, HMM

### Classification

Nonclassic alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

MGI Pharma

### Mechanism of Action

- Triazine derivative that requires biochemical activation in the liver for its antitumor activity.
- Exact mechanism(s) of action unclear but appears to act like an alkylating agent. Forms cross-links with DNA resulting in inhibition of DNA synthesis and function.
- May also inhibit RNA synthesis.

### Mechanism of Resistance

- Mechanisms of resistance have not been well characterized.
- Does not exhibit cross-resistance to other classic alkylating agents and does not exhibit multidrug-resistant phenotype.

### Absorption

Oral absorption is extremely variable secondary to extensive first-pass metabolism in the liver. Peak plasma levels are achieved 0.5–3 hours after an oral dose.

### Distribution

Widely distributed throughout the body, with highest concentrations found in tissues with high fat content. About 90% of drug is bound to plasma proteins.

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### Metabolism

Extensively metabolized in the liver by the microsomal P<sub>450</sub> system. Less than 1% of parent compound is excreted in urine. About 60% of drug is eliminated in urine as demethylated metabolites (pentamethylmelamine and tetramethylmelamine) within the first 24 hours. The terminal elimination half-life is on the order of 4–10 hours.

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### Indications

Ovarian cancer—Active in advanced disease and in persistent and/or recurrent tumors following first-line therapy with a cisplatin- and/or alkylating agent-based regimen.

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### Dosage Range

Usual dose is 260 mg/m<sup>2</sup>/day PO for either 14 or 21 days on a 28-day schedule. Total daily dose is given in four divided doses after meals and bedtime.

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### Drug Interaction 1

Cimetidine—Cimetidine increases the half-life and subsequent toxicity of altretamine. In contrast, ranitidine does not affect drug metabolism.

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### Drug Interaction 2

Phenobarbital—Phenobarbital may decrease the half-life and toxicity of altretamine.

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### Drug Interaction 3

Monamine oxidase (MAO) inhibitors—Concurrent use of MAO inhibitors with altretamine may result in significant orthostatic hypotension.

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### Special Considerations

1. Closely monitor patient for signs of neurologic toxicity.
2. Vitamin B<sub>6</sub> (pyridoxine) may be used to decrease the incidence and severity of neurologic toxicity. However, antitumor activity may be compromised with vitamin B<sub>6</sub> treatment.
3. Pregnancy category D.

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### Toxicity 1

Nausea and vomiting. Usual dose-limiting toxicity. Mild to moderate, observed in 30% of patients. Worsens with increasing cumulative doses of drug.

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### Toxicity 2

Myelosuppression. Dose-limiting toxicity. Leukocyte and platelet nadirs occur at 3–4 weeks with recovery by day 28. Anemia occurs in 20% of patients.

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## Toxicity 3

Neurotoxicity in the form of somnolence, mood changes, lethargy, depression, agitation, hallucinations, and peripheral neuropathy. Observed in about 25% of patients.

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## Toxicity 4

Hypersensitivity, skin rash.

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## Toxicity 5

Elevations in LFTs, mainly alkaline phosphatase.

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## Toxicity 6

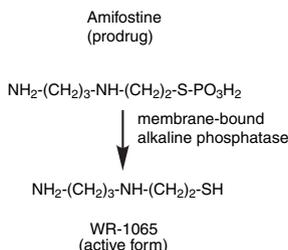
Flulike syndrome in the form of fever, malaise, arthralgias, and myalgias.

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## Toxicity 7

Abdominal cramps and diarrhea are occasionally observed.

# Amifostine



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## Trade Names

Ethyol, WR2721

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## Classification

Organic thiophosphate analog

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## Category

Chemoprotective drug

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## Drug Manufacturer

Alza Pharmaceuticals, MedImmune

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## Mechanism of Action

- Organic thiophosphate analog originally developed by Walter Reed Army Institute.
- Inactive in its parent form and serves as a prodrug.
- Requires activation by the enzyme alkaline phosphatase to the active, free thiol metabolite WR1065. This enzyme is expressed on the plasma membrane surface of endothelial cells lining blood vessels and on the surface of proximal renal tubular cells.
- Activation occurs to a greater extent in normal cells when compared to tumor cells because of a higher level of expression of alkaline phosphatase.
- Free thiol acts as a potent scavenger of oxygen free radicals and superoxide anions to inactivate the reactive species of cisplatin and radiation.
- Does not adversely affect the antitumor activity of cisplatin and/or radiation.

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## Absorption

Amifostine is not orally bioavailable. Approximately 50% of drug bioavailable after SC injection.

## Distribution

Amifostine is confined primarily to the intravascular compartment. Rapidly cleared from plasma with a distribution half-life of <1 minute and <10% of drug remains in plasma six minutes after drug administration. The active metabolite of the drug is widely distributed in body tissues, but it does not cross the blood-brain barrier or distribute into skeletal muscle.

## Metabolism

Rapidly metabolized by the enzyme alkaline phosphatase to the active, free thiol metabolite WR1065. Activation occurs to a much greater extent in normal cells versus tumor cells given the higher levels of alkaline phosphatase, higher pH, and increased vascularity in normal cells. The elimination half-life is eight minutes, and <5% of drug is excreted in urine either as the parent form or as amifostine metabolites.

## Indications

1. Reduce the incidence of nephrotoxicity in patients with ovarian cancer and non-small cell lung cancer receiving cisplatin-based chemotherapy.
2. Reduce the incidence of moderate to severe xerostomia in patients undergoing postoperative radiation treatment for head and neck cancer, where the radiation port includes a significant portion of the parotid glands.

## Dosage Range

1. Recommended dose for reduction of cumulative renal toxicity is 910 mg/m<sup>2</sup> IV, administered once daily 30 minutes before cisplatin chemotherapy.
2. Recommended dose for reduction of xerostomia is 200 mg/m<sup>2</sup> administered once daily 15–30 minutes before radiation therapy.
3. Alternative regimen for head and neck cancer patients is 500 mg SC administered once daily 20 minutes before radiation therapy.

## Special Considerations

1. Patients should be given antiemetics before drug treatment, because amifostine is a moderate to severe emetogenic agent. Antiemetic cocktail should include a 5-HT<sub>3</sub> inhibitor (granisetron or ondansetron), Benadryl, and Decadron.
2. Patients should be well hydrated before drug treatment and be kept in a supine position during the infusion.

3. Antihypertensive medications should be stopped at least 24 hours before starting therapy, because amifostine induces hypotension.
4. Blood pressure and vital signs of patients must be monitored every five minutes during the infusion and 10 minutes after the infusion. In the event of hypotension, the infusion should be stopped immediately, and the patient treated with IV fluids and/or pressors. Treatment can resume if the blood pressure has returned to normal within five minutes and the patient remains asymptomatic.
5. Infuse amifostine over a period of 15 minutes when used before chemotherapy and over three minutes when used before radiation, as longer infusion times are associated with an increased risk of side effects.
6. SC administration is associated with a lower incidence of nausea/vomiting and hypotension and is a more convenient treatment option.
7. Pregnancy category C. Breast-feeding should be avoided.

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### Drug Interactions

None well characterized to date.

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### Toxicity 1

Nausea and vomiting are common and may be severe.

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### Toxicity 2

Hypotension occurs in up to 60% of patients. Usually asymptomatic. Mean time of onset is 14 minutes into the infusion. Blood pressure usually returns to normal within 5–15 minutes.

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### Toxicity 3

Infusion-related reaction in the form of flushing, chills, dizziness, somnolence, and sneezing.

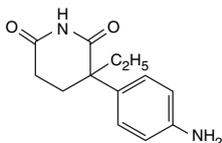
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### Toxicity 4

Hypocalcemia develops in <1% of patients and usually is clinically asymptomatic. Amifostine affects the release of parathyroid hormone.

# A

## Aminoglutethimide



### Trade Names

Cytadren, Epiten

### Classification

Adrenal steroid inhibitor

### Category

Hormonal agent

### Drug Manufacturer

Novartis

### Mechanism of Action

- Nonsteroidal inhibitor of corticosteroid biosynthesis.
- Produces a chemical adrenalectomy with a decreased synthesis of estrogens, androgens, glucocorticoids, and mineralocorticoids.

### Absorption

Excellent bioavailability via the oral route. Peak plasma concentrations occur within 1–1.5 hours after ingestion.

### Distribution

Approximately 25% of the drug is bound to plasma proteins. Significant reduction in distribution with prolonged treatment.

### Metabolism

Metabolized in the liver by the cytochrome P<sub>450</sub> system with N-acetylaminoglutethimide being the major metabolite. Metabolism is under genetic control, and acetylator status of patients is important. About 40%–50% of the drug is excreted unchanged in the urine. Initial half-life of drug is about 13 hours but decreases to 7 hours with chronic treatment, suggesting that the drug may accelerate its own rate of degradation.

### Indications

1. Breast cancer—Hormone-responsive, advanced disease.
2. Prostate cancer—Hormone-responsive, advanced disease.

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### Dosage Range

Usual dose is 250 mg PO qid (1,000 mg total).

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### Drug Interaction 1

Warfarin, phenytoin, phenobarbital, theophylline, medroxyprogesterone, and digoxin—Aminoglutethimide enhances the metabolism of warfarin, phenytoin, phenobarbital, theophylline, medroxyprogesterone, and digoxin, thereby decreasing their clinical activity.

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### Drug Interaction 2

Dexamethasone—Aminoglutethimide enhances the metabolism of dexamethasone but not hydrocortisone.

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### Special Considerations

1. Administer hydrocortisone along with aminoglutethimide to prevent adrenal insufficiency. The use of higher doses during the initial two weeks of therapy reduces the frequency of adverse events. For example, start at 100 mg PO daily for the first two weeks, then 40 mg PO daily in divided doses. Higher doses of steroid replacement may be required under conditions of stress such as surgery, trauma, or acute infection.
  2. Closely monitor patient for signs and symptoms of hypothyroidism. Monitor thyroid function tests on a regular basis.
  3. Monitor for signs and symptoms of orthostatic hypotension. May need to add fludrocortisone (Florinef) 0.1–0.2 mg PO qd.
  4. Monitor patient for signs of somnolence and lethargy. Severe cases may warrant immediate discontinuation of drug.
  5. Discontinue drug if skin rash persists for more than one week.
  6. Pregnancy category D.
- 

### Toxicity 1

Maculopapular skin rash. Usually seen in the first week of therapy. Self-limited with resolution in 5–7 days, and discontinuation of therapy not necessary.

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### Toxicity 2

Fatigue, lethargy, and somnolence. Occurs in 40% of patients, and onset is within the first week of therapy. Dizziness, nystagmus, and ataxia are less common (10% of patients).

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### Toxicity 3

Mild nausea and vomiting.

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**A**

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**Toxicity 4**

Hypothyroidism.

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**Toxicity 5**

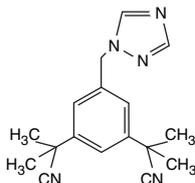
Adrenal insufficiency. Occurs in the absence of hydrocortisone replacement. Presents as postural hypotension, hyponatremia, and hyperkalemia.

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**Toxicity 6**

Myelosuppression. Leukopenia and thrombocytopenia rarely occur.

# Anastrozole



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## Trade Names

Arimidex

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## Classification

Nonsteroidal aromatase inhibitor

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## Category

Hormonal agent

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## Drug Manufacturer

AstraZeneca

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## Mechanism of Action

- Potent and selective nonsteroidal inhibitor of aromatase.
- Inhibits the synthesis of estrogens by inhibiting the conversion of adrenal androgens (androstenedione and testosterone) to estrogens (estrone, estrone sulfate, and estradiol). Serum estradiol levels are suppressed by 90% within 14 days, and nearly completely suppressed after six weeks of therapy.
- No inhibitory effect on adrenal corticosteroid or aldosterone biosynthesis.

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## Mechanism of Resistance

None characterized.

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## Absorption

Excellent bioavailability via the oral route, with 85% of a dose absorbed within two hours of ingestion. Absorption is not affected by food.

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## Distribution

Widely distributed throughout the body. About 40% of drug is bound to plasma proteins.

# A

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## Metabolism

Extensively metabolized in the liver (up to 85%) by N-dealkylation, hydroxylation, and glucuronidation, to inactive forms. Half-life of drug is about 50 hours. Steady-state levels of drug are achieved after 7 days of a once-daily administration. The major route of elimination is fecal, with renal excretion accounting for only 10% of drug clearance.

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## Indications

1. Metastatic breast cancer—First-line treatment of postmenopausal women with hormone-receptor positive or hormone-receptor unknown disease. FDA-approved.
2. Metastatic breast cancer—Postmenopausal women with hormone-receptor positive, advanced disease, and progression while on tamoxifen therapy.
3. Adjuvant treatment of postmenopausal women with hormone-receptor positive early-stage breast cancer. FDA-approved.

---

## Dosage Range

1. Recommended dose is 1 mg PO qd for both first- and second-line therapy.
2. Recommended dose is 1 mg PO qd for adjuvant therapy. The optimal duration of therapy is unknown. In the ATAC trial, anastrozole was given for 5 years.

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## Drug Interactions

None known.

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## Special Considerations

1. No dose adjustments are required for patients with either hepatic or renal dysfunction.
2. Caution patients about the risk of hot flashes.
3. No need for glucocorticoid and/or mineralocorticoid replacement.
4. Closely monitor women with osteoporosis or at risk of osteoporosis by performing bone densitometry at the start of therapy and at regular intervals. Treatment or prophylaxis for osteoporosis should be initiated when appropriate.
5. Pregnancy category D.

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## Toxicity 1

Asthenia. Most common toxicity, occurs in up to 20% of patients.

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## Toxicity 2

Mild nausea and vomiting. Constipation or diarrhea can also occur.

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**Toxicity 3**

Hot flashes. Occurs in 10% of patients.

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**Toxicity 4**

Dry, scaling skin rash.

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**Toxicity 5**

Arthralgias occur in 10% to 15% of patients involving hands, knees, hips, lower back, and shoulders. Early morning stiffness is usual presentation.

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**Toxicity 6**

Headache.

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**Toxicity 7**

Peripheral edema in 7% of patients.

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**Toxicity 8**

Flulike syndrome in the form of fever, malaise, and myalgias.

# A

## Arsenic trioxide ( $\text{As}_2\text{O}_3$ )

### Trade Names

Trisenox

### Classification

Natural product

### Category

Chemotherapy and differentiating agent

### Drug Manufacturer

Cell Therapeutics

### Mechanism of Action

- Precise mechanism of action has not been fully elucidated.
- Induces differentiation of acute promyelocytic leukemic cells by degrading the chimeric PML/RAR- $\alpha$  protein, resulting in release of the maturation block at the promyelocyte stage of myelocyte differentiation.
- Induces apoptosis through a mitochondrial-dependent pathway, resulting in release of cytochrome C and subsequent caspase activation.
- Direct antiproliferative activity by arresting cells at either the G<sub>1</sub>-S or G<sub>2</sub>-M checkpoints.
- Inhibits the process of angiogenesis through apoptosis of endothelial cells and/or inhibition of production of critical angiogenic factors, including vascular endothelial growth factor.

### Mechanism of Resistance

None well characterized to date.

### Absorption

Arsenic trioxide is given only by the IV route.

### Distribution

Widely distributes in liver, kidneys, heart, lung, hair, nails, and skin.

### Metabolism

The clinical pharmacology of arsenic trioxide has not been well characterized. Metabolism occurs via reduction of pentavalent arsenic to trivalent arsenic and methylation reactions mediated by methyltransferase enzymes that occur primarily in the liver. However, the methyltransferases appear to

be distinct from the liver microsomal P<sub>450</sub> system. The methylated trivalent arsenic metabolite is excreted mainly in the urine.

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### Indications

Acute promyelocytic leukemia (APL)—FDA-approved for induction of remission and consolidation in patients with APL who are refractory to or have relapsed following first-line therapy with all-trans retinoic acid (ATRA) and anthracycline-based chemotherapy and whose APL is characterized by the presence of the t(15;17) translocation or PML/RAR- $\alpha$  gene expression.

---

### Dosage Range

1. Induction therapy—0.15 mg/kg/day IV for a maximum of 60 days.
2. Consolidation therapy—Should be initiated three weeks after completion of induction treatment and only in those patients who achieve a complete bone marrow remission. The recommended dosage is 0.15 mg/kg/day IV for five days/week for a total of five weeks.

---

### Drug Interaction 1

Medications that can prolong the QT interval such as antiarrhythmics—Increased risk of prolongation of the QT interval and subsequent arrhythmias when arsenic trioxide is administered concomitantly.

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### Drug Interaction 2

Amphotericin B—Increased risk of prolonged QT interval and Torsade de Pointes ventricular arrhythmia in patients receiving amphotericin and induction therapy with arsenic trioxide.

---

### Special Considerations

1. Use with caution in patients who are on agents that prolong the QT interval, in those who have a history of torsade de pointes, pre-existing QT interval prolongation, untreated sinus node dysfunction, high-degree atrioventricular block, or in those who may be severely dehydrated or malnourished at baseline.
2. Use with caution in patients with renal impairment as renal excretion is the main route of elimination of arsenic.
3. Before initiation of therapy, all patients should have a baseline electrocardiogram (EKG) performed and serum electrolytes, including potassium, calcium, magnesium, blood urea nitrogen (BUN), and creatinine, should be evaluated. Any pre-existing electrolyte abnormalities should be corrected before starting therapy.
4. Serum electrolytes should be closely monitored during therapy. Serum potassium concentrations should be maintained above 4 mEq/L and magnesium concentrations above 1.8 mg/dL.

5. Therapy should be stopped when the QT interval  $>500$  millisecond and only resumed when the QT interval drops to below  $460$  millisecond, all electrolyte abnormalities are corrected, and cardiac monitoring shows no evidence of arrhythmias.
6. Monitor closely for new-onset fever, dyspnea, weight gain, abnormal respiratory symptoms, and/or physical findings, or chest x-ray abnormalities, because 30% of patients will develop the APL differentiation syndrome. This syndrome can be fatal, and high-dose steroids with dexamethasone 10 mg IV bid should be started immediately and continued for 3–5 days. While this syndrome more commonly occurs with median baseline white blood cells of  $5,000 \text{ mm}^3$ , it can occur in the absence of leukocytosis. In most cases, therapy can be resumed once the syndrome has completely resolved.
7. Monitor CBC every other day and bone marrow cytology every 10 days during induction therapy.
8. Pregnancy category D. Breast-feeding should be avoided as arsenic is excreted in breast milk.

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#### Toxicity 1

Fatigue.

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#### Toxicity 2

Prolonged QT interval ( $>500$  msec) on EKG seen in 40%–50% of patients. Does not usually increase upon repeat exposure to arsenic trioxide, and QT interval returns to baseline following termination of therapy. Torsade de Pointes ventricular arrhythmia and/or complete AV block can be observed in this setting.

---

#### Toxicity 3

APL differentiation syndrome. Occurs in about 30% of patients and is characterized by fever, dyspnea, skin rash, fluid retention and weight gain, pleural and/or pericardial effusions. This syndrome is identical to the retinoid acid syndrome observed with retinoid therapy.

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#### Toxicity 4

Leukocytosis is observed in 50%–60% of patients with a gradual increase in WBC that peaks between two and three weeks after starting therapy. Usually resolves spontaneously without treatment and/or complications.

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#### Toxicity 5

Light-headedness most commonly observed during drug infusion. Headache and insomnia.

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#### Toxicity 6

Mild nausea and vomiting, abdominal pain, and diarrhea.

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**Toxicity 7**

Musculoskeletal pain.

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**Toxicity 8**

Mild hyperglycemia.

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**Toxicity 9**

Peripheral neuropathy.

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**Toxicity 10**

Carcinogen and teratogen.

**A**

# A

## Asparaginase

### Trade Names

Elspar, L-Asparaginase

### Classification

Enzyme

### Category

Chemotherapy drug

### Drug Manufacturer

Merck

### Mechanism of Action

- Purified from *Escherichia coli* and/or *Erwinia chrysanthemi*.
- Tumor cells lack asparagine synthetase and thus require exogenous sources of L-asparagine.
- L-Asparaginase hydrolyzes circulating L-asparagine to aspartic acid and ammonia.
- Depletion of the essential amino acid L-asparagine results in rapid inhibition of protein synthesis. Cytotoxicity of drug correlates well with inhibition of protein synthesis.

### Mechanism of Resistance

- Increased expression of the L-asparagine synthetase gene. This facilitates the cellular production of L-asparagine from endogenous sources.
- Formation of antibodies against L-Asparaginase, resulting in inhibition of function.

### Absorption

L-Asparaginase is not orally bioavailable.

### Distribution

Remains in the vascular compartment after IV administration. After intramuscular (IM) injection, peak plasma levels are reached within 14–24 hours. Peak plasma levels after IM injection are 50% lower than those achieved with IV injection. Plasma protein binding is on the order of 30%. The apparent volume of distribution is about 70%–80% of the plasma volume. Cerebrospinal fluid (CSF) penetration is negligible (<1% of plasma level).

---

### Metabolism

Metabolism is not well characterized. Minimal urinary and/or biliary excretion occurs. Plasma half-life depends on formulation of drug: 40–50 hours for *E. coli*-derived L-Asparaginase and 3–5 days for polyethylene glycol (PEG)-Asparaginase.

---

### Indications

Acute lymphocytic leukemia.

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### Dosage Range

1. Dose varies depending on specific regimens. L-Asparaginase is given at a dose of 6,000–10,000 IU/m<sup>2</sup> IM every three days for a total of nine doses. Treatment with L-Asparaginase is started after completion of other chemotherapy drugs used in the induction therapy of acute lymphoblastic leukemia (vincristine, prednisone, and adriamycin).
2. Less commonly, L-Asparaginase is given as a single agent at a dose of 200 IU/kg IV for 28 consecutive days.

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### Drug Interaction 1

Methotrexate—L-Asparaginase can inhibit the cytotoxic effects of methotrexate and thus rescue from methotrexate antitumor activity and host toxicity. It is recommended that these drugs be administered 24 hours apart.

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### Drug Interaction 2

Vincristine—L-Asparaginase inhibits the clearance of vincristine resulting in increased host toxicity, especially neurotoxicity. Vincristine should be administered 12–24 hours before L-Asparaginase.

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### Special Considerations

1. An intradermal skin test dose of 2 IU should be performed before the initial administration of L-Asparaginase or whenever the dose is being repeated more than one week from the immediately previous one. The patient should be observed for at least one hour before the full dose is given. A negative dermal test does not completely rule out the possibility of an allergic reaction.
2. Monitor patient for allergic reactions and/or anaphylaxis. Contraindicated in patients with a prior history of anaphylactic reaction. L-Asparaginase isolated from the *Erwinia* species may be tried in patients previously treated with *E. coli* Asparaginase, but allergic reactions may still occur.
3. L-Asparaginase is a contact irritant in both powder and solution forms. The drug must be handled and administered with caution.

# A

4. Induction treatment of acute lymphoblastic leukemia with L-Asparaginase may induce rapid lysis of blast cells. Prophylaxis against tumor lysis syndrome with vigorous IV hydration, urinary alkalinization, and allopurinol is recommended for all patients.
5. Contraindicated in patients with either active pancreatitis or a history of pancreatitis. If pancreatitis develops while on therapy, L-Asparaginase should be stopped immediately.
6. Close monitoring of LFTs, amylase, coagulation tests, and fibrinogen levels.
7. L-Asparaginase can interfere with thyroid function tests. This effect is probably due to a marked reduction in serum concentration of thyroxine-binding globulin, which is observed within two days after the first dose. Levels of thyroxine-binding globulin return to normal within four weeks of the last dose.
8. Pregnancy category C.

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## Toxicity 1

Hypersensitivity reaction. Occurs in up to 25% of patients. Mild form manifested by skin rash and urticaria. Anaphylactic reaction may be life-threatening and presents as bronchospasm, respiratory distress, and hypotension. Resuscitation drugs and equipment should be readily available at bedside before drug treatment.

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## Toxicity 2

Fever, chills, nausea, and vomiting. Acute reaction observed in about two-thirds of patients.

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## Toxicity 3

Mild elevation in LFTs, including serum bilirubin, alkaline phosphatase, and SGOT. Common and usually transient. Liver biopsy reveals fatty changes.

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## Toxicity 4

Increased risk of both bleeding and clotting. Alterations in clotting with decreased levels of clotting factors, including fibrinogen, factors IX and XI, antithrombin III, proteins C and S, plasminogen, and alpha-2-antiplasmin. Observed in over 50% of patients.

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## Toxicity 5

Pancreatitis develops in up to 10% of patients. Usually manifested as transient increase in serum amylase levels with quick resolution upon cessation of therapy.

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**Toxicity 6**

Neurologic toxicity, including lethargy, confusion, agitation, hallucinations, and/or coma. These side effects may require treatment discontinuation. Severe neurotoxicity resembles ammonia toxicity.

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**Toxicity 7**

Myelosuppression is mild and rarely observed.

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**Toxicity 8**

Decreased serum levels of insulin, lipoproteins, and albumin.

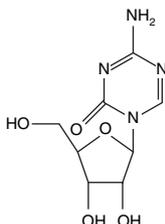
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**Toxicity 9**

Renal toxicity. Usually mild and manifested by mild elevations in BUN and creatinine, proteinuria, and elevated serum acid levels.

# A

## Azacitidine



### Trade Name

Vidaza

### Classification

Antimetabolite, hypomethylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

Pharmion

### Mechanism of Action

- Cytidine analogue.
- Cell cycle-specific with activity in the S-phase.
- Requires activation to the nucleotide metabolite azacitidine triphosphate.
- Incorporation of azacitidine triphosphate into RNA, resulting in inhibition of RNA processing and function.
- Incorporation of azacitidine triphosphate into DNA, resulting in inhibition of DNA methyltransferases, which then leads to a loss of DNA methylation and gene reactivation. Aberrantly silenced genes, such as tumor suppressor genes, are reactivated and expressed.

### Mechanism of Resistance

None well characterized to date.

### Absorption

Not available for oral use and is administered via the SC and IV route. The bioavailability of SC azacitidine is 89% relative to IV azacitidine.

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### Distribution

The distribution in humans has not been fully characterized. Does cross blood-brain barrier.

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### Metabolism

The precise route of elimination and metabolic fate of azacitidine is not well characterized in humans. In vitro studies suggest that azacitidine may be metabolized by the liver. One of the elimination pathways is via deamination by cytidine deaminase, found principally in the liver but also in plasma, granulocytes, intestinal epithelium, and peripheral tissues. Urinary excretion is the main route of elimination of the parent drug and its metabolites. The half-lives of azacitidine and its metabolites are approximately 4 hours.

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### Indications

FDA-approved for treatment of patients with myelodysplastic syndromes (MDS), including refractory anemia, refractory anemia with ringed sideroblasts, refractory anemia with excess blasts, refractory anemia with excess blasts in transformation, and chronic myelomonocytic leukemia.

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### Dosage Range

Recommended dose is 75 mg/m<sup>2</sup> SC/IV daily for 7 days. Cycles should be repeated every 4 weeks.

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### Drug Interactions

None characterized to date.

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### Special Considerations

1. Patients should be treated for a minimum of four cycles, as a response may take longer than four cycles.
2. Patients should be pretreated with effective antiemetics to prevent nausea/vomiting.
3. Monitor complete blood counts on a regular basis during therapy.
4. Use with caution in patients with underlying kidney dysfunction. If unexplained elevations in BUN or serum creatinine occur, the next cycle should be delayed, and the subsequent dose should be reduced by 50%. If unexplained reductions in serum bicarbonate levels to <20 mEq/L occur, the subsequent dose should be reduced by 50%.
5. Pregnancy category D. Breast-feeding should be avoided.

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### Toxicity 1

Myelosuppression with neutropenia and thrombocytopenia.

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**Toxicity 2**

Fatigue and anorexia.

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**Toxicity 3**

GI toxicity in the form of nausea/vomiting, constipation, and abdominal pain.

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**Toxicity 4**

Renal toxicity with elevations in serum creatinine, renal tubular acidosis, and hypokalemia.

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**Toxicity 5**

Peripheral edema.

# Bevacizumab

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## Trade Names

Avastin

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## Classification

Monoclonal antibody, anti-VEGF-antibody

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Genentech

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## Mechanism of Action

- Recombinant humanized monoclonal antibody directed against the vascular endothelial growth factor (VEGF). Binds to all isoforms of VEGF-A (VEGF). VEGF is a pro-angiogenic growth factor that is overexpressed in a wide range of solid human cancers, including colorectal cancer.
- Precise mechanism(s) of action remains unknown.
- Binding of VEGF prevents its subsequent interaction with VEGFR-receptors on the surface of endothelial cells and tumors, and in so doing, results in inhibition of VEGFR-signaling.
- Inhibits formation of new blood vessels in primary tumor and metastatic tumors.
- Inhibits tumor blood vessel permeability and reduces interstitial tumoral pressures, and in so doing, may enhance blood flow delivery within tumor.
- Restores antitumor response by enhancing dendritic cell function.
- Immunologic mechanisms may also be involved in antitumor activity, and they include recruitment of ADCC and/or complement-mediated cell lysis.

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## Mechanism of Resistance

- None have been characterized to date.

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## Distribution

Distribution in body is not well characterized. The predicted time to reach steady-state levels is on the order of 100 days.

# B

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## Metabolism

Metabolism of bevacizumab has not been extensively characterized. Half-life is on the order of 17–21 days with minimal clearance by the liver or kidneys, as has been observed for other monoclonal antibodies and peptides used in the clinic.

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## Indications

1. Metastatic colorectal cancer—FDA-approved for use in combination with any intravenous 5-fluorouracil-based chemotherapy in first-line therapy.
2. Metastatic colorectal cancer—FDA-approved for use in combination with FOLFOX-4 in second-line therapy.
3. Non-small cell lung cancer—FDA-approved for non-squamous, non-small cell lung cancer in combination with carboplatin/paclitaxel.
4. Renal cell cancer—remains investigational.
5. Breast cancer—remains investigational.

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## Dosage Range

1. Recommended dose for the first-line treatment of advanced colorectal cancer is 5 mg/kg IV in combination with intravenous 5-FU-based chemotherapy on an every 2-week schedule.
2. Recommended dose for the second-line treatment of advanced colorectal cancer in combination with FOLFOX-4 is 10 mg/kg IV on an every 2-week schedule.
3. Can also be administered at 7.5 mg/kg IV every three weeks when used in combination with capecitabine-based regimens for advanced colorectal cancer.
4. Recommended dose for advanced non-small cell lung cancer is 15 mg/kg IV every three weeks.

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## Drug Interactions

No formal drug interactions have been well characterized to date.

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## Special Considerations

1. Patients should be warned of the increased risk of arterial thromboembolic events, including myocardial infarction and stroke. Risk factors are age >65 years and history of angina, stroke, and prior arterial thromboembolic events. This represents a black-box warning.
2. Patients should be warned of the potential for serious and, in some cases, fatal hemorrhage resulting from hemoptysis in patients with non-small cell lung cancer. These events have been mainly observed in patients with a central, cavitory, and/or necrotic lesion involving

the pulmonary vasculature and have occurred suddenly. Patients with recent hemoptysis ( $>1/2$  tsp of red blood) should not receive bevacizumab. This represents a black-box warning.

3. Bevacizumab treatment can result in the development of GI perforations and wound dehiscence, which in some cases has resulted in death. These events represent a black-box warning for the drug. Caution should be exercised in treating patients who have undergone recent surgical and/or invasive procedures, and bevacizumab should be given at least 28 days after any surgical and/or invasive intervention. In patients who have undergone surgical resection of the liver, bevacizumab should not be given for at least 6 to 8 weeks after the surgical procedure.
4. Bevacizumab treatment can result in the development of wound dehiscence, which in some cases can be fatal. This represents a black-box warning.
5. Carefully monitor for infusion-related symptoms. May need to treat with benadryl and acetaminophen.
6. Use with caution in patients with uncontrolled hypertension as bevacizumab can result in grade 3 hypertension in about 10% of patients. Should be permanently discontinued in patients who develop hypertensive crisis. In most cases, however, hypertension is well-managed with increasing the dose of the anti-hypertensive medication and/or with the addition of another anti-hypertensive medication.
7. Bevacizumab should be terminated in patients who develop the nephrotic syndrome. Therapy should be interrupted for proteinuria  $>2$  grams/24 hours and resumed when  $<2$  grams/24 hours.
8. Bevacizumab treatment can result in reversible posterior leukoencephalopathy syndrome (RPLS), as manifested by headache, seizure, lethargy, confusion, blindness and other visual side effects, as well as other neurologic disturbances. This syndrome can occur from 16 hours to 1 year after initiation of therapy, and magnetic resonance imaging is necessary to confirm the diagnosis.
9. Pregnancy category B.

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### Toxicity 1

Gastrointestinal perforations and wound healing complications.

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### Toxicity 2

Bleeding complications with epistaxis being most commonly observed. Serious life-threatening pulmonary hemorrhage can occur in rare cases in patients with non-small cell lung cancer as outlined above in Special Considerations.

# B

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## Toxicity 3

Increased risk of arterial thromboembolic events, including myocardial infarction, angina, and stroke. No increased incidence of venous thromboembolic events.

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## Toxicity 4

Hypertension occurs in up to 20%–30% of patients with grade 3 hypertension observed in 10%–15% of patients. Usually well-controlled with oral anti-hypertensive medication.

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## Toxicity 5

Proteinuria with nephrotic syndrome developing in up to 5% of patients.

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## Toxicity 6

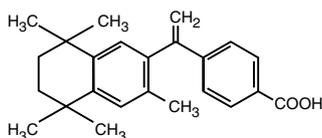
Infusion-related symptoms with fever, chills, urticaria, flushing, fatigue, headache, bronchospasm, dyspnea, angioedema, and hypotension. Relatively uncommon event occurring in less than 5% of patients.

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## Toxicity 7

Posterior leukoencephalopathy syndrome presenting with headache, seizure, lethargy, confusion, blindness, and other visual disturbances. Occurs rarely (<0.1%).

# Bexarotene



## Trade Names

Targretin

## Classification

Retinoid

## Category

Differentiating agent

## Drug Manufacturer

Ligand

## Mechanism of Action

- Selectively binds and activates retinoid X receptors (RXRs).
- RXRs form heterodimers with various other receptors, including retinoic acid receptors (RARs), vitamin D receptors, and thyroid receptors. Once activated, these receptors function as transcription factors, which then regulate the expression of various genes involved in controlling cell differentiation, growth, and proliferation.
- Precise mechanism by which bexarotene exerts its antitumor activity in cutaneous T-cell lymphoma (CTCL) remains unknown.

## Absorption

Well absorbed by the GI tract. Peak plasma levels observed two hours after oral administration.

## Distribution

Distribution is not well characterized. Highly bound to plasma proteins (>99%).

## Metabolism

Extensive metabolism occurs in the liver via the cytochrome P<sub>450</sub> system to both active and inactive metabolites. Both parent drug and its metabolites are eliminated primarily through the hepatobiliary system and in feces. Renal clearance is minimal accounting for <1%. The elimination half-life is about seven hours.

# B

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## Indications

Treatment of cutaneous manifestations of CTCL in patients who are refractory to at least one prior systemic therapy.

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## Dosage Range

Recommended initial dose is 300 mg/m<sup>2</sup>/day PO. Should be taken as a single dose with food.

---

## Drug Interaction 1

Gemfibrozil—Gemfibrozil inhibits metabolism of bexarotene by the liver P<sub>450</sub> system resulting in increased plasma concentrations. Concurrent administration of gemfibrozil with bexarotene is not recommended.

---

## Drug Interaction 2

Inhibitors of cytochrome P<sub>450</sub> system—Drugs that inhibit the liver P<sub>450</sub> system, such as ketoconazole, itraconazole, and erythromycin, may cause an increase in plasma concentrations of bexarotene.

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## Drug Interaction 3

Inducers of cytochrome P<sub>450</sub> system—Drugs that induce the liver P<sub>450</sub> system, such as rifampin, phenytoin, and phenobarbital, may cause a reduction in plasma bexarotene concentrations.

---

## Special Considerations

1. Use with caution in patients with abnormal liver function. Monitor liver function tests at baseline and during therapy. Treatment should be discontinued when LFTs are three-fold higher than the upper limit of normal.
2. Use with caution in diabetic patients who are on insulin, agents enhancing insulin secretion, or insulin sensitizers as bexarotene therapy can enhance their effects resulting in hypoglycemia.
3. Use with caution in patients with history of lipid disorders as significant alterations in lipid profile are observed with bexarotene therapy. Lipid profile should be obtained at baseline, weekly until the lipid response is established, and at eight-week intervals.
4. Thyroid function tests should be obtained at baseline and during therapy as bexarotene is associated with hypothyroidism.
5. Use with caution in patients with known hypersensitivity to retinoids.
6. Patients should be advised to limit vitamin A supplementation to <1,500 IU/day to avoid potential additive toxic effects with bexarotene.
7. Patients should be advised to avoid exposure to sunlight as bexarotene is associated with photosensitivity.

8. Patients who experience new-onset visual difficulties should have an ophthalmologic evaluation as bexarotene is associated with retinal complications, development of new cataracts, and/or worsening of pre-existing cataracts.
9. Pregnancy category X. Must not be given to a pregnant woman or to a woman who intends to become pregnant. If a woman becomes pregnant while on therapy, bexarotene must be stopped immediately.

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**Toxicity 1**

Hypertriglyceridemia and hypercholesterolemia are common. Reversible upon dose reduction, cessation of therapy, or when antilipemic therapy is begun (gemfibrozil is not recommended, see Drug Interaction 1).

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**Toxicity 2**

Hypothyroidism develops in 50% of patients.

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**Toxicity 3**

Headache and asthenia.

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**Toxicity 4**

Myelosuppression with leukopenia more common than anemia.

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**Toxicity 5**

Nausea, abdominal pain, and diarrhea.

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**Toxicity 6**

Skin rash, dry skin, and rarely alopecia.

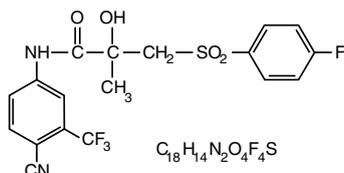
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**Toxicity 7**

Dry eyes, conjunctivitis, blepharitis, cataracts, corneal lesions, and visual field defects.

# B

## Bicalutamide



### Trade Names

Casodex

### Classification

Anti-androgen

### Category

Hormonal drug

### Drug Manufacturer

AstraZeneca

### Mechanism of Action

- Nonsteroidal, anti-androgen agent that binds to androgen receptor and inhibits androgen uptake as well as inhibits androgen binding in nucleus in androgen-sensitive prostate cancer cells.
- Affinity to androgen receptor is four times greater than that of flutamide.

### Mechanism of Resistance

- Decreased expression of androgen receptor.
- Mutation in androgen receptor leading to decreased binding affinity to bicalutamide.

### Absorption

Well absorbed by the GI tract. Peak plasma levels observed 1–2 hours after oral administration. Absorption is not affected by food.

### Distribution

Distribution is not well characterized. Extensively bound to plasma proteins (96%).

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### Metabolism

Extensive metabolism occurs in the liver via oxidation and glucuronidation by cytochrome P<sub>450</sub> enzymes to inactive metabolites. Both parent drug and its metabolites are cleared in urine and feces. The elimination half-life is long, on the order of several days.

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### Indications

Stage D<sub>2</sub> metastatic prostate cancer.

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### Dosage Range

Recommended dose is 50 mg PO once daily either alone or in combination with a luteinizing hormone–releasing hormone (LHRH) analog.

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### Drug Interactions

Warfarin—Bicalutamide can displace warfarin from their protein-binding sites leading to increased anticoagulant effect. Coagulation parameters (PT and INR) must be followed closely, and dose adjustments may be needed.

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### Special Considerations

1. Use with caution in patients with abnormal liver function. Monitor LFTs at baseline and during therapy.
2. Caution patients about the potential for hot flashes. Consider the use of clonidine 0.1–0.2 mg PO daily, Megace 20 mg PO bid, or soy tablets one tablet PO tid for prevention and/or treatment.
3. Instruct patients on the potential risk of altered sexual function and impotence.
4. Pregnancy category D.

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### Toxicity 1

Hot flashes, decreased libido, impotence, gynecomastia, nipple pain, and galactorrhea. Occur in 50% of patients.

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### Toxicity 2

Constipation observed in 10% of patients. Nausea, vomiting, and diarrhea occur rarely.

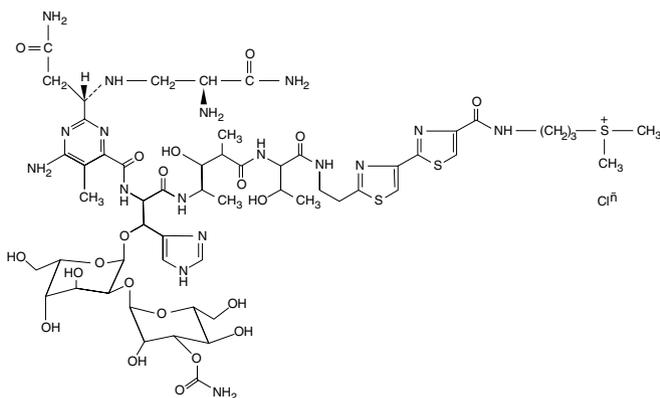
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### Toxicity 3

Transient elevations in serum transaminases are rare.

# B

## Bleomycin



### Trade Names

Blenoxane

### Classification

Antitumor antibiotic

### Category

Chemotherapy drug

### Drug Manufacturer

Bristol-Myers Squibb

### Mechanism of Action

- Small peptide with a molecular weight of 1,500.
- Contains a DNA-binding region and an iron-binding region at opposite ends of the molecule.
- Iron is absolutely necessary as a cofactor for free radical generation and bleomycin's cytotoxic activity.
- Cytotoxic effects result from the generation of activated oxygen free radical species, which causes single- and double-strand DNA breaks and eventual cell death.

---

### Mechanism of Resistance

- Increased expression of DNA repair enzymes resulting in enhanced repair of DNA damage.
- Decreased drug accumulation through altered uptake of drug.

---

### Absorption

Oral bioavailability of bleomycin is poor. After IM administration, peak levels are obtained in about 60 minutes but reach only one-third the levels achieved after an IV dose. When administered in the intrapleural space for the treatment of malignant pleural effusion (pleurodesis), approximately 45%–50% of the drug is absorbed into the systemic circulation.

---

### Distribution

Distributes into intra- and extracellular fluid. Less than 10% of drug bound to plasma proteins.

---

### Metabolism

After IV administration, there is a rapid biphasic disappearance from the circulation. The terminal half-life is approximately three hours in patients with normal renal function. Bleomycin is rapidly inactivated in tissues, especially the liver and kidney, by the enzyme bleomycin hydrolase. Elimination of bleomycin is primarily via the kidneys, with 50%–70% of a given dose being excreted unchanged in urine. Patients with impaired renal function may experience increased drug accumulation and are at risk for increased toxicity. Dose reductions are required in the presence of renal dysfunction.

---

### Indications

1. Hodgkin's disease and non-Hodgkin's lymphoma.
2. Germ cell tumors.
3. Head and neck cancer.
4. Squamous cell carcinomas of the skin, cervix, and vulva.
5. Sclerosing agent for malignant pleural effusion and ascites.

---

### Dosage Range

1. Hodgkin's disease: 10 units/m<sup>2</sup> IV on days 1 and 15 every 28 days, as part of the ABVD regimen.
2. Testicular cancer: 30 units IV on days 2, 9, and 16 every 21 days, as part of the PEB regimen.
3. Intracavitary instillation into pleural space: 60 units/m<sup>2</sup>.

# B

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## Drug Interaction 1

Oxygen—High concentrations of oxygen may enhance the pulmonary toxicity of bleomycin. FIO<sub>2</sub> should be maintained at no higher than 25% when possible.

---

## Drug Interaction 2

Phenothiazines—Phenothiazines enhance the activity of bleomycin by competing with liver P<sub>450</sub> enzymes.

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## Drug Interaction 3

Cisplatin—Cisplatin decreases renal clearance of bleomycin and, in so doing, may enhance toxicity.

---

## Drug Interaction 4

Radiation therapy—Radiation therapy enhances the pulmonary toxicity of bleomycin.

---

## Special Considerations

1. PFTs with special focus on carbon monoxide diffusion in the lung. DLCO and vital capacity should be obtained at baseline and before each cycle of therapy. A decrease of >15% in PFTs should mandate the immediate discontinuation of bleomycin, even in the absence of clinical symptoms. Increased risk of pulmonary toxicity when cumulative dose >400 units.
2. Chest x-ray should be obtained at baseline and before each cycle of therapy to monitor for evidence of infiltrates and/or interstitial lung findings.
3. Monitor for clinical signs of pulmonary dysfunction, including shortness of breath, dyspnea, decreased O<sub>2</sub> saturation, and decreased lung expansion.
4. Use with caution in patients with impaired renal function because drug clearance may be reduced. Doses should be reduced in the presence of renal dysfunction. Baseline creatinine clearance should be obtained, and renal status should be monitored before each cycle.
5. Patients with lymphoma may be at increased risk for developing an anaphylactic reaction. This complication can be immediate or delayed. An anaphylaxis kit that includes epinephrine, antihistamines, and corticosteroids should be readily available at bedside during bleomycin administration.
6. Premedicate patients with acetaminophen 30 minutes before administration of drug and every six hours for 24 hours if fever and chills are noted.

7. Patients undergoing surgery must inform the surgeon and anesthesiologist of prior treatment with bleomycin. High concentrations of forced inspiratory oxygen (FIO<sub>2</sub>) at the time of surgery may enhance the pulmonary toxicity of bleomycin.

---

#### Toxicity 1

Skin reactions are the most common side effects and include erythema, hyperpigmentation of the skin, striae, and vesiculation. Skin peeling, thickening of the skin and nail beds, hyperkeratosis, and ulceration can also occur. These manifestations usually occur in the second and third week after treatment, when the cumulative dose has reached 150–200 units. Alopecia is common.

---

#### Toxicity 2

Pulmonary toxicity is dose-limiting. Occurs in 10% of patients. Usually presents as pneumonitis with cough, dyspnea, dry inspiratory crackles, and infiltrates on chest x-ray. This complication is both dose- and age-related. Increased incidence in patients >70 years of age and with cumulative doses >400 units. Rarely progresses to pulmonary fibrosis but can be fatal in about 1% of patients. PFTs are the most sensitive approach to follow, with specific focus on DLCO and vital capacity. A decrease of 15% or more in the PFTs should mandate immediate stoppage of the drug.

---

#### Toxicity 3

Hypersensitivity reaction in the form of fever and chills observed in up to 25% of patients. True anaphylactoid reactions are rare but more common in patients with lymphoma.

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#### Toxicity 4

Vascular events, including myocardial infarction, stroke, and Raynaud's phenomenon, are rarely reported.

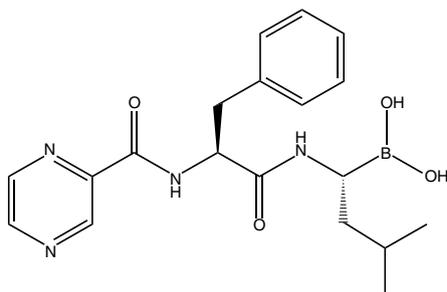
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#### Toxicity 5

Myelosuppression is relatively mild.

# B

## Bortezomib



### Trade Names

Velcade

### Classification

Proteasome inhibitor

### Category

Chemotherapy drug

### Drug Manufacturer

Millennium

### Mechanism of Action

- Reversible inhibitor of the 26S proteasome.
- The 26S proteasome is a large protein complex that degrades ubiquitinated proteins. This pathway plays an essential role in regulating the intracellular concentrations of various cellular proteins.
- Inhibition of the 26S proteasome prevents the targeted proteolysis of ubiquitinated proteins, and disruption of this normal pathway can affect multiple signaling pathways within the cell, leading to cell death.
- Results in down-regulation of the NF- $\kappa$ B pathway. NF- $\kappa$ B is a transcription factor that stimulates the production of various growth factors, including IL-6, cell adhesion molecules, and anti-apoptotic proteins, all of which contribute to cell growth and chemoresistance. Inhibition of the NF- $\kappa$ B pathway by bortezomib leads to inhibition of cell growth and restores chemosensitivity.

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### Mechanism of Resistance

None well characterized to date.

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### Absorption

Bortezomib is given only by the intravenous route.

---

### Distribution

Volume of distribution not well characterized. About 80% of drug bound to plasma proteins.

---

### Metabolism

Bortezomib has a terminal half-life of 9–15 hours. It is metabolized by the liver cytochrome P450 system. The major metabolic pathway is deboronation, forming two deboronated metabolites. The deboronated metabolites are inactive as 26S proteasome inhibitors. Elimination pathways for bortezomib have not been well characterized.

---

### Indications

1. Relapsing or refractory multiple myeloma—FDA-approved for patients who have received at least one prior therapy and who have had disease progression while on their most recent therapy. Also indicated for patients who have already undergone or are unsuitable for bone marrow transplantation.
  2. Non-Hodgkin's lymphoma and, in particular, mantle cell lymphoma.
- 

### Dosage Range

Recommended dose is 1.3 mg/m<sup>2</sup> administered by IV twice weekly for 2 weeks (on days 1, 4, 8, and 11) followed by a 10-day rest period (days 12–21).

---

### Drug Interactions

No formal drug interactions have been investigated with bortezomib.

---

### Special Considerations

1. Contraindicated in patients with hypersensitivity to boron, bortezomib, and/or mannitol.
2. Use with caution in patients with impaired liver function, because drug metabolism and/or clearance may be reduced. No formal dose recommendations in this setting, although patients should be closely monitored for toxicities.
3. Use with caution in patients with impaired renal function, especially if the creatinine clearance is <30 mL/min. Dose reduction should be considered in this setting.

# B

4. Use with caution in patients with a history of syncope, patients who are on antihypertensive medications, and patients who are dehydrated, because bortezomib can cause orthostatic hypotension.
5. Bortezomib should be withheld at the onset of any grade 3 nonhematologic toxicity, excluding neuropathy, or any grade 4 hematologic toxicities. After symptoms have resolved, therapy can be restarted with a 25% dose reduction. With respect to neuropathy, the dose of bortezomib should be reduced to 1.0 mg/m<sup>2</sup> with grade 1 neurotoxicity. In the presence of grade 2 neurotoxicity, therapy should be withheld until symptoms have resolved and restarted at a dose of 0.7 mg/m<sup>2</sup> along with changing the treatment schedule to once per week. In the presence of grade 4 neurotoxicity, therapy should be discontinued.
6. Pregnancy category D.

---

## Toxicity 1

Fatigue, malaise, and generalized weakness. Usually observed during the first and second cycles of therapy.

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## Toxicity 2

GI toxicity in the form of nausea/vomiting and diarrhea.

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## Toxicity 3

Myelosuppression with thrombocytopenia and neutropenia.

---

## Toxicity 4

Peripheral sensory neuropathy, although a mixed sensorimotor neuropathy has also been observed. Symptoms may improve and/or return to baseline upon discontinuation of bortezomib.

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## Toxicity 5

Fever (>38°C) in up to 40% of patients.

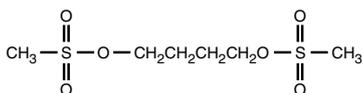
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## Toxicity 6

Orthostatic hypotension in up to 12% of patients.

# Busulfan

# B



## Trade Names

Myleran, Busulfex

## Classification

Alkylating agent

## Category

Chemotherapy drug

## Drug Manufacturer

GlaxoSmithKline

## Mechanism of Action

- Methanesulfonate-type bifunctional alkylating agent.
- Interacts with cellular thiol groups and nucleic acids to form DNA-DNA and DNA-protein cross-links. Cross-linking of DNA results in inhibition of DNA synthesis and function.
- Cell cycle–nonspecific, active in all phases of the cell cycle.

## Mechanism of Resistance

- Decreased cellular uptake of drug.
- Increased intracellular thiol content due to glutathione or glutathione-related enzymes.
- Enhanced activity of DNA repair enzymes.

## Absorption

Excellent oral bioavailability with peak levels in serum occurring within 2–4 hours after administration. About 30% of drug is bound to plasma proteins.

## Distribution

Distributes rapidly in plasma with broad tissue distribution. Crosses the blood-brain barrier and also crosses the placental barrier.

# B

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## Metabolism

Metabolized primarily in the liver by the cytochrome P<sub>450</sub> system. Metabolites, including sulfoxane, 3-hydroxysulfoxane, and methanesulfonic acid, are excreted in urine, with 50%–60% excreted within 48 hours. Metabolism may be influenced by circadian rhythm with higher clearance rates observed in the evening, especially in younger patients. The terminal half-life is 2.5 hours.

---

## Indications

1. Chronic myelogenous leukemia (CML) (standard dose).
2. Bone marrow/stem cell transplantation for refractory leukemia, lymphoma (high dose). Use in combination with cyclophosphamide as conditioning regimen prior to allogeneic stem cell transplantation for CML.

---

## Dosage Range

1. CML: Usual dose for remission induction is 4–8 mg/day PO. Dosing on a weight basis is 1.8 mg/m<sup>2</sup>/day. Maintenance dose is usually 1–3 mg/day PO.
2. Transplant setting: 4 mg/kg/day IV for four days to a total dose of 16 mg/kg.

---

## Drug Interaction 1

Acetaminophen—Acetaminophen may decrease busulfan metabolism in the liver when given 72 hours before busulfan, resulting in enhanced toxicity.

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## Drug Interaction 2

Itraconazole—Itraconazole reduces busulfan metabolism by up to 20%.

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## Drug Interaction 3

Phenytoin—Phenytoin increases busulfan metabolism in the liver by inducing the activity of the liver microsomal system.

---

## Special Considerations

1. Monitor CBC while on therapy. When the total WBC count has declined to approximately 15,000/mm<sup>3</sup>, busulfan should be withheld until the nadir is reached and the counts begin to rise above this level. A decrease in the WBC count may not be seen during the first 10–15 days of therapy, and it may continue to fall for more than one month even after the drug has been stopped.
2. Monitor patients for pulmonary symptoms as busulfan can cause interstitial pneumonitis.

3. Ingestion of busulfan on an empty stomach may decrease the risk of nausea and vomiting.
4. Pregnancy category D. Breast-feeding should be avoided.

---

#### Toxicity 1

Myelosuppression with pancytopenia. Dose-limiting toxicity.

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#### Toxicity 2

Nausea/vomiting and diarrhea are common (>80% of patients) but generally mild with standard doses. Anorexia is also frequently observed.

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#### Toxicity 3

Mucositis is dose-related and may require interruption of therapy in some instances.

---

#### Toxicity 4

Hyperpigmentation of skin, especially in hand creases and nail beds. Skin rash and pruritus also observed.

---

#### Toxicity 5

Impotence, male sterility, amenorrhea, ovarian suppression, menopause, and infertility.

---

#### Toxicity 6

Pulmonary symptoms, including cough, dyspnea, and fever, can be seen after long-term therapy. Interstitial pulmonary fibrosis, referred to as “busulfan lung,” is a rare but severe side effect of therapy. May occur 1–10 years after discontinuation of therapy.

---

#### Toxicity 7

Adrenal insufficiency occurs rarely.

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#### Toxicity 8

Hepatotoxicity with elevations in LFTs. Hepato-veno-occlusive disease is observed with high doses of busulfan (>16 mg/day) used in transplant setting.

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#### Toxicity 9

Insomnia, anxiety, dizziness, and depression are the most common neurologic side effects. Seizures can occur, usually with high-dose therapy.

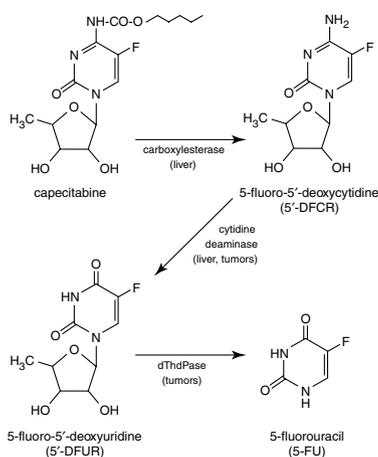
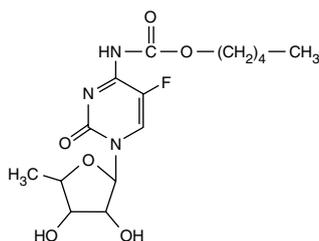
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#### Toxicity 10

Increased risk of secondary malignancies, especially acute myelogenous leukemia, with long-term chronic use.

## C

## Capecitabine



## Trade Names

Xeloda

## Classification

Antimetabolite

## Category

Chemotherapy drug

## Drug Manufacturer

Roche

## Mechanism of Action

- Fluoropyrimidine carbamate prodrug form of 5-fluorouracil (5-FU). Capecitabine itself is inactive.

- Activation to cytotoxic forms is a complex process. Metabolized in liver to 5'-deoxy-5-fluorocytidine (5'-DFCR) by the carboxylesterase enzyme and then to 5'-deoxy-5-fluorouridine (5'-DFUR) by cytidine deaminase (found in liver and in tumor tissues). Subsequently converted to 5-FU by the enzyme thymidine phosphorylase, which is expressed in higher levels in tumor versus normal tissue.
- Inhibition of the target enzyme thymidylate synthase by the 5-FU metabolite FdUMP.
- Incorporation of 5-FU metabolite FUTP into RNA resulting in alterations in RNA processing and/or translation.
- Incorporation of 5-FU metabolite FdUTP into DNA resulting in inhibition of DNA synthesis and function.
- Inhibition of TS leads to accumulation of dUMP and subsequent misincorporation of dUTP into DNA, resulting in inhibition of DNA synthesis and function.

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### Mechanism of Resistance

- Increased expression of thymidylate synthase.
- Decreased levels of reduced folate substrate 5,10-methylenetetrahydrofolate for thymidylate synthase reaction.
- Decreased incorporation of 5-FU into RNA.
- Decreased incorporation of 5-FU into DNA.
- Increased activity of DNA repair enzymes, uracil glycosylase and dUTPase.
- Increased salvage of physiologic nucleosides including thymidine.
- Increased expression of dihydropyrimidine dehydrogenase.
- Alterations in thymidylate synthase with decreased binding affinity of enzyme for FdUMP.

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### Absorption

Capecitabine is readily absorbed by the GI tract. Peak plasma levels are reached in 1.5 hours, while peak 5-FU levels are achieved at 2 hours after oral administration. The rate and extent of absorption are reduced by food.

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### Distribution

Plasma protein binding of capecitabine and its metabolites is less than 60%. Primarily bound to albumin (35%).

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### Metabolism

Capecitabine undergoes extensive enzymatic metabolism to 5-FU. After being absorbed as an intact molecule from the GI tract, it undergoes an initial hydrolysis reaction in the liver catalyzed by carboxylesterase to

5'-DFCR. In the next step, 5'-DFCR is converted in the liver and other tissues to 5'-DFUR by the enzyme cytidine deaminase. Finally, 5'-DFUR is converted to 5-FU by the enzyme thymidine phosphorylase in tumor tissue as well as in normal tissues expressing this enzyme.

Catabolism accounts for >85% of drug metabolism. Dihydropyrimidine dehydrogenase is the main enzyme responsible for the catabolism of 5-FU, and it is present in liver and extrahepatic tissues such as GI mucosa, WBCs, and the kidneys. Greater than 90% of an administered dose of drug and its metabolites is cleared in the urine. The major metabolite excreted in urine is alpha-fluoro-beta-alanine (FBAL). Only 3% of the drug is cleared by fecal elimination. The elimination half-life of both capecitabine and 5-FU is 45 minutes.

---

### Indications

1. Metastatic breast cancer—FDA-approved when used in combination with docetaxel for the treatment of patients with metastatic breast cancer after failure of prior anthracycline-containing chemotherapy.
2. Metastatic breast cancer—FDA-approved as monotherapy in patients refractory to both paclitaxel- and anthracycline-based chemotherapy or when anthracycline therapy is contraindicated.
3. Metastatic colorectal cancer—FDA-approved as first-line therapy when fluoropyrimidine therapy alone is preferred.
4. Stage III colon cancer—FDA-approved as adjuvant therapy when fluoropyrimidine therapy alone is preferred.

---

### Dosage Range

1. Recommended dose is 1,250 mg/m<sup>2</sup> PO bid (morning and evening) for two weeks with one week rest. For combination therapy (capecitabine in combination with docetaxel) with docetaxel being dosed at 75 mg/m<sup>2</sup> day one of a 21-day cycle.
2. May decrease dose of capecitabine to 850–1000 mg/m<sup>2</sup> bid on days 1–14 to reduce risk of toxicity without compromising efficacy. [See section Special Considerations (8).]
3. An alternative dosing schedule is 1,250–1,500 mg/m<sup>2</sup> PO bid for 1 week on and 1 week off. This schedule appears to be well tolerated, with no compromise in clinical efficacy.
4. Capecitabine should be used at lower doses when used in combination with other cytotoxic agents.

---

### Drug Interaction 1

Capecitabine-Warfarin interaction: Patients receiving concomitant capecitabine and oral coumarin-derivative anticoagulant therapy should have their coagulation parameters (PT and INR) monitored frequently in

order to adjust the anticoagulant dose accordingly. A clinically important Capecitabine-Warfarin drug interaction was demonstrated in a clinical pharmacology trial (see CLINICAL PHARMACOLOGY and PRECAUTIONS). Altered coagulation parameters and/or bleeding, including death, have been reported in patients taking capecitabine concomitantly with coumarin-derivative anticoagulants such as warfarin and phenprocoumon. Postmarketing reports have shown clinically significant increases in PT and INR in patients who were stabilized on anticoagulants at the time capecitabine was introduced. These events occurred within several days and up to several months after initiating capecitabine therapy and, in a few cases, within one month after stopping capecitabine. These events occurred in patients with and without liver metastases. Age greater than 60 and a diagnosis of cancer independently predispose patients to an increased risk of coagulopathy.

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### Drug Interaction 2

Aluminum hydroxide, magnesium hydroxide—Concomitant use of aluminum hydroxide- or magnesium hydroxide-containing antacids may increase the bioavailability of capecitabine by 16%–35%.

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### Drug Interaction 3

Phenytoin—Capecitabine may increase phenytoin blood levels and subsequent phenytoin toxicity. Dose adjustment of phenytoin may be necessary.

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### Drug Interaction 4

Leucovorin—Leucovorin enhances the toxicity and antitumor activity of capecitabine.

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### Special Considerations

1. Capecitabine should be taken with a glass of water within 30 minutes after a meal.
2. Contraindicated in patients with known hypersensitivity to 5-FU.
3. Contraindicated in patients with known dihydropyrimidine dehydrogenase (DPD) deficiency.
4. No dose adjustments are necessary in patients with mild to moderate liver dysfunction. However, patients should be closely monitored.
5. In the setting of moderate renal dysfunction (baseline creatinine clearance, 30–50 mL/min), a 25% dose reduction is recommended. Patients should be closely monitored as they may be at greater risk for increased host toxicity. Contraindicated in patients with severe renal impairment (creatinine clearance <30 mL/min).
6. Patients should be monitored for diarrhea and its associated sequelae, including dehydration, fluid imbalance, and infection. Elderly patients (>80 years of age) are especially vulnerable to the

GI toxicity of capecitabine. Moderate to severe diarrhea (grade 2, 3, or 4) is an indication to interrupt therapy immediately. Subsequent doses should be reduced accordingly.

7. Drug therapy should be stopped immediately in the presence of grades 2 to 4 hyperbilirubinemia until complete resolution or a decrease in intensity to grade 1.
8. Drug therapy should be stopped immediately in the presence of grades 2 or higher adverse event until complete resolution or a decrease in intensity to grade 1. Treatment should continue at 75% of the initial starting dose for grade 2 or 3 toxicity. For grade 4 toxicities, if the physician chooses to continue treatment, treatment should continue at 50% of the initial starting dose.
9. Patients who experience unexpected, severe grade 3 or 4 myelosuppression, GI toxicity, and/or neurologic toxicity upon initiation of therapy may have an underlying deficiency in dihydropyrimidine dehydrogenase. Therapy must be discontinued immediately, and further testing to identify the presence of this pharmacogenetic syndrome should be considered.
10. Vitamin B6 (pyridoxine, 50 mg PO bid) may be used to prevent and/or reduce the incidence and severity of hand-foot syndrome. Dose may be increased to 100 mg PO bid if symptoms do not resolve within 3–4 days.
11. Celecoxib at a dose of 200 mg PO bid may be effective in preventing and/or reducing the incidence and severity of hand-foot syndrome. A low-dose nicotine patch has also been found to be effective in this setting.
12. In patients with the hand-foot syndrome, the affected skin should be well hydrated using a bland and mild moisturizer. Instruct patients to soak affected hands and feet in cool to tepid water for 10 minutes, then apply petroleum jelly onto the wet skin. The use of lanolin-containing salves or ointments such as Bag-Balm emollient may help.
13. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Diarrhea. Dose-limiting, observed in up to 55% of patients. Similar to GI toxicity observed with continuous infusion 5-FU. Mucositis, loss of appetite, dehydration also noted.

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#### Toxicity 2

Hand-foot syndrome (palmar-plantar erythrodysesthesia). Severe hand-foot syndrome is seen in 15–20% of patients. Characterized by tingling, numbness, pain, erythema, dryness, rash, swelling, increased pigmentation,

and/or pruritus of the hands and feet. Similar to dermatologic toxicity observed with continuous infusion 5-FU.

---

**Toxicity 3**

Nausea and vomiting. Occur in 15%–53% of patients.

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**Toxicity 4**

Elevations in serum bilirubin (20%–40%), alkaline phosphatase, and hepatic transaminases (SGOT, SGPT). Usually transient and clinically asymptomatic.

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**Toxicity 5**

Myelosuppression is observed less frequently than with IV 5-FU. Leukopenia more common than thrombocytopenia.

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**Toxicity 6**

Neurologic toxicity manifested by confusion, cerebellar ataxia, and rarely encephalopathy.

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**Toxicity 7**

Cardiac symptoms of chest pain, EKG changes, and serum enzyme elevation. Rare event but increased risk in patients with prior history of ischemic heart disease.

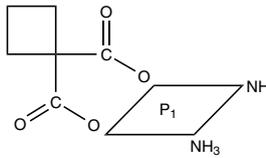
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**Toxicity 8**

Tear-duct stenosis, acute and chronic conjunctivitis.

# C

## Carboplatin



### Trade Names

Paraplatin, CBDCA

### Classification

Platinum analog

### Category

Chemotherapy drug

### Drug Manufacturer

Bristol-Myers Squibb

### Mechanism of Action

- Covalently binds to DNA with preferential binding to the N-7 position of guanine and adenine.
- Reacts with two different sites on DNA to produce cross-links, either intrastrand (<90%) or interstrand (<5%). Formation of DNA adducts results in inhibition of DNA synthesis and function as well as inhibition of transcription.
- Binding to nuclear and cytoplasmic proteins may result in cytotoxic effects.
- Cell cycle–nonspecific agent.

### Mechanism of Resistance

- Reduced accumulation of carboplatin due to alterations in cellular transport.
- Increased inactivation by thiol-containing proteins such as glutathione and glutathione-related enzymes.
- Enhanced DNA repair enzyme activity (e.g., ERCC-1).
- Deficiency in mismatch repair (MMR) genes (e.g., hMLH1, hMSH2).

### Absorption

Not absorbed by the oral route.

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### Distribution

Widely distributed in body tissues. Crosses the blood-brain barrier and enters the CSF. Does not bind to plasma proteins and has an apparent volume of distribution of 16 L.

---

### Metabolism

Carboplatin does not undergo significant metabolism. As observed with cisplatin, carboplatin undergoes aquation reaction in the presence of low concentrations of chloride. This reaction is 100-fold slower with carboplatin when compared to cisplatin. Carboplatin is extensively cleared by the kidneys, with about 60%–70% of drug excreted in urine within 24 hours. The elimination of carboplatin is slower than that of cisplatin, with a terminal half-life of 2–6 hours.

---

### Indications

1. Ovarian cancer.
2. Germ cell tumors.
3. Head and neck cancer.
4. Small cell and non-small cell lung cancer.
5. Bladder cancer.
6. Relapsed and refractory acute leukemia.
7. Endometrial cancer.

---

### Dosage Range

1. Dose of carboplatin is usually calculated to a target area under the curve (AUC) based on the glomerular filtration rate (GFR).
2. Calvert formula is used to calculate dose: Total dose (mg) = (target AUC) × (GFR + 25). \*Note: Dose is in mg **NOT** mg/m<sup>2</sup>.
3. Target AUC is usually between 5 and 7 mg/mL/min for previously untreated patients. In previously treated patients, lower AUCs (between 4 and 6 mg/mL/min) are recommended. AUCs >7 are not associated with improved response rates.
4. Bone marrow/stem cell transplant setting: Doses up to 1,600 mg/m<sup>2</sup> divided over several days.

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### Drug Interaction 1

Myelosuppressive agents—Increased risk of myelosuppression when carboplatin is combined with other myelosuppressive drugs.

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### Drug Interaction 2

Paclitaxel—Carboplatin should be administered after paclitaxel when carboplatin and paclitaxel are used in combination. This sequence prevents delayed paclitaxel excretion and increased host toxicity.

---

### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose reduction is required in the setting of renal dysfunction. Baseline creatinine clearance must be obtained. Renal status must be closely monitored during therapy.
2. Although carboplatin is not as emetogenic as cisplatin, pretreatment with antiemetic agents is strongly recommended.
3. Use with caution in the presence of other nephrotoxic agents, such as aminoglycoside antibiotics, because such use may increase the risk of renal toxicity.
4. Avoid needles or IV administration sets containing aluminum because precipitation of drug may occur.
5. Contraindicated in patients with a history of severe allergic reactions to cisplatin, other platinum compounds, or mannitol.
6. In contrast to cisplatin, IV hydration pretreatment and posttreatment are not necessary. However, patients should still be instructed to maintain adequate oral hydration.
7. Hemodialysis clears carboplatin at 25% of the rate of renal clearance. Peritoneal dialysis is unable to remove carboplatin.
8. Risk of hypersensitivity reactions increases from 1% to 27% in patients receiving more than seven courses of carboplatin-based therapy. For such patients, a 0.02 mL-intradermal injection of an undiluted aliquot of their planned carboplatin dose should be administered one hour before each cycle of carboplatin. This skin test identifies patients in whom carboplatin may be safely administered.
9. Pregnancy category D.

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### Toxicity 1

Myelosuppression is significant and dose-limiting. Dose-dependent, cumulative toxicity is more severe in elderly patients. Thrombocytopenia is most commonly observed, with nadir by day 21.

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### Toxicity 2

Nausea and vomiting. Delayed nausea and vomiting can also occur, albeit rarely. Significantly less emetogenic than cisplatin.

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### Toxicity 3

Renal toxicity. Significantly less common than with cisplatin and rarely symptomatic. Electrolyte imbalance commonly observed, with hypocalcemia, hypokalemia, hypomagnesemia, and hyponatremia.

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**Toxicity 4**

Peripheral neuropathy is observed in less than 10% of patients. Patients older than 65 years and/or previously treated with cisplatin may be at higher risk for developing neurologic toxicity.

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**Toxicity 5**

Mild and reversible elevation of liver enzymes, particularly alkaline phosphatase and SGOT.

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**Toxicity 6**

Allergic reaction. Can occur within a few minutes of starting therapy. Presents mainly as skin rash, urticaria, and pruritus. Bronchospasm and hypotension are uncommon.

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**Toxicity 7**

Amenorrhea, azoospermia, impotence, and sterility.

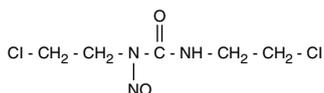
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**Toxicity 8**

Alopecia is uncommon.

# C

## Carmustine



### Trade Names

BCNU, Bischloronitrosourea

### Classification

Alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

Bristol-Myers Squibb

### Mechanism of Action

- Nitrosourea analog.
- Cell cycle–nonspecific.
- Chloroethyl metabolites interfere with the synthesis of DNA, RNA, and protein.

### Mechanism of Resistance

- Decreased cellular uptake of drug.
- Increased intracellular thiol content due to glutathione or glutathione-related enzymes.
- Enhanced activity of DNA repair enzymes.

### Absorption

Not absorbed via the oral route.

### Distribution

Lipid-soluble drug with broad tissue distribution. Crosses the blood-brain barrier, reaching concentrations >50% of those in plasma.

### Metabolism

After IV infusion, carmustine is rapidly taken up into tissues and degraded. Extensively metabolized in the liver. Approximately 60%–70% of drug is excreted in urine in its metabolite form, while 10% is excreted as respiratory CO<sub>2</sub>. Short serum half-life of only 15–20 minutes.

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### Indications

1. Brain tumors—Glioblastoma multiforme, brain stem glioma, medulloblastoma, astrocytoma, and ependymoma.
2. Hodgkin's disease.
3. Non-Hodgkin's lymphoma.
4. Multiple myeloma.
5. Glioblastoma multiforme—implantable BCNU-impregnated wafer (Gliadel).

---

### Dosage Range

1. Usual dose is 200 mg/m<sup>2</sup> IV every six weeks. Dose can sometimes be divided over two days.
2. Higher doses (450–600 mg/m<sup>2</sup>) are used with stem cell rescue.
3. Implantable BCNU-impregnated wafers: Up to 8 wafers are placed into the surgical resection site after excision of the primary brain tumor.

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### Drug Interaction 1

Cimetidine—Cimetidine enhances the toxicity of carmustine.

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### Drug Interaction 2

Amphotericin B—Amphotericin B enhances the cellular uptake of carmustine, thus resulting in increased host toxicity, including renal toxicity.

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### Drug Interaction 3

Digoxin—Carmustine may decrease the plasma levels of digoxin.

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### Drug Interaction 4

Phenytoin—Carmustine may decrease the plasma levels of phenytoin.

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### Special Considerations

1. Administer carmustine slowly over a period of 1–2 hours to avoid intense pain and/or burning at the site of injection. Strategies to decrease pain and/or burning include diluting the drug, slowing the rate of administration, or placing ice above the IV injection site.
2. Monitor CBC while on therapy. Repeated cycles should not be given before six weeks, given the delayed and potentially cumulative myelosuppressive effects of carmustine.
3. PFTs should be obtained at baseline and monitored periodically during therapy. There is an increased risk of pulmonary toxicity in patients with a baseline forced vital capacity (FVC) or DLCO below 70% of predicted.
4. Pregnancy category D.

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**Toxicity 1**

Myelosuppression is dose-limiting. Nadir typically occurs at 4–6 weeks after therapy and may persist for 1–3 weeks.

---

**Toxicity 2**

Nausea and vomiting may occur within two hours after a dose of drug and can last for up to 4–6 hours.

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**Toxicity 3**

Facial flushing and a burning sensation at the IV injection site. Skin contact with drug may cause brownish discoloration and pain.

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**Toxicity 4**

Hepatotoxicity with transient elevations in serum transaminases develops in up to 90% of patients within one week of therapy. With high-dose therapy, hepato-veno-occlusive disease may be observed in 5%–20% of patients.

---

**Toxicity 5**

Impotence, male sterility, amenorrhea, ovarian suppression, menopause, and infertility. Gynecomastia is occasionally observed.

---

**Toxicity 6**

Pulmonary toxicity is uncommon at low doses. At cumulative doses greater than 1,400 mg/m<sup>2</sup>, interstitial lung disease and pulmonary fibrosis in the form of an insidious cough, dyspnea, pulmonary infiltrates, and/or respiratory failure may develop.

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**Toxicity 7**

Renal toxicity is uncommon at total cumulative doses of less than 1,000 mg/m<sup>2</sup>.

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**Toxicity 8**

Increased risk of secondary malignancies, especially acute myelogenous leukemia and myelodysplasia.

# Cetuximab

C

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## Trade Names

Erbix

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## Classification

Monoclonal antibody, anti-EGFR-antibody

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Bristol Myers-Squibb and ImClone

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## Mechanism of Action

- Recombinant humanized monoclonal antibody directed against the epidermal growth factor receptor (EGFR). EGFR is overexpressed in a broad range of human solid tumors, including colorectal cancer, head and neck cancer, non-small cell lung cancer, pancreatic cancer, and breast cancer.
- Precise mechanism(s) of action remains unknown.
- Binds with nearly 10-fold higher affinity to EGFR than normal ligands EGF and TGF- $\alpha$ , which then results in inhibition of EGFR. Prevents both homodimerization and heterodimerization of the EGFR which leads to inhibition of autophosphorylation and inhibition of EGFR signaling.
- Inhibition of the EGFR signaling pathway results in inhibition of critical mitogenic and anti-apoptotic signals involved in proliferation, growth, invasion/metastasis, angiogenesis.
- Inhibition of the EGFR pathway enhances the response to chemotherapy and/or radiation therapy.
- Immunologic mechanisms may also be involved in antitumor activity, and they include recruitment of ADCC and/or complement-mediated cell lysis.

---

## Mechanism of Resistance

- Mutation in the EGFR leading to decreased binding affinity to cetuximab.
- Decreased expression of EGFR.
- Presence of K-ras mutations.
- Activation/induction of alternative cellular signaling pathways, such as IGF-1R.

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### Distribution

Distribution in the body is not well characterized.

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### Metabolism

Metabolism of cetuximab has not been extensively characterized. Half-life is on the order of 5–7 days with minimal clearance by the liver or kidneys, as has been observed for other monoclonal antibodies and peptides used in the clinic.

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### Indications

1. Treatment of EGFR-expressing colorectal cancer in combination with irinotecan in irinotecan-refractory disease or as monotherapy in patients who are deemed to be irinotecan-intolerant. FDA-approved.
  2. Head and neck cancer—used in combination with radiation therapy for the treatment of locally or regionally advanced squamous cell cancer of the head and neck. FDA-approved.
  3. Pancreatic cancer—remains investigational.
  4. Non-small cell lung cancer—remains investigational.
  5. Breast cancer—remains investigational.
- 

### Dosage Range

Loading dose of 400 mg/m<sup>2</sup> IV administered over 120 minutes, followed by maintenance dose of 250 mg/m<sup>2</sup> IV given on a weekly basis.

An alternative dosing schedule is 500 mg/m<sup>2</sup> IV every 2 weeks with no need for a loading dose.

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### Drug Interactions

None well characterized to date.

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### Special Considerations

1. Cetuximab should be used with caution in patients with known hypersensitivity to murine proteins and/or any individual components.
2. The level of EGFR expression does not accurately predict for cetuximab clinical activity. As such, EGFR testing should not be required for the clinical use of cetuximab.
3. Development of skin toxicity appears to be a surrogate marker for cetuximab clinical activity.
4. Use with caution in patients with underlying interstitial lung disease as these patients are at increased risk for developing worsening of their interstitial lung disease.

5. In patients who develop a skin rash, topical antibiotics such as Cleocin gel or either oral Cleocin and/or oral minocycline may help. Topical steroids and/or oral steroid treatment do not appear to be helpful in this setting. Patients should be warned to avoid sunlight exposure.
6. About 90% of patients experience severe infusion reactions with the first infusion despite the use of prophylactic antihistamine therapy. However, some patients may experience infusion reactions with later infusions.
7. Electrolyte status should be closely monitored, especially serum magnesium and calcium levels, as hypomagnesemia and hypocalcemia have been observed with cetuximab treatment.
8. Pregnancy category C. Breast-feeding should be avoided.

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#### Toxicity 1

Infusion-related symptoms with fever, chills, urticaria, flushing, fatigue, headache, bronchospasm, dyspnea, angioedema, and hypotension. Occurs in 40%–50% of patients, although severe reactions occur in less than 1%. Usually mild to moderate in severity and observed most commonly with administration of the first infusion.

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#### Toxicity 2

Pruritus, dry skin with mainly a pustular, acneiform skin rash. Presents mainly on the face and upper trunk. Improves with continued treatment and resolves upon cessation of therapy.

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#### Toxicity 3

Pulmonary toxicity in the form of interstitial lung disease (ILD) manifested by increased cough, dyspnea, and pulmonary infiltrates. Observed in less than 1% of patients and more frequent in patients with underlying pulmonary disease.

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#### Toxicity 4

Hypomagnesemia.

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#### Toxicity 5

Asthenia and generalized malaise observed in nearly 50% of patients.

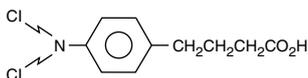
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#### Toxicity 6

Paronychia inflammation with swelling of the lateral nail folds of the toes and fingers.

# C

## Chlorambucil



### Trade Names

Leukeran

### Classification

Alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

GlaxoSmithKline

### Mechanism of Action

- Aromatic analog of nitrogen mustard.
- Functions as a bifunctional alkylating agent.
- Forms cross-links with DNA resulting in inhibition of DNA synthesis and function.
- Cell cycle–nonspecific. Active in all phases of the cell cycle.

### Mechanism of Resistance

- Decreased cellular uptake of drug.
- Increased activity of DNA repair enzymes.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-related enzymes.

### Absorption

Oral bioavailability is approximately 75% when taken with food. Maximum plasma levels are achieved within 1–2 hours after oral administration. Extensively bound to plasma proteins.

### Distribution

Distribution of chlorambucil has not been well studied.

### Metabolism

Metabolized extensively by the liver cytochrome P450 system to both active and inactive forms. Parent drug and its metabolites are eliminated

by the kidneys, and 60% of drug metabolites are excreted in urine within 24 hours. The terminal elimination half-life is 1.5–2.5 hours for the parent drug and about 2.5–4 hours for drug metabolites.

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### Indications

1. Chronic lymphocytic leukemia (CLL).
2. Non-Hodgkin's lymphoma.
3. Hodgkin's lymphoma.
4. Waldenström's macroglobulinemia.

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### Dosage Range

CLL: 0.1–0.2 mg/kg PO daily for 3–6 weeks as required. This dose for initiation of therapy. For maintenance therapy, a dose of 2–4 mg PO daily is recommended.

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### Drug Interactions

Phenobarbital, dilantin, and other drugs that stimulate the liver P450 system—Concurrent use of chlorambucil with these drugs may increase its metabolic activation, leading to increased formation of toxic metabolites.

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### Special Considerations

1. Careful review of patient's medication list is required.
2. Contraindicated within one month of radiation and/or cytotoxic therapy, recent smallpox vaccine, and seizure history.
3. Use with caution when combined with allopurinol or colchicine as drug-induced hyperuricemia may be exacerbated.
4. Closely monitor CBCs. Discontinuation of chlorambucil is not necessary at the first sign of a reduction in the WBC. However, fall may continue for 10 days or more after the last dose.
5. Therapy should be discontinued promptly if generalized skin rash develops as this side effect may rapidly progress to erythema multiforme, toxic epidermal necrolysis, or Stevens-Johnson syndrome.
6. Pregnancy category D.

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### Toxicity 1

Myelosuppression is dose-limiting. Leukopenia and thrombocytopenia observed equally, with delayed and prolonged nadir occurring 25–30 days and recovery by 40–45 days. Usually reversible, but irreversible bone marrow failure can occur.

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### Toxicity 2

Mild nausea and vomiting are common.

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**Toxicity 3**

Hyperuricemia.

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**Toxicity 4**

Pulmonary fibrosis and pneumonitis are dose-related and potentially life-threatening. Relatively rare event.

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**Toxicity 5**

Seizures. Children with nephrotic syndrome and patients receiving large cumulative doses are at increased risk. Patients with a history of seizure disorder may be especially prone to seizures.

---

**Toxicity 6**

Skin rash, urticaria on face, scalp, and trunk with spread to legs seen in the early stages of therapy. Stevens-Johnson syndrome and toxic epidermal neurolysis are rare events.

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**Toxicity 7**

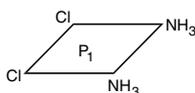
Amenorrhea, oligospermia/azoospermia, and sterility.

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**Toxicity 8**

Increased risk of secondary malignancies, including acute myelogenous leukemia.

# Cisplatin



## Trade Names

Cis-diamminedichloroplatinum, CDDP, Platinol

## Classification

Platinum analog

## Category

Chemotherapy drug

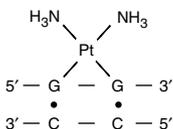
## Drug Manufacturer

Bristol-Myers Squibb

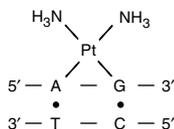
## Mechanism of Action

- Covalently binds to DNA with preferential binding to the N-7 position of guanine and adenine.
- Reacts with two different sites on DNA to produce cross-links, either intrastrand (>90%) or interstrand (<5%). Formation of DNA adducts results in inhibition of DNA synthesis and function as well as inhibition of transcription.
- Binding to nuclear and cytoplasmic proteins may result in cytotoxic effects.

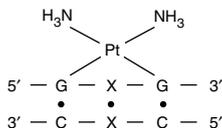
d(GpG) adduct



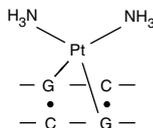
d(ApG) adduct



d(GpXpG) adduct



Interstrand cross-link



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### Mechanism of Resistance

- Decreased drug accumulation due to alterations in cellular transport.
- Increased inactivation by thiol-containing proteins such as glutathione and glutathione-related enzymes.
- Increased DNA repair enzyme activity (e.g., ERCC-1).
- Deficiency in MMR enzymes (e.g., hMHL1, hMSH2).

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### Absorption

Not absorbed orally. Systemic absorption is rapid and complete after intraperitoneal (IP) administration.

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### Distribution

Widely distributed to all tissues with highest concentrations in the liver and kidneys. Less than 10% remaining in the plasma one hour after infusion.

---

### Metabolism

Plasma concentrations of cisplatin decay rapidly, with a half-life of approximately 20–30 minutes following bolus administration. Within the cytoplasm of the cell, low concentrations of chloride (4 mM) favor the aquation reaction whereby the chloride atom is replaced by a water molecule, resulting in a highly reactive species. Platinum clearance from plasma proceeds slowly after the first two hours due to covalent binding with serum proteins, such as albumin, transferrin, and  $\gamma$ -globulin. Approximately 10%–40% of a given dose of cisplatin is excreted in the urine in 24 hours, with 35%–50% being excreted in the urine after five days of administration. Approximately 15% of the drug is excreted unchanged.

---

### Indications

1. Testicular cancer.
2. Ovarian cancer.
3. Bladder cancer.
4. Head and neck cancer.
5. Esophageal cancer.
6. Small cell and non-small cell lung cancer.
7. Non-Hodgkin's lymphoma.
8. Trophoblastic neoplasms.

---

### Dosage Range

1. Ovarian cancer: 75 mg/m<sup>2</sup> IV on day one every 21 days as part of the cisplatin/paclitaxel regimen, and 100 mg/m<sup>2</sup> on day one every 21 days as part of the cisplatin/cyclophosphamide regimen.

2. Testicular cancer: 20 mg/m<sup>2</sup> IV on days 1–5 every 21 days as part of the PEB regimen.
3. Non-small cell lung cancer: 60–100 mg/m<sup>2</sup> IV on day one every 21 days as part of the cisplatin/etoposide or cisplatin/gemcitabine regimens.
4. Head and neck cancer: 20 mg/m<sup>2</sup>/day IV continuous infusion for four days.

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#### Drug Interaction 1

Phenytoin—Cisplatin decreases pharmacologic effect of phenytoin. For this reason, phenytoin dose may need to be increased with concurrent use with cisplatin.

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#### Drug Interaction 2

Amifostine, mesna—The nephrotoxic effect of cisplatin is inactivated by amifostine and mesna.

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#### Drug Interaction 3

Aminoglycosides, amphotericin B, other nephrotoxic agents—Increased renal toxicity with concurrent use of cisplatin and aminoglycosides, amphotericin B, and/or other nephrotoxic agents.

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#### Drug Interaction 4

Etoposide, methotrexate, ifosfamide, bleomycin—Cisplatin reduces the renal clearance of etoposide, methotrexate, ifosfamide, and bleomycin, resulting in the increased accumulation of each of these drugs.

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#### Drug Interaction 5

Etoposide—Cisplatin may enhance the antitumor activity of etoposide.

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#### Drug Interaction 6

Radiation therapy—Cisplatin acts as a radiosensitizing agent.

---

#### Drug Interaction 7

Paclitaxel—Cisplatin should be administered after paclitaxel when cisplatin and paclitaxel are used in combination. This sequence prevents delayed paclitaxel excretion and increased host toxicity.

---

#### Drug Interaction 8

Aminoglycosides, furosemide—Risk of ototoxicity is increased when cisplatin is combined with aminoglycosides and loop diuretics such as furosemide.

---

#### Special Considerations

1. Contraindicated in patients with known hypersensitivity to cisplatin or other platinum analogs.

2. Use with caution in patients with abnormal renal function. Dose of drug must be reduced in the setting of renal dysfunction. Creatinine clearance should be obtained at baseline and before each cycle of therapy. Carefully monitor renal function (BUN and creatinine) as well as serum electrolytes (Na, Mg, Ca, K) during treatment.
3. Fluid status of patient is critical. Patients must be hydrated before, during, and post drug administration. Usual approach is to give at least one liter before and one liter post drug treatment of 0.9% sodium chloride with 20 mEq of KCl. With higher doses of drug, more aggressive hydration should be considered with at least two liters of fluid administered before drug. In this setting, urine output should be greater than 100 cc/hr. Furosemide diuresis may be used after every two liters of fluid.
4. Use with caution in patients with hearing impairment or preexisting peripheral neuropathy. Baseline audiology exam and periodic evaluation during therapy are recommended to monitor the effects of drug on hearing. Contraindicated in patients with pre-existing hearing deficit.
5. Cisplatin is a potent emetogenic agent. Give antiemetic premedication to prevent cisplatin-induced nausea and vomiting. Prophylaxis against delayed emesis (>24 hours after the drug administration) is also recommended. A combination of a 5-HT<sub>3</sub> antagonist (ondansetron or granisetron) and dexamethasone is standard therapy for prevention of nausea and vomiting.
6. Avoid aluminum needles when administering the drug because precipitate may form, resulting in decreased potency.
7. Cisplatin is inactivated in the presence of alkaline solutions containing sodium bicarbonate.

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#### Toxicity 1

Nephrotoxicity. Dose-limiting toxicity in up to 35%–40% of patients. Effects on renal function are dose-related and usually observed at 10–20 days after therapy. Generally reversible. Electrolyte abnormalities, mainly hypomagnesemia, hypocalcemia, and hypokalemia, are common. Hyperuricemia rarely occurs.

---

#### Toxicity 2

Nausea and vomiting. Two forms are observed: acute (within the first 24 hours) and delayed (>24 hours). Early form begins within one hour of starting cisplatin therapy and may last for 8–12 hours. The delayed form can last for 3–5 days.

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#### Toxicity 3

Myelosuppression. Occurs in 25%–30% of patients, with WBCs, platelets, and RBCs equally affected. Leukopenia and thrombocytopenia are more

pronounced at higher doses. Coombs-positive hemolytic anemia also observed.

---

**Toxicity 4**

Neurotoxicity usually in the form of peripheral sensory neuropathy. Paresthesias and numbness in a classic “stocking-glove” pattern. Tends to occur after several cycles of therapy and risk increases with cumulative doses. Loss of motor function, focal encephalopathy, and seizures also observed. Neurologic effects may be irreversible.

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**Toxicity 5**

Ototoxicity with high-frequency hearing loss and tinnitus.

---

**Toxicity 6**

Hypersensitivity reactions consisting of facial edema, wheezing, bronchospasm, and hypotension. Occur within a few minutes of drug administration.

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**Toxicity 7**

Ocular toxicity manifested as optic neuritis, papilledema, and cerebral blindness. Altered color perception may be observed in rare cases.

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**Toxicity 8**

Transient elevation in LFTs, mainly SGOT and serum bilirubin.

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**Toxicity 9**

Metallic taste of foods and loss of appetite.

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**Toxicity 10**

Vascular events, including myocardial infarction, arteritis, cerebrovascular accidents, and thrombotic microangiopathy. Raynaud’s phenomenon has been reported.

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**Toxicity 11**

Azoospermia, impotence, and sterility.

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**Toxicity 12**

Alopecia.

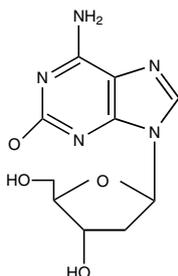
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**Toxicity 13**

Inappropriate secretion of antidiuretic hormone (SIADH).

# C

## Cladribine



### Trade Names

2-Chlorodeoxyadenosine, 2-CdA, Leustatin

### Classification

Antimetabolite

### Category

Chemotherapy drug

### Drug Manufacturer

Ortho Biotech

### Mechanism of Action

- Purine deoxyadenosine analog with high specificity for lymphoid cells.
- Presence of the 2-chloro group on adenine ring renders cladribine resistant to breakdown by adenosine deaminase.
- Antitumor activity against both dividing and resting cells.
- Metabolized intracellularly to 5'-triphosphate form (Cld-ATP), which is the presumed active species.
- Triphosphate metabolite incorporates into DNA resulting in inhibition of DNA chain extension and inhibition of DNA synthesis and function.
- Inhibition of ribonucleotide reductase.
- Depletes nicotinic adenine dinucleotide (NAD) concentration, resulting in depletion of ATP.
- Induction of apoptosis (programmed cell death).

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### Mechanism of Resistance

- Decreased expression of the activating enzyme deoxycytidine kinase resulting in decreased formation of cytotoxic cladribine metabolites.
- Increased expression of 5'-nucleotidase, which dephosphorylates cladribine nucleotide metabolites Cld-AMP and Cld-ATP.

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### Absorption

Oral absorption is variable with about 50% of drug orally bioavailable. About 97% of drug is bioavailable after SC injection.

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### Distribution

Widely distributed throughout the body. About 20% of drug is bound to plasma proteins. Crosses the blood-brain barrier, but CSF concentrations reach only 25% of those in plasma.

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### Metabolism

Extensively metabolized intracellularly to nucleotide metabolite forms. Intracellular concentrations of phosphorylated metabolites exceed those in plasma by several hundred-fold. Terminal half-life is on the order of 5–7 hours. Cleared by the kidneys via a cation organic carrier system. Renal clearance is approximately 50%, with 20%–35% of drug eliminated unchanged.

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### Indications

1. Hairy cell leukemia.
2. Chronic lymphocytic leukemia.
3. Non-Hodgkin's lymphoma (low-grade).

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### Dosage Range

Usual dose is 0.09 mg/kg/day IV via continuous infusion for seven days. One course is usually administered. If patient does not respond to one course, it is unlikely that a response will be seen with a second course of therapy.

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### Drug Interactions

None known.

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### Special Considerations

1. Use with caution in patients with abnormal renal function.
2. Closely monitor for signs of infection. Patients are at increased risk for opportunistic infections, including herpes, fungus, and *Pneumocystis carinii*.
3. Closely monitor for signs of tumor lysis syndrome. Increased risk in patients with a high tumor cell burden.

4. Allopurinol should be given before initiation of therapy to prevent hyperuricemia.
5. Pregnancy category D.

---

#### Toxicity 1

Myelosuppression. Dose-limiting toxicity. Neutropenia more commonly observed than anemia or thrombocytopenia. Leukocyte nadir occurs 7–14 days, with recovery in 3–4 weeks.

---

#### Toxicity 2

Immunosuppression. Decrease in CD4+ and CD8+ cells occurs in most patients. Increased risk of opportunistic infections, including fungus, herpes, and *Pneumocystis carinii*. Complete recovery of CD4+ counts to normal may take up to 40 months.

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#### Toxicity 3

Fever occurs in 40%–50% of patients. Most likely due to release of pyrogens and/or cytokines from tumor cells. Associated with fatigue, malaise, myalgias, arthralgias, and chills. Incidence decreases with continued therapy.

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#### Toxicity 4

Mild nausea and vomiting observed in less than 30% of patients.

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#### Toxicity 5

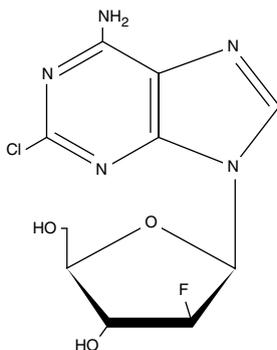
Tumor lysis syndrome. Rare event, most often in the setting of high tumor cell burden.

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#### Toxicity 6

Skin reaction at the site of injection.

# Clofarabine



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## Trade Names

Clolar

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## Classification

Antimetabolite

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## Category

Chemotherapy drug

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## Drug Manufacturer

Genzyme

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## Mechanism of Action

- Purine deoxyadenosine nucleoside analog.
- Presence of the 2-fluoro group on the sugar ring renders clofarabine resistant to breakdown by adenosine deaminase.
- Cell cycle-specific with activity in the S-phase.
- Requires intracellular activation to the cytotoxic triphosphate nucleotide metabolite.
- Incorporation of clofarabine triphosphate into DNA resulting in chain termination and inhibition of DNA synthesis and function.
- Clofarabine triphosphate inhibits DNA polymerases  $\alpha$ ,  $\beta$ , and  $\gamma$ , which, in turn, interferes with DNA chain elongation, DNA synthesis, and DNA repair.
- Clofarabine triphosphate disrupts the mitochondrial membrane, leading to release of cytochrome C and the induction of apoptosis.

- Inhibits the enzyme ribonucleotide reductase, resulting in decreased levels of essential deoxyribonucleotides for DNA synthesis and function.

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### Mechanism of Resistance

- Decreased activation of drug through decreased expression of the anabolic enzyme deoxycytidine kinase.
- Decreased transport of drug into cells.
- Increased expression of CTP synthetase activity resulting in increased concentrations of competing physiologic nucleotide substrate dCTP.

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### Absorption

Not absorbed via the oral route.

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### Distribution

Approximately 50% bound to plasma proteins, primarily to albumin.

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### Metabolism

Extensively metabolized intracellularly to nucleotide metabolite forms. Clofarabine has high affinity for the activating enzyme deoxycytidine kinase and is a more efficient substrate for this enzyme than the normal substrate deoxycytidine. Renal clearance is approximately 50%–60%. The pathways of non-renal elimination remain unknown. The terminal elimination half-life is on the order of five hours.

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### Indications

FDA-approved for the treatment of pediatric patients 1–21 years of age with relapsed or refractory acute lymphoblastic leukemia after at least two prior regimens.

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### Dosage Range

Recommended dose is 52 mg/m<sup>2</sup> IV over two hours daily for five days every 2–6 weeks.

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### Drug Interactions

None well characterized to date.

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### Special Considerations

1. Use with caution in patients with abnormal liver and/or renal function. Closely monitor liver and renal function during therapy.
2. As clofarabine is excreted mainly by the kidneys, drugs with known renal toxicity should be avoided during the five days of drug treatment.
3. Concomitant use of medications known to cause liver toxicity should be avoided.

4. Patients should be closely monitored for evidence of tumor lysis syndrome and systemic inflammatory response syndrome (SIRS)/capillary leak syndrome which result from rapid reduction in peripheral leukemic cells following drug treatment. The use of hydrocortisone 100 mg/m<sup>2</sup> IV on days 1–3 may prevent the development of SIRS or capillary leak.
5. Pregnancy category D.

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**Toxicity 1**

Myelosuppression is dose-limiting with neutropenia, anemia, and thrombocytopenia.

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**Toxicity 2**

Capillary leak syndrome/SIRS with tachypnea, tachycardia, pulmonary edema, and hypotension.

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**Toxicity 3**

Nausea/vomiting and diarrhea are most common GI side effects.

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**Toxicity 4**

Hepatic dysfunction with elevation of serum transaminases and bilirubin. Usually reversible with resolution in 14 days.

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**Toxicity 5**

Increased risk of opportunistic infections, including fungal, viral, and bacterial infections.

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**Toxicity 6**

Renal toxicity with elevation in serum creatinine observed in up to 10% of patients.

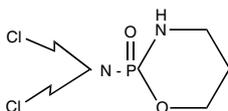
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**Toxicity 7**

Cardiac toxicity as manifested by left ventricular dysfunction and tachycardia.

# C

## Cyclophosphamide



### Trade Names

Cytoxan, CTX

### Classification

Alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

Bristol-Myers Squibb

### Mechanism of Action

- Inactive in its parent form.
- Activated by the liver cytochrome P<sub>450</sub> microsomal system to the cytotoxic metabolites phosphoramidate mustard and acrolein.
- Cyclophosphamide metabolites form cross-links with DNA resulting in inhibition of DNA synthesis and function.
- Cell cycle-nonspecific agent, active in all phases of the cell cycle.

### Mechanism of Resistance

- Decreased cellular uptake of drug.
- Decreased expression of drug-activating enzymes of the liver P<sub>450</sub> system.
- Increased expression of sulfhydryl proteins including glutathione and glutathione-associated enzymes.
- Increased expression of aldehyde dehydrogenase resulting in enhanced enzymatic detoxification of drug.
- Enhanced activity of DNA repair enzymes.

### Absorption

Well-absorbed by the GI tract with a bioavailability of nearly 90%.

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### Distribution

Distributed throughout the body, including brain and CSF. Also distributed in milk and saliva. Minimal binding of parent drug to plasma proteins; however, about 60% of the phosphoramidate mustard metabolite is bound to plasma proteins.

---

### Metabolism

Extensively metabolized in the liver by the liver cytochrome P<sub>450</sub> system to both active and inactive forms. The active forms are 4-hydroxycyclophosphamide, phosphoramidate mustard, and acrolein. Parent drug and its metabolites are eliminated exclusively in urine. The elimination half-life ranges from four to six hours.

---

### Indications

1. Breast cancer.
2. Non-Hodgkin's lymphoma.
3. Chronic lymphocytic leukemia.
4. Ovarian cancer.
5. Bone and soft tissue sarcoma.
6. Rhabdomyosarcoma.
7. Neuroblastoma and Wilms' tumor.

---

### Dosage Range

1. Breast cancer: When given orally, the usual dose is 100 mg/m<sup>2</sup> PO on days 1–14 given every 28 days. When administered IV, the usual dose is 600 mg/m<sup>2</sup> given every 21 days as part of the AC or CMF regimens.
2. Non-Hodgkin's lymphoma: Usual dose is 400–600 mg/m<sup>2</sup> IV on day one every 21 days, as part of the CVP regimen, and 750 mg/m<sup>2</sup> on day one every 21 days, as part of the CHOP regimen.
3. High-dose bone marrow transplantation: Usual dose in the setting of bone marrow transplantation is 60 mg/kg IV for two days.

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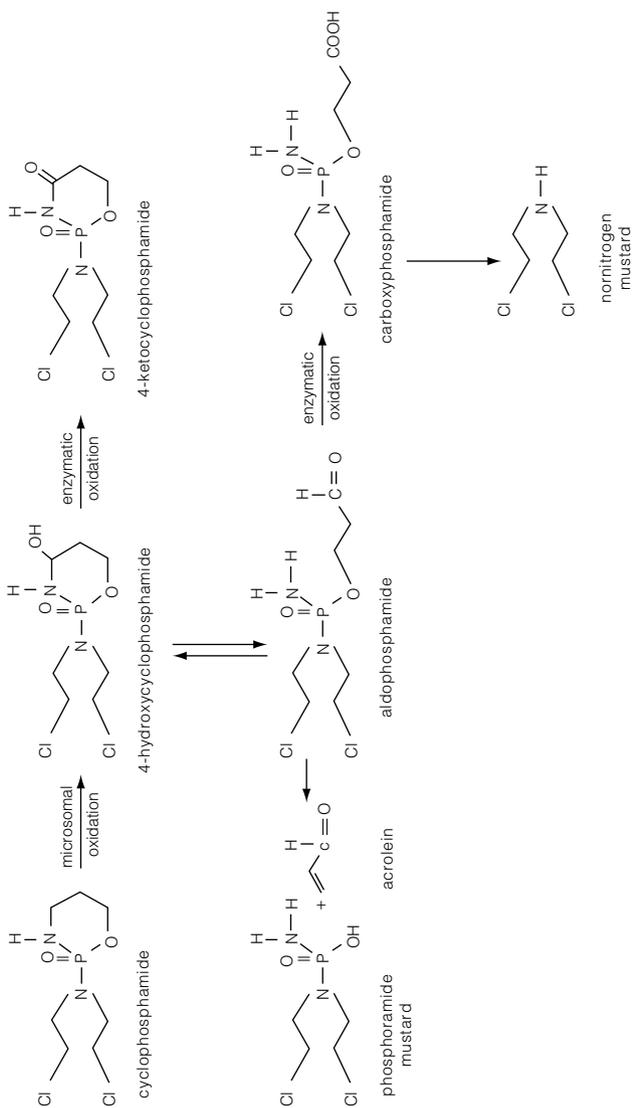
### Drug Interaction 1

Phenobarbital, phenytoin, and other drugs that stimulate the liver P<sub>450</sub> system—Increase the rate of metabolic activation of cyclophosphamide to its toxic metabolites.

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### Drug Interaction 2

Anticoagulants—Cyclophosphamide increases the effect of anticoagulants, and thus the dose of anticoagulants may need to be decreased depending on the coagulation parameters, PT/INR.



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### Drug Interaction 3

Digoxin—Cyclophosphamide decreases the plasma levels of digoxin by activating its metabolism in the liver.

---

### Drug Interaction 4

Doxorubicin—Cyclophosphamide may increase the risk of doxorubicin-induced cardiotoxicity.

---

### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose should be reduced in the setting of renal dysfunction. Creatinine clearance should be obtained at baseline and before each cycle of therapy.
  2. Administer oral form of drug during the daytime.
  3. Encourage fluid intake of at least 2–3 L/day to reduce the risk of hemorrhagic cystitis. High-dose therapy requires administration of IV fluids for hydration.
  4. Encourage patients to empty bladder several times daily (on average, every two hours) to reduce the risk of bladder toxicity.
  5. Pregnancy category D.
- 

### Toxicity 1

Myelosuppression is dose-limiting. Mainly leukopenia, with nadir occurring at 7–14 days with recovery by day 21. Thrombocytopenia may occur, usually with high-dose therapy.

---

### Toxicity 2

Bladder toxicity in the form of hemorrhagic cystitis, dysuria, and increased urinary frequency occurs in 5%–10% of patients. Time of onset is variable and may begin within 24 hours of therapy or may be delayed for up to several weeks. Usually reversible upon discontinuation of drug. Uroprotection with mesna and hydration must be used with high-dose therapy to prevent bladder toxicity.

---

### Toxicity 3

Nausea and vomiting. Usually dose-related, occurs within 2–4 hours of therapy, and may last up to 24 hours. Anorexia is fairly common.

---

### Toxicity 4

Alopecia generally starting 2–3 weeks after starting therapy. Skin and nails may become hyperpigmented.

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### Toxicity 5

Amenorrhea with ovarian failure. Sterility may be permanent.

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**Toxicity 6**

Cardiotoxicity is observed with high-dose therapy.

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**Toxicity 7**

Increased risk of secondary malignancies, including acute myelogenous leukemia and bladder cancer, especially in patients with chronic hemorrhagic cystitis.

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**Toxicity 8**

Immunosuppression with an increased risk of infections.

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**Toxicity 9**

Inappropriate SIADH.

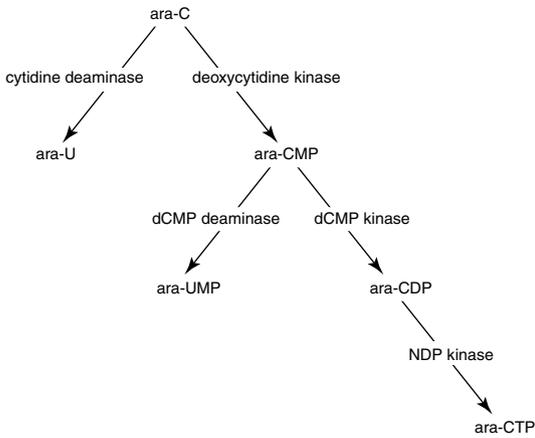
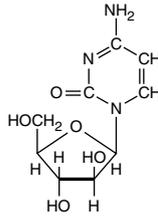
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**Toxicity 10**

Hypersensitivity reaction with rhinitis and irritation of the nose and throat. Usually self-resolving in 1–3 days, but steroids and/or diphenhydramine may be required.

# Cytarabine

C



## Trade Names

Cytosine arabinoside, Ara-C

## Classification

Antimetabolite

## Category

Chemotherapy drug

## Drug Manufacturer

Bedford Laboratories

## Mechanism of Action

- Deoxycytidine analog originally isolated from the sponge *Cryptothethya crypta*.
- Cell cycle-specific with activity in the S-phase.

- Requires intracellular activation to the nucleotide metabolite ara-CTP. Antitumor activity of cytarabine is determined by a balance between intracellular activation and degradation and the subsequent formation of cytotoxic ara-CTP metabolites.
- Incorporation of ara-CTP into DNA resulting in chain termination and inhibition of DNA synthesis and function.
- Ara-CTP inhibits several DNA polymerases  $\alpha$ ,  $\beta$ , and  $\gamma$ , which, in turn, interferes with DNA chain elongation, DNA synthesis, and DNA repair.
- Ara-CTP inhibits the enzyme ribonucleotide reductase, resulting in decreased levels of essential deoxyribonucleotides required for DNA synthesis and function.

---

### Mechanism of Resistance

- Decreased activation of drug through decreased expression of the anabolic enzyme deoxycytidine kinase.
- Increased breakdown of drug by the catabolic enzymes, cytidine deaminase and deoxycytidylate (dCMP) deaminase.
- Decreased transport of drug into cells.
- Increased expression of CTP synthetase activity resulting in increased concentrations of competing physiologic nucleotide substrate dCTP.

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### Absorption

Poor oral bioavailability (~20%) as a result of extensive deamination within the GI tract.

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### Distribution

Rapidly cleared from the bloodstream after IV administration. Distributes rapidly into tissues and total body water. Crosses the blood-brain barrier with CSF levels reaching 20%–40% of those in plasma. Binding to plasma proteins has not been well characterized.

---

### Metabolism

Undergoes extensive metabolism, with approximately 70%–80% of drug being recovered in the urine as the ara-U metabolite within 24 hours. Deamination occurs in liver, plasma, and peripheral tissues. The principal enzyme involved in drug catabolism is cytidine deaminase, which converts ara-C into the inactive metabolite ara-U. dCMP-deaminase converts ara-CMP into ara-UMP, and this represents an additional catabolic pathway of the drug. The terminal elimination half-life is 2–6 hours. The half-life of ara-C in CSF is somewhat longer, ranging from 2 to 11 hours, due to the relatively low activity of cytidine deaminase present in CSF.

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### Indications

1. Acute myelogenous leukemia.
2. Acute lymphocytic leukemia.
3. Chronic myelogenous leukemia.
4. Leptomeningeal carcinomatosis.
5. Non-Hodgkin's lymphoma.

---

### Dosage Range

Several different doses and schedules have been used:

1. Standard dose: 100 mg/m<sup>2</sup>/day IV on days 1–7 as a continuous IV infusion, in combination with an anthracycline as induction chemotherapy for AML.
2. High-dose: 1.5–3.0 g/m<sup>2</sup> IV q 12 hours for 3 days as a high-dose, intensification regimen for AML.
3. SC: 20 mg/m<sup>2</sup> SC for 10 days per month for 6 months, associated with IFN- $\alpha$  for treatment of CML.
4. Intrathecal: 10–30 mg intrathecal (IT) up to 3 times weekly in the treatment of leptomeningeal carcinomatosis secondary to leukemia or lymphoma.

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### Drug Interaction 1

Gentamicin—Cytarabine antagonizes the efficacy of gentamicin.

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### Drug Interaction 2

5-Fluorocytosine—Cytarabine inhibits the efficacy of 5-fluorocytosine by preventing its cellular uptake.

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### Drug Interaction 3

Digoxin—Cytarabine decreases the oral bioavailability of digoxin, thereby decreasing its efficacy. Digoxin levels should be monitored closely while on therapy.

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### Drug Interaction 4

Alkylating agents, cisplatin, and ionizing radiation—Cytarabine enhances the cytotoxicity of various alkylating agents (cyclophosphamide, carmustine), cisplatin, and ionizing radiation by inhibiting DNA repair mechanisms. Concurrent use of high-dose cytarabine and cisplatin may increase risk of ototoxicity.

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### Drug Interaction 5

Methotrexate—Pretreatment with methotrexate enhances the formation of ara-CTP metabolites resulting in enhanced cytotoxicity.

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### Drug Interaction 6

Fludarabine, hydroxyurea—Pretreatment with fludarabine and/or hydroxy urea potentiates the cytotoxicity of cytarabine by enhancing the formation of cytotoxic ara-CTP metabolites.

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### Drug Interaction 7

GM-CSF, interleukin-3—Cytokines including GM-CSF and interleukin-3 enhance cytarabine-mediated apoptosis mechanisms.

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### Drug Interaction 8

L-Asparaginase—Increased risk of pancreatitis when L-Asparaginase given before cytarabine.

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### Special Considerations

1. Monitor CBCs on a regular basis during therapy.
2. Use with caution in patients with abnormal liver and/or renal function. Dose modification should be considered in this setting as patients are at increased risk for toxicity. Monitor hepatic and renal function during therapy.
3. Alkalinization of the urine (pH >7.0), allopurinol, and vigorous IV hydration are recommended to prevent tumor lysis syndrome in patients with acute myelogenous leukemia.
4. High-dose therapy should be administered over a one- to two-hour period.
5. Conjunctivitis is observed with high-dose therapy as the drug is excreted in tears. Patients should be treated with hydrocortisone eye drops (2 drops OU qid for 10 days) on the night before the start of therapy.
6. Pregnancy category D.

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### Toxicity 1

Myelosuppression is dose-limiting. Leukopenia and thrombocytopenia are common. Nadir usually occurs by days 7–10, with recovery by days 14–21. Megaloblastic anemia is also observed.

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### Toxicity 2

Nausea and vomiting. Mild to moderate emetogenic agent with increased severity observed with high-dose therapy. Anorexia, diarrhea, and mucositis usually occur 7–10 days after therapy.

---

### Toxicity 3

Cerebellar ataxia, lethargy, and confusion. Neurotoxicity develops in up to 10% of patients. Onset usually five days after drug treatment and lasts

up to one week. In most cases, CNS toxicities are mild and reversible. Risk factors for neurotoxicity include high-dose therapy, age older than 40, abnormal renal function with serum creatinine  $\geq 1.2$  mg/dL, and abnormal liver function.

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#### Toxicity 4

Transient hepatic dysfunction with elevation of serum transaminases and bilirubin. Most often associated with high-dose therapy.

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#### Toxicity 5

Acute pancreatitis.

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#### Toxicity 6

Ara-C syndrome. Described in pediatric patients and represents an allergic reaction to cytarabine. Characterized by fever, myalgia, malaise, bone pain, maculopapular skin rash, conjunctivitis, and occasional chest pain. Usually occurs within 12 hours of drug infusion. Steroids appear to be effective in treating and/or preventing the onset of this syndrome.

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#### Toxicity 7

Pulmonary complications include noncardiogenic pulmonary edema, acute respiratory distress, and *Streptococcus viridans* pneumonia. Observed with high-dose therapy.

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#### Toxicity 8

Erythema of skin, alopecia, and hidradenitis are usually mild and self-limited. Hand-foot syndrome observed rarely with high-dose therapy.

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#### Toxicity 9

Conjunctivitis and keratitis. Associated with high-dose regimens.

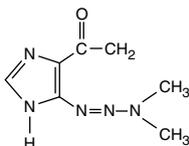
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#### Toxicity 10

Seizures, alterations in mental status, and fever may be observed within the first 24 hours after IT administration.

# D

## Dacarbazine



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### Trade Names

DIC, DTIC-Dome, Imidazole Carboxamide

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### Classification

Nonclassic alkylating agent

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### Category

Chemotherapy drug

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### Drug Manufacturer

Ben Venue Laboratories, Bayer

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### Mechanism of Action

- Cell cycle–nonspecific drug.
- Initially developed as a purine antimetabolite, but its antitumor activity is not mediated via inhibition of purine biosynthesis.
- Metabolic activation is required for antitumor activity.
- While the precise mechanism of cytotoxicity is unclear, this drug methylates nucleic acids and inhibits DNA, RNA, and protein synthesis.

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### Mechanism of Resistance

- Increased activity of DNA repair enzymes such as O6-alkylguanine-DNA alkyltransferase (AGAT).

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### Absorption

Slow and variable oral absorption. For this reason, IV administration preferred.

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### Distribution

Volume of distribution exceeds total body water content, and drug distributed in body tissues. About 20% of drug is loosely bound to plasma proteins.

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### Metabolism

Metabolized in the liver by the microsomal P<sub>450</sub> system to active metabolites (MTIC, AIC). The elimination half-life of the drug is five hours. About 40%–50% of the parent drug is excreted unchanged in urine within six hours, and tubular secretion appears to predominate. No specific guidelines for dacarbazine dosing in the setting of hepatic and/or renal dysfunction. However, dose modification should be considered in patients with moderately severe hepatic and/or renal dysfunction.

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### Indications

1. Metastatic malignant melanoma.
2. Hodgkin's disease.
3. Soft tissue sarcomas.
4. Neuroblastoma.

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### Dosage Range

1. Hodgkin's disease: 375 mg/m<sup>2</sup> IV on days 1 and 15 every 28 days, as part of the ABVD regimen.
2. Melanoma: 220 mg/m<sup>2</sup> IV on days 1–3 and days 22–24 every six weeks, as part of the Dartmouth regimen. As a single agent, 250 mg/m<sup>2</sup> IV for five days or 800–1,000 mg/m<sup>2</sup> IV every three weeks.

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### Drug Interaction 1

Heparin, lidocaine, and hydrocortisone—Incompatible with dacarbazine.

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### Drug Interaction 2

Phenytoin, phenobarbital—Decreased efficacy of dacarbazine when administered with phenytoin and phenobarbital as these drugs induce dacarbazine metabolism by the liver P<sub>450</sub> system.

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### Special Considerations

1. Dacarbazine is a potent vesicant, and it should be carefully administered to avoid the risk of extravasation.
2. Dacarbazine is a highly emetogenic agent. Use of aggressive antiemetics before drug administration to decrease risk of nausea and vomiting.
3. Patients should avoid sun exposure for several days after dacarbazine therapy.
4. Pregnancy category C.

D

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**Toxicity 1**

Myelosuppression. Dose-limiting toxicity. Leukopenia and thrombocytopenia are equally affected with nadir occurring at 21–25 days.

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**Toxicity 2**

Nausea and vomiting can be severe, usually occurring within 1–3 hours and lasting for up to 12 hours. Aggressive antiemetic therapy strongly recommended. Anorexia is common, but diarrhea occurs rarely.

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**Toxicity 3**

Flulike syndrome in the form of fever, chills, malaise, myalgias, and arthralgias. May last for several days after therapy.

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**Toxicity 4**

Pain and/or burning at the site of injection.

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**Toxicity 5**

CNS toxicity in the form of paresthesias, neuropathies, ataxia, lethargy, headache, confusion, and seizures has all been observed.

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**Toxicity 6**

Increased risk of photosensitivity.

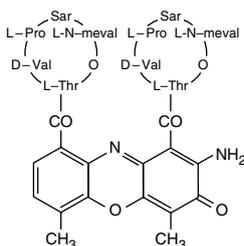
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**Toxicity 7**

Teratogenic, mutagenic, and carcinogenic.

# Dactinomycin-D

D



## Trade Names

Actinomycin-D, Cosmegen

## Classification

Antitumor antibiotic

## Category

Chemotherapy drug

## Drug Manufacturer

Merck

## Mechanism of Action

- Product of the *Streptomyces* species.
- Consists of a tricyclic phenoxazine chromophore, which is linked to two short, identical cyclic polypeptides.
- Chromophore moiety preferentially binds to guanine-cytidine base pairs. Binding to single- and double-stranded DNA results in inhibition of DNA synthesis and function.
- Formation of toxic oxygen free radicals results in single- and double-stranded DNA breaks and subsequent inhibition of DNA synthesis and function.
- Inhibition of RNA and protein synthesis may also contribute to the cytotoxic effects.

## Mechanism of Resistance

- Reduced cellular uptake of drug, resulting in decreased intracellular drug accumulation.
- Increased expression of the multidrug-resistant gene with elevated P170 protein levels leads to increased drug efflux and decreased intracellular drug accumulation.

# D

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## Absorption

Poor oral bioavailability and is administered only via the IV route.

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## Distribution

After an IV bolus injection, dactinomycin rapidly disappears from the circulation in about two minutes. Concentrates in nucleated blood cells. Does not cross the blood-brain barrier. Appears to be highly bound to plasma proteins.

---

## Metabolism

Clinical pharmacology is not well characterized. Metabolized only to small extent. Most of drug is eliminated in unchanged form by biliary (50%) and renal (20%) excretion. Terminal elimination half-life ranges from 30 to 40 hours.

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## Indications

1. Wilms' tumor.
2. Rhabdomyosarcoma.
3. Germ cell tumors.
4. Gestational trophoblastic disease.
5. Ewing's sarcoma.

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## Dosage Range

1. Adults: 0.4–0.45 mg/m<sup>2</sup> IV on days 1–5 every 2–3 weeks.
2. Children: 0.015 mg/kg/day (up to a maximum dose of 0.5 mg/day) IV on days 1–5 over a period of 16–45 weeks depending on the specific regimen.

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## Drug Interactions

None known.

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## Special Considerations

1. Administer drug slowly by IV push to avoid extravasation.
2. Contraindicated in patients actively infected with chickenpox or herpes zoster as generalized infection may result in death.
3. Use with caution in patients either previously treated with radiation therapy or currently receiving radiation therapy. Increased risk of radiation recall skin reaction.
4. Patients should be cautioned against sun exposure while on therapy.
5. Pregnancy category C. May be excreted in breast milk.

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**Toxicity 1**

Myelosuppression. Dose-limiting and severe. Leukopenia and thrombocytopenia equally observed. Nadir occurs at days 8–14 after administration.

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**Toxicity 2**

Nausea and vomiting. Onset within the first two hours of therapy, lasts for up to 24 hours, and may be severe.

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**Toxicity 3**

Mucositis and/or diarrhea. Usually occurs within 5–7 days and can be severe.

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**Toxicity 4**

Alopecia is common.

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**Toxicity 5**

Hyperpigmentation of skin, erythema, and increased sensitivity to sunlight. Radiation recall reaction with erythema and desquamation of skin observed with prior or concurrent radiation therapy.

---

**Toxicity 6**

Potent vesicant. Tissue damage occurs with extravasation of drug.

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**Toxicity 7**

Elevation of serum transaminases in less than 15% of patients. Dose- and schedule-dependent. Hepato-veno-occlusive disease observed rarely with higher doses and daily schedule.

# D

## Darbopoetin alfa

### Trade Names

Aranesp

### Classification

Colony-stimulating growth factor, cytokine

### Category

Biologic response modifier agent

### Drug Manufacturer

Amgen

### Mechanism of Action

- Glycoprotein produced by recombinant DNA techniques. Has the same biologic effects as endogenous erythropoietin.
- It is a 165-amino acid protein that differs from recombinant human erythropoietin in containing five N-linked oligosaccharide chains, while recombinant human erythropoietin contains three chains. The additional carbohydrate chains increase the approximate molecular weight from 30,000 to 37,000 daltons.
- Stimulates division and differentiation of red blood cells in the bone marrow.
- Does not possess antitumor activity.

### Absorption

Administered either by the IV or SC route. Following SC injection, absorption is slow and rate-limiting. Peak concentrations are observed about 34 hours post SC administration, while peak concentrations are 90 hours post SC administration in cancer patients. The bioavailability of darbopoetin in chronic renal failure patients after SC injection is 37%.

### Distribution

Distributes into total plasma volume. Binding to plasma proteins is not known. Steady-state serum levels are achieved within four weeks.

### Metabolism

Metabolism is not entirely clear, although catabolism in liver and bone marrow appears to play a role. About 10% of the drug is cleared in urine in unchanged form. The terminal half-life in patients with chronic renal failure is 49 hours, which is about three-fold longer than erythropoietin when administered by either the IV or SC route and is about 40 hours in cancer patients receiving chemotherapy.

### Indications

1. Chemotherapy-induced anemia in patients with non-myeloid malignancies.
2. Anemia associated with chronic renal failure, including patients on dialysis and those not on dialysis.

### Dosage Range

1. Chemotherapy-induced anemia: Recommended starting dose is 2.25  $\mu\text{g}/\text{kg}$  administered as a weekly SC injection. The dose should be adjusted for each patient to achieve and maintain a target hemoglobin level of 12 g/dL. If there is less than a 1 g/dL increase in hemoglobin after 6 weeks of therapy, the dose of darbopoetin should be increased to 4.5  $\mu\text{g}/\text{kg}$ . If the hemoglobin increases by more than 1 g/dL in a 2-week period or if the hemoglobin exceeds 12 g/dL, the dose should be reduced by 25%. If the hemoglobin level exceeds 13 g/dL, doses should be held until the hemoglobin falls to 11 g/dL. At that point, therapy should be restarted at a dose that is 40% lower than the previous dose.
2. Alternative treatment schedules include 100  $\mu\text{g}/\text{week}$ , 200  $\mu\text{g}$  every two weeks, or 300  $\mu\text{g}$  every three weeks.
3. Chronic renal failure: recommended starting dose is 0.45  $\mu\text{g}/\text{kg}$  body weight administered as a single IV or SC injection once weekly.

### Drug Interactions

None characterized.

### Special Considerations

1. Contraindicated in patients with uncontrolled hypertension.
2. Use with caution in patients with a history of hypertension and/or cardiovascular disease. Patients should be advised of the importance of close compliance with antihypertensive therapy and dietary restriction. The dose of darbopoetin should be reduced or withheld if the blood pressure cannot be effectively controlled by pharmacologic and/or dietary measures.
3. Contraindicated in patients with known hypersensitivity to mammalian-derived products.
4. Contraindicated in patients with known hypersensitivity to the active substance and/or any of the excipients.
5. Use with caution in patients with known porphyria as exacerbation has been observed in patients treated with erythropoietin.
6. Obtain baseline erythropoietin levels before start of therapy. The optimal response is observed in cancer patients with endogenous

levels  $\leq 200$  U/mL. A baseline serum ferritin level and transferrin saturation should also be obtained. Transferrin saturation should be at least 20%, and ferritin should be at least 100 mg/mL. Patients may benefit from concomitant treatment with iron supplementation, ferrous sulfate one tablet PO bid or tid.

7. The lowest dose of darbopoetin should be used to increase gradually the need for hemoglobin concentrations to the lowest level sufficient to avoid the need for red blood cell transfusions. Increases in dose should not be made more frequently than once a month. The dose of darbopoetin should be adjusted for each patient to achieve and maintain a target hemoglobin level not to exceed 12 g/dL. If the hemoglobin level is increasing and approaching 12 g/dL, the dose should be reduced by 25%.
8. Patients should be closely monitored to ensure that the hemoglobin levels are not greater than 12 g/dL. An increased risk of death and serious cardiovascular events, including myocardial infarction, heart failure, stroke, and thrombosis, has been observed in this setting (this represents a black-box warning).
9. Blood counts should be monitored on a weekly basis during darbopoetin therapy. If the increase in hemoglobin is less than 1 g/dL after four weeks of therapy, the dose of darbopoetin can be increased by 25% of the previous dose. Further increases may be made at 4-week intervals until the specified hemoglobin level is achieved.
10. The starting weekly dose of darbopoetin should be estimated on the basis of the weekly erythropoietin dose at the time of substitution. Due to the longer half-life, darbopoetin should be administered once a week if a patient was receiving erythropoietin 2–3 times weekly and should be administered once every two weeks if a patient was receiving erythropoietin once per week.
11. Patients should be warned that there is a rare risk of transmission of viral diseases with a remote risk of transmission of Creutzfeldt-Jacob disease (CJD).
12. Pregnancy category C. Breast-feeding should be avoided as it is not known whether darbopoetin is excreted in human milk.

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#### Toxicity 1

Hypertension is common but usually mild.

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#### Toxicity 2

Diarrhea and occasional nausea and vomiting.

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#### Toxicity 3

Local pain at injection site.

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**Toxicity 4**

Headache, fever, fatigue, asthenia, arthralgias, and myalgias.

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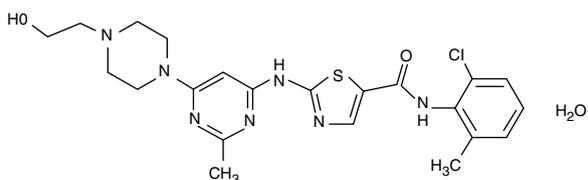
**Toxicity 5**

Rare cases of allergic reactions, including skin rash and urticaria.

D

# D

## Dasatinib



### Trade Name

Sprycel, BMS-354825

### Classification

Signal transduction inhibitor

### Category

Chemotherapy drug

### Drug Manufacturer

Bristol-Meyers Squibb

### Mechanism of Action

- Potent inhibitor of the BCR-ABL kinase and SRC family of kinases (SRC, LCK, YES, FYN), c-KIT, and PDGFR- $\beta$ .
- Differs from imatinib in that it binds to the active and inactive conformations of the ABL kinase domain and overcomes imatinib resistance resulting from BCR-ABL mutations.

### Mechanism of Resistance

- Single point mutation within the ATP-binding pocket of the ABL tyrosine kinase (T315I).

### Absorption

Dasatinib has good oral bioavailability. Rapidly absorbed following oral administration. Peak plasma concentrations are observed between 30 minutes and 6 hours of oral ingestion.

### Distribution

Extensive distribution in the extravascular space. Binding of parent drug and its active metabolite to plasma proteins in the range of 90%–95%.

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### Metabolism

Metabolized in the liver primarily by the CYP<sub>3A4</sub> liver microsomal enzyme. Other liver P<sub>450</sub> enzymes, such as UGT, play a relatively minor role in metabolism. Approximately 85% of an administered dose is eliminated in feces within 10 days. The terminal half-life of the parent drug is in the order of 4 to 6 hours.

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### Indications

1. FDA-approved for the treatment of adults with chronic phase (CP), accelerated phase (AP), or myeloid or lymphoid (MB or LB) phase CML with resistance or intolerance to imatinib.
2. FDA-approved for the treatment of adults with Ph+ ALL with resistance or intolerance to prior therapy.

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### Dosage Range

Recommended dose is 70 mg PO bid.

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### Drug Interaction 1

Dasatinib is an inhibitor of CYP<sub>3A4</sub> and may decrease the metabolic clearance of drugs that are metabolized by CYP<sub>3A4</sub>.

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### Drug Interaction 2

Drugs such as ketoconazole, itraconazole, erythromycin, and clarithromycin decrease the rate of metabolism of dasatinib, resulting in increased drug levels and potentially increased toxicity.

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### Drug Interaction 3

Drugs such as rifampin, Dilantin, phenobarbital, carbamazepine, and St. John's Wort increase the rate of metabolism of dasatinib, resulting in its inactivation.

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### Drug Interaction 4

Solubility of dasatinib is pH-dependent. In the presence of famotidine, proton-pump inhibitors, and/or antacids, dasatinib concentrations are reduced.

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### Special Considerations

1. Oral dasatinib tablets can be taken with or without food, but must not be crushed or cut.
2. Important to review patient's list of medications as dasatinib has several potential drug–drug interactions.
3. Patients should be warned about not taking the herbal medicine St. John's Wort while on dasatinib therapy.

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4. Monitor CBC on a weekly basis for the first two months, and periodically thereafter.
5. Use with caution when patients are on aspirin, NSAIDs, or anticoagulation as there is an increased risk of bleeding.
6. Closely monitor electrolyte status, especially calcium and phosphate levels, as oral calcium supplementation may be required.
7. Sexually active patients on dasatinib therapy should use adequate contraception.
8. Pregnancy category D.

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**Toxicity 1**

Myelosuppression with thrombocytopenia, neutropenia, and anemia.

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**Toxicity 2**

Bleeding complications in up to 40% of patients resulting from platelet dysfunction.

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**Toxicity 3**

Fluid retention occurs in 50% of patients, with peripheral edema and pleural effusions. Usually mild to moderate in severity.

---

**Toxicity 4**

GI toxicity in the form of diarrhea, nausea/vomiting, and abdominal pain.

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**Toxicity 5**

Fatigue, asthenia, and anorexia.

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**Toxicity 6**

Elevations in serum transaminases and/or bilirubin.

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**Toxicity 7**

Hypocalcemia and hypophosphatemia.

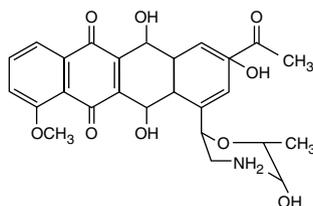
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**Toxicity 8**

Cardiac toxicity in the form of heart failure and QTc prolongation. Occurs rarely (3% to 4%).

# Daunorubicin

# D



## Trade Names

Daunomycin, Cerubidine, Rubidomycin

## Classification

Antitumor antibiotic

## Category

Chemotherapy drug

## Drug Manufacturer

Ben Venue and Bedford Laboratories

## Mechanism of Action

- Cell cycle–nonspecific agent.
- Intercalates into DNA resulting in inhibition of DNA synthesis and function.
- Inhibits transcription through inhibition of DNA-dependent RNA polymerase.
- Inhibits topoisomerase II by forming a cleavable complex with DNA and topoisomerase II to create uncompensated DNA helix torsional tension, leading to eventual DNA breaks.
- Formation of cytotoxic oxygen free radicals results in single- and double-stranded DNA breaks with inhibition of DNA synthesis and function.

## Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with elevated P170 levels. This leads to increased drug efflux and decreased intracellular drug accumulation.
- Decreased expression of topoisomerase II.
- Mutation in topoisomerase II with decreased binding affinity to drug.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-dependent enzymes.

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## Absorption

Daunorubicin is not absorbed orally.

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## Distribution

Significantly more lipid-soluble than doxorubicin. Widely distributed to tissues with high concentrations in heart, liver, lungs, kidneys, and spleen. Does not cross the blood-brain barrier. Extensively binds to plasma proteins (60%–70%).

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## Metabolism

Metabolism in the liver with formation of one of its primary metabolites, daunorubicinol, which has antitumor activity. Parent compound and its metabolites are excreted mainly through the hepatobiliary system into feces. Renal clearance accounts for only 10%–20% of drug elimination. The half-life of the parent drug is 20 hours, while the half-life of the daunorubicinol metabolite is 30–40 hours.

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## Indications

1. Acute myelogenous leukemia—Remission induction and relapse.
  2. Acute lymphoblastic leukemia—Remission induction and relapse.
- 

## Dosage Range

1. AML: 45 mg/m<sup>2</sup> IV on days 1–3 of the first course of induction therapy and on days one and two on subsequent courses. Used in combination with continuous infusion ara-C.
  2. ALL: 45 mg/m<sup>2</sup> IV on days 1–3 in combination with vincristine, prednisone, and L-Asparaginase.
  3. Single agent: 40 mg/m<sup>2</sup> IV every two weeks.
- 

## Drug Interaction 1

Dexamethasone, heparin—Daunorubicin is incompatible with dexamethasone and heparin as a precipitate will form.

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## Drug Interaction 2

Dexrazoxane—Cardiotoxic effects of daunorubicin are inhibited by the iron-chelating agent dexrazoxane (ICRF-187, Zinecard).

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## Special Considerations

1. Use with caution in patients with abnormal liver function. Dose reduction is required in the setting of liver dysfunction.
2. Because daunorubicin is a vesicant, administer slowly over 60 minutes with a rapidly flowing IV. Careful administration of the drug, usually through a central venous catheter, is necessary

as the drug is a strong vesicant. Close monitoring is necessary to avoid extravasation. If extravasation is suspected, immediately stop infusion, withdraw fluid, elevate extremity, and apply ice to involved site. May administer local steroids. In severe cases, consult a plastic surgeon.

3. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess left ventricular ejection fraction. Risk of cardiotoxicity is higher in patients >70 years of age, in patients with prior history of hypertension or pre-existing heart disease, and in patients previously treated with anthracyclines or prior radiation therapy to the chest. Cumulative doses of >550 mg/m<sup>2</sup> are associated with increased risk for cardiotoxicity.
4. Use with caution in patients previously treated with radiation therapy as daunorubicin can cause a radiation recall skin reaction.
5. Patients should be cautioned to avoid sun exposure and to wear sun protection when outside.
6. Patients should be warned about the potential for red-orange discoloration of urine that may occur for 1–2 days after drug administration.
7. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting toxicity with leukopenia being more common than thrombocytopenia. Nadir occurs at 10–14 days with recovery by day 21.

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#### Toxicity 2

Nausea and vomiting. Usually mild, occurring in 50% of patients within 1–2 hours of treatment.

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#### Toxicity 3

Mucositis and diarrhea are common within the first week of treatment but not dose-limiting.

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#### Toxicity 4

- Cardiotoxicity. Acute form presents within the first 2–3 days as arrhythmias and/or conduction abnormalities, EKG changes, pericarditis, and/or myocarditis. Usually transient and mostly asymptomatic.
- Chronic form associated with a dose-dependent, dilated cardiomyopathy and congestive heart failure. Incidence increases with cumulative doses greater than 550 mg/m<sup>2</sup>.

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**Toxicity 5**

Strong vesicant. Extravasation can lead to tissue necrosis and chemical thrombophlebitis at the injection site.

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**Toxicity 6**

Hyperpigmentation of nails, rarely skin rash, and urticaria. Radiation recall skin reaction can occur at prior sites of irradiation. Increased hypersensitivity to sunlight.

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**Toxicity 7**

Alopecia is universal. Usually reversible within 5–7 weeks after termination of treatment.

---

**Toxicity 8**

Red-orange discoloration of urine. Lasts 1–2 days after drug administration.

# Daunorubicin liposome

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## Trade Names

DaunoXome

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## Classification

Antitumor antibiotic

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## Category

Chemotherapy drug

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## Drug Manufacturer

Gilead

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## Mechanism of Action

- Liposomal encapsulation of daunorubicin.
- Protected from chemical and enzymatic degradation, displays reduced plasma protein binding, and shows decreased uptake in normal tissues when compared to parent compound, daunorubicin.
- Penetrates tumor tissue into which daunorubicin is released, possibly through increased permeability of tumor neovasculature to liposome particles.
- Cell cycle–nonspecific agent.
- Intercalates into DNA resulting in inhibition of DNA synthesis and function.
- Inhibits transcription through inhibition of DNA-dependent RNA polymerase.
- Inhibits topoisomerase II by forming a cleavable complex with DNA and topoisomerase II to create uncompensated DNA helix torsional tension, leading to eventual DNA breaks.
- Formation of toxic oxygen free radicals results in single- and double-stranded DNA breaks with subsequent inhibition of DNA synthesis and function.

---

## Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with elevated P170 levels. This leads to increased drug efflux and decreased intracellular drug accumulation.
- Decreased expression of topoisomerase II.
- Mutation in topoisomerase II with decreased binding affinity to drug.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-dependent enzymes.

# D

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## Absorption

Daunorubicin liposome is not absorbed orally.

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## Distribution

Small steady-state volume of distribution (6 L) in contrast to the parent drug, daunorubicin. Distribution is limited mainly to the intravascular compartment. Does not cross the blood-brain barrier. Minimal binding to plasma proteins.

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## Metabolism

Metabolism in the liver but the primary metabolite, daunorubicinol, is present only in low concentrations. Cleared from plasma at 17 mL/min in contrast to daunorubicin, which is cleared at 240 mL/min. Elimination half-life is about 4–5 hours, far shorter than that of daunorubicin.

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## Indications

HIV-associated, advanced Kaposi's sarcoma—First-line therapy.

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## Dosage Range

Usual dose is 40 mg/m<sup>2</sup> IV every two weeks.

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## Drug Interactions

None known.

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## Special Considerations

1. Use with caution in patients with abnormal liver function. Dose reduction is required in the setting of liver dysfunction.
2. Because the parent drug, daunorubicin, is a vesicant, administer slowly over 60 minutes with a rapidly flowing IV. Careful monitoring is necessary to avoid extravasation. If extravasation is suspected, immediately stop infusion, withdraw fluid, elevate extremity, and apply ice to involved site. May administer local steroids. In severe cases, consult a plastic surgeon.
3. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. Risk of cardiotoxicity is higher in patients >70 years of age, in patients with prior history of hypertension or pre-existing heart disease, and in patients previously treated with anthracyclines or prior radiation therapy to the chest. Cumulative doses of >320 mg/m<sup>2</sup> are associated with increased risk for cardiotoxicity.
4. Patients may develop back pain, flushing, and chest tightness during the first five minutes of infusion. These symptoms are probably related to the lipid component of liposomal daunorubicin. Infusion

should be discontinued until symptoms resolve and then resumed at a slower rate.

5. Pregnancy category D.

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**Toxicity 1**

Myelosuppression. Dose-limiting toxicity with leukopenia being moderate to severe.

---

**Toxicity 2**

Nausea and vomiting. Occur in 50% of patients and are usually mild.

---

**Toxicity 3**

Mucositis and diarrhea are common but not dose-limiting.

---

**Toxicity 4**

Cardiotoxicity. Acute form presents within the first 2–3 days as arrhythmias and/or conduction abnormalities, EKG changes, pericarditis, and/or myocarditis. Usually transient and mostly asymptomatic.

Chronic form associated with a dose-dependent, dilated cardiomyopathy associated with congestive heart failure. Incidence increases when cumulative doses are greater than 320 mg/m<sup>2</sup>.

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**Toxicity 5**

Infusion-related reaction. Occurs within the first five minutes of infusion and manifested by back pain, flushing, and tightness in chest and throat. Observed in about 15% of patients and usually with the first infusion. Improves upon termination of infusion and typically does not recur upon reinstitution at a slower infusion rate.

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**Toxicity 6**

Vesicant. Extravasation can lead to tissue necrosis and chemical thrombophlebitis at the site of injection.

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**Toxicity 7**

Hyperpigmentation of nails, rarely skin rash, and urticaria. Radiation recall skin reaction can occur at prior sites of irradiation. Increased hypersensitivity to sunlight.

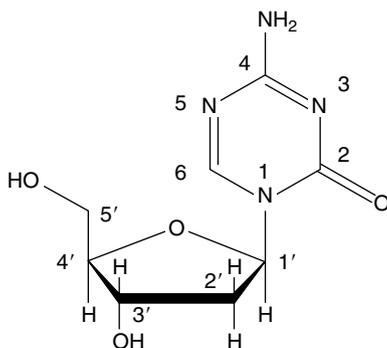
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**Toxicity 8**

Alopecia. Lower incidence than its parent compound, daunorubicin.

# D

## Decitabine



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### Trade Name

5-Aza-2'-deoxycytidine, Dacogen

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### Classification

Antimetabolite

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### Category

Antineoplastic agent, hypomethylating agent

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### Drug Manufacturer

MGI Pharma

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### Mechanism of Action

- Deoxycytidine analog
- Cell cycle-specific with activity in the S-phase.
- Requires activation to the nucleotide metabolite decitabine triphosphate.
- Incorporation of decitabine triphosphate into DNA, results in inhibition of DNA methyltransferases, which then leads to loss of DNA methylation and gene reactivation. Aberrantly silenced genes, such as tumor suppressor genes, are reactivated and expressed.

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### Mechanism of Resistance

None well characterized to date.

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### Absorption

Administered only by the IV route.

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### Distribution

Distribution in humans has not been fully characterized. Does cross blood-brain barrier. Plasma protein binding of decitabine is negligible.

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### Metabolism

The precise route of elimination and metabolic fate of decitabine is not known in humans. One of the elimination pathways is via deamination by cytidine deaminase, found principally in the liver but also in plasma, granulocytes, intestinal epithelium, and peripheral tissues.

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### Indications

FDA-approved for treatment of patients with MDS including previously treated and untreated, *de novo* and secondary MDS of all French-American-British subtypes (refractory anemia, refractory anemia with ringed sideroblasts, refractory anemia with excess blasts, refractory anemia with excess blasts in transformation, and chronic myelomonocytic leukemia) and intermediate-1, intermediate-2, and high-risk International Prognostic Scoring System groups.

---

### Dosage Range

1. The recommended dose is 15 mg/m<sup>2</sup> continuous infusion IV over three hours repeated every eight hours for three days. Cycles should be repeated every six weeks.
2. An alternative schedule is 20 mg/m<sup>2</sup> IV over one hour daily for five days given every 28 days.

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### Drug Interactions

None characterized to date.

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### Special Considerations

1. Patients should be treated for a minimum of four cycles. In some cases, a complete or partial response may take longer than four cycles.
2. Monitor CBC on a regular basis during therapy. See package insert for recommendations regarding dose adjustments.
3. Decitabine therapy should not be resumed if serum creatinine  $\geq 2$  mg/dL, SGPT and/or total bilirubin two times ULN, and ongoing active or uncontrolled infection.
4. Use with caution in patients with underlying liver and/or kidney dysfunction.
5. Pregnancy category D. Breast-feeding should be avoided.

D

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**Toxicity 1**

Myelosuppression with pancytopenia is dose-limiting.

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**Toxicity 2**

Fatigue and anorexia.

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**Toxicity 3**

GI toxicity in the form of nausea/vomiting, constipation, and abdominal pain.

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**Toxicity 4**

Hyperbilirubinemia.

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**Toxicity 5**

Peripheral edema.

## Denileukin diftitox

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### Trade Names

Ontak, DAB389

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### Classification

Immunotherapy

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### Category

Biologic response modifier agent

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### Drug Manufacturer

Ligand

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### Mechanism of Action

- Recombinant fusion protein composed of amino acid sequences of human interleukin-2 (IL-2) and the enzymatic and translocation domains of diphtheria toxin.
- Specifically binds to the CD25 component of the IL-2 receptor and then internalized via endocytosis.
- Upon release of diphtheria toxin into cytosol, cellular protein synthesis is inhibited, and cell death via apoptosis occurs.

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### Absorption

Not available for oral use and is administered only via the IV route.

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### Distribution

Volume of distribution is similar to that of circulating blood, and the initial distribution half-life is approximately 2–5 minutes.

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### Metabolism

Metabolized primarily via catabolism by proteolytic degradation pathways. The elimination half-life is 70–80 minutes.

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### Indications

Persistent or recurrent cutaneous T-cell lymphoma whose malignant cells express the CD25 component of the IL-2 receptor.

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### Dosage Range

Recommended dose is 9 or 18  $\mu\text{g}/\text{kg}/\text{day}$  IV on days 1–5 every 21 days.

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### Drug Interactions

None known.

# D

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## Special Considerations

1. Expression of CD25 on tumor skin biopsy must be confirmed before administration of denileukin diftitox. A testing service is available and can be reached by calling 1-800-964-5836.
2. Contraindicated in patients with a known hypersensitivity to denileukin diftitox or any of its components including IL-2 and diphtheria toxin.
3. Use with caution in patients with pre-existing cardiac and pulmonary disease as they are at increased risk for developing serious and sometimes fatal reactions.
4. Resuscitative medications, including IV antihistamines, corticosteroids, and epinephrine, and equipment should be readily available at bedside prior to treatment.
5. Monitor serum albumin at baseline and during therapy. Low serum albumin levels place patient at increased risk for vascular leak syndrome. Delay administration of denileukin until the serum albumin is 3 g/dL.
6. Patients should be monitored closely throughout the entire treatment, including vital signs, pre- and post-infusion weights, and evidence of peripheral edema.
7. Premedication with acetaminophen, nonsteroidal anti-inflammatory agents, and antihistamines can help to reduce the incidence and severity of hypersensitivity reactions.
8. Pregnancy category C.

---

## Toxicity 1

Flulike symptoms with fever, chills, asthenia, myalgias, arthralgias, and headache. Usually mild, transient, and easily manageable.

---

## Toxicity 2

Hypersensitivity reaction manifested by hypotension, back pain, dyspnea, skin rash, chest pain or tightness, tachycardia, dysphagia, and rarely anaphylaxis. Observed in nearly 70% of patients during or within the first 24 hours of drug infusion.

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## Toxicity 3

Vascular leak syndrome characterized by hypotension, edema, and/or hypoalbuminemia. Usually self-limited process. Pre-existing low serum albumin (<3 g/dL) predisposes patients to this syndrome.

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**Toxicity 4**

Diarrhea may be delayed with prolonged duration. Anorexia along with nausea and vomiting also observed.

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**Toxicity 5**

Myelosuppression is uncommon with anemia occurring more frequently than neutropenia.

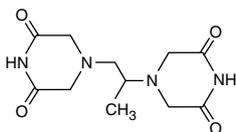
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**Toxicity 6**

Hepatotoxicity with elevations in serum transaminases and hypoalbuminemia (albumin  $< 2.3$  g/dL) in 15%–20% of patients. Usually occurs during the first course and resolves within two weeks.

# D

## Dexrazoxane



### Trade Names

Zinecard, ICRF-187

### Classification

Iron-chelating agent

### Category

Chemoprotective drug

### Drug Manufacturer

Pfizer

### Mechanism of Action

- Hydrolyzed intracellularly by enzymatic and nonenzymatic mechanisms to yield an EDTA-derived analog.
- Chelator of iron that strips iron from the doxorubicin-iron complex, thereby preventing free radical formation.
- Protects against myocardial toxicity without affecting antitumor activity.
- No pharmacokinetic interaction with anthracycline compounds.

### Absorption

Available only for IV use.

### Distribution

Rapidly distributed to all body tissues. Not bound to plasma proteins. Peak plasma concentrations are achieved rapidly within 15 minutes of drug infusion.

### Metabolism

Metabolism in cells via enzymatic and nonenzymatic mechanisms to yield an EDTA analog. Over 40% of drug is cleared in urine. Plasma elimination half-life is approximately 2–3 hours.

### Indications

- i. Dexrazoxane is FDA-approved to prevent and/or reduce anthracycline-induced cardiotoxicity in women with metastatic breast cancer who

- have received a total cumulative dose of doxorubicin of 300 mg/m<sup>2</sup> and who would benefit from continued treatment.
2. Dexrazoxane is **NOT** recommended in women who are being started on initial doxorubicin-based therapy.
  3. Dexrazoxane is **NOT** recommended in the adjuvant therapy of breast cancer.

---

### Dosage Range

Recommended dose is to give dexrazoxane IV, 30 minutes before doxorubicin, at a ratio of dexrazoxane:doxorubicin of 10:1. For example, with a doxorubicin dose of 50 mg/m<sup>2</sup>, the dose of dexrazoxane should be 500 mg/m<sup>2</sup>.

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### Drug Interactions

Doxorubicin, epirubicin—Dexrazoxane prevents the cardiotoxicity associated with doxorubicin and epirubicin but may also reduce their respective antitumor activities.

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### Special Considerations

1. Dexrazoxane should not be used at the start of doxorubicin therapy as there is evidence to suggest that it may interfere with the antitumor efficacy of doxorubicin leading to decreased response rates observed with the FAC regimen.
2. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. Treatment with dexrazoxane does not completely eliminate the risk of cardiotoxicity.
3. Sequencing of drugs is important as dexrazoxane should be administered 30 minutes before doxorubicin. Doxorubicin should **NOT** be given before dexrazoxane.
4. Monitor weekly CBC while on therapy. Dexrazoxane may increase the myelosuppressive effects of doxorubicin.
5. Pregnancy category C. Breast-feeding should be avoided.

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### Toxicity 1

Myelosuppression. Generally mild and reversible.

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### Toxicity 2

Pain at injection site.

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### Toxicity 3

Mild nausea and vomiting.



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### Distribution

Distributes widely to all body tissues. Extensive binding (>90%) to plasma and cellular proteins.

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### Metabolism

Extensively metabolized by the hepatic P450 microsomal system. About 75% of drug is excreted via fecal elimination. Less than 10% is eliminated as the parent compound with the majority being eliminated as metabolites. Renal clearance is relatively minor with less than 10% of drug clearance via the kidneys. Plasma elimination is triexponential with a terminal half-life of 11 hours.

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### Indications

1. Breast cancer—Locally advanced or metastatic breast cancer after failure of prior chemotherapy. FDA-approved.
  2. Breast cancer—FDA-approved in combination with doxorubicin and cyclophosphamide for the adjuvant treatment of patients with node-positive breast cancer.
  3. Non-small cell lung cancer—Locally advanced or metastatic disease after failure of prior platinum-based chemotherapy. FDA-approved.
  4. Non-small cell lung cancer—FDA-approved in combination with cisplatin for the treatment of locally advanced or metastatic disease who have not previously received chemotherapy.
  5. Prostate cancer—FDA-approved in combination with prednisone for androgen-independent (hormone-refractory) metastatic prostate cancer.
  6. Gastric cancer—FDA-approved in combination with cisplatin and 5-fluorouracil for advanced gastric cancer, including adenocarcinoma of the gastroesophageal junction, who have not received prior chemotherapy.
  7. Head and neck cancer—FDA-approved for use in combination with cisplatin and 5-fluorouracil for the induction treatment of patients with inoperable, locally advanced disease.
  8. Small cell lung cancer.
  9. Refractory ovarian cancer—advanced platinum.
  10. Bladder cancer.
- 

### Dosage Range

1. Metastatic breast cancer: 60, 75, and 100 mg/m<sup>2</sup> IV every 3 weeks or 35–40 mg/m<sup>2</sup> IV weekly for 3 weeks with 1 week of rest.
2. Breast cancer: 75 mg/m<sup>2</sup> IV every 3 weeks in combination with cyclophosphamide and doxorubicin for adjuvant therapy.

3. Non–small cell lung cancer: 75 mg/m<sup>2</sup> IV every 3 weeks or 35–40 mg/m<sup>2</sup> IV weekly for 3 weeks with 1 week rest after platinum-based chemotherapy.
4. Non–small cell lung cancer: 75 mg/m<sup>2</sup> IV every 3 weeks in combination with cisplatin in patients who have not received prior chemotherapy.
5. Metastatic prostate cancer: 75 mg/m<sup>2</sup> IV every 3 weeks in combination with prednisone.
6. Advanced gastric cancer: 75 mg/m<sup>2</sup> IV every 3 weeks in combination with cisplatin and 5-FU.
7. Head and neck cancer: 75 mg/m<sup>2</sup> IV every 3 weeks in combination with cisplatin and 5-FU for induction therapy of locally advanced disease.

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### Drug Interaction 1

Radiation therapy—Docetaxel acts as a radiosensitizing agent.

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### Drug Interaction 2

Inhibitors and/or activators of the liver cytochrome P<sub>450</sub> CYP<sub>3A4</sub> enzyme system—Concurrent use with drugs such as cyclosporine, ketoconazole, and erythromycin may affect docetaxel metabolism and its subsequent antitumor and toxic effects.

---

### Special Considerations

1. Use with caution in patients with abnormal liver function. Patients with abnormal liver function are at significantly higher risk for toxicity, including treatment-related mortality.
2. Closely monitor CBCs, and docetaxel therapy should not be given to patients with neutrophil counts of <1,500 cells/mm<sup>3</sup>.
3. Patients should receive steroid premedication to reduce the incidence and severity of fluid retention and hypersensitivity reactions. Give dexamethasone 8 mg PO bid for three days beginning one day before drug administration.
4. Closely monitor patients for allergic and/or hypersensitivity reactions. Usually occur with the first and second treatments. Emergency equipment, including Ambu bag, EKG machine, fluids, pressors, and other drugs for resuscitation, must be at bedside before initiation of treatment.
5. Contraindicated in patients with known hypersensitivity reactions to docetaxel and/or polysorbate 80.
6. Use only glass, polypropylene bottles, or polypropylene or polyolefin plastic bags for drug infusion. Administer only through polyethylene-lined administration sets.
7. Monitor patient's weight, measure daily input and output, and evaluate for peripheral edema.
8. Pregnancy category D. Breast-feeding should be avoided.

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### Toxicity 1

Myelosuppression. Neutropenia is dose-limiting with nadir at days 7–10 and recovery by day 14. Thrombocytopenia and anemia are also observed.

---

### Toxicity 2

Hypersensitivity reactions with generalized skin rash, erythema, hypotension, dyspnea, and/or bronchospasm. Usually occur within the first 2–3 minutes of an infusion and almost always within the first 10 minutes. Most frequently observed with first or second treatments. Usually prevented by premedication with steroid; overall incidence decreased to less than 3%. When it occurs during drug infusion, treat with hydrocortisone IV, diphenhydramine 50 mg IV, and/or cimetidine 300 mg IV.

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### Toxicity 3

Fluid retention syndrome. Presents as weight gain, peripheral and/or generalized edema, pleural effusion, and ascites. Incidence increases with total doses  $>400$  mg/m<sup>2</sup>. Occurs in about 50% of patients.

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### Toxicity 4

Maculopapular skin rash and dry, itchy skin. Most commonly affect forearms and hands. Brown discoloration of fingernails may occur. Observed in up to 50% of patients usually within one week after therapy.

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### Toxicity 5

Alopecia occurs in up to 80% of patients.

---

### Toxicity 6

Mucositis and/or diarrhea seen in 40% of patients. Mild to moderate nausea and vomiting, usually of brief duration.

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### Toxicity 7

Peripheral neuropathy is less commonly observed with docetaxel than with paclitaxel.

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### Toxicity 8

Generalized fatigue and asthenia are common, occurring in 60%–70% of patients. Arthralgias and myalgias also observed.

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### Toxicity 9

Reversible elevations in serum transaminases, alkaline phosphatase, and bilirubin.

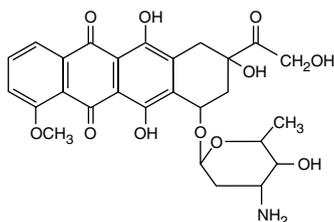
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### Toxicity 10

Vesicant. Phlebitis and/or swelling can be seen at the injection site.

# D

## Doxorubicin



### Trade Names

Adriamycin, Hydroxydaunorubicin

### Classification

Antitumor antibiotic

### Category

Chemotherapy drug

### Drug Manufacturer

Bedford Laboratories

### Mechanism of Action

- Anthracycline antibiotic isolated from *Streptomyces* species.
- Intercalates into DNA resulting in inhibition of DNA synthesis and function.
- Inhibits transcription through inhibition of DNA-dependent RNA polymerase.
- Inhibits topoisomerase II by forming a cleavable complex with DNA and topoisomerase II to create uncompensated DNA helix torsional tension, leading to eventual DNA breaks.
- Formation of cytotoxic oxygen free radicals results in single- and double-stranded DNA breaks with subsequent inhibition of DNA synthesis and function.

### Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with elevated P<sub>170</sub> levels. This leads to increased drug efflux and decreased intracellular drug accumulation.
- Decreased expression of topoisomerase II.

- Mutation in topoisomerase II with decreased binding affinity to doxorubicin.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-dependent proteins.

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### Absorption

Not absorbed orally.

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### Distribution

Widely distributed to tissues. Does not cross the blood-brain barrier. About 75% of doxorubicin and its metabolites are bound to plasma proteins.

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### Metabolism

Metabolized extensively in the liver to the active hydroxylated metabolite, doxorubicinol. About 40%–50% of drug is eliminated via biliary excretion in feces. Less than 10% of drug is cleared by the kidneys. Prolonged terminal half-life of 20–48 hours.

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### Indications

1. Breast cancer.
2. Hodgkin's and non-Hodgkin's lymphoma.
3. Soft tissue sarcoma.
4. Ovarian cancer.
5. Non-small cell and small cell lung cancer.
6. Bladder cancer.
7. Thyroid cancer.
8. Hepatoma.
9. Gastric cancer.
10. Wilms' tumor.
11. Neuroblastoma.
12. Acute lymphoblastic leukemia.

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### Dosage Range

1. Single agent: 60–75 mg/m<sup>2</sup> IV every three weeks.
2. Single agent: 15–20 mg/m<sup>2</sup> IV weekly.
3. Combination therapy: 45–60 mg/m<sup>2</sup> every three weeks.
4. Continuous infusion: 60–90 mg/m<sup>2</sup> IV over 96 hours.

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### Drug Interaction 1

Dexamethasone, 5-FU, heparin—Doxorubicin is incompatible with dexamethasone, 5-FU, and heparin, as concurrent use will lead to precipitate formation.

# D

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## Drug Interaction 2

Dexrazoxane—The cardiotoxic effects of doxorubicin are inhibited by the iron-chelating agent dexrazoxane (ICRF-187, Zinecard).

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## Drug Interaction 3

Cyclophosphamide—Increased risk of hemorrhagic cystitis and cardiotoxicity when doxorubicin is given with cyclophosphamide. Important to be able to distinguish between hemorrhagic cystitis and the normal red-orange urine observed with doxorubicin therapy.

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## Drug Interaction 4

Phenobarbital, phenytoin—Increased plasma clearance of doxorubicin when given concurrently with barbiturates and phenytoin.

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## Drug Interaction 5

Herceptin, mitomycin-C—Increased risk of cardiotoxicity when doxorubicin is given with Herceptin or mitomycin-C.

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## Drug Interaction 6

Digoxin—Doxorubicin decreases the oral bioavailability of digoxin.

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## Drug Interaction 7

6-Mercaptopurine—Increased risk of hepatotoxicity when doxorubicin is given with 6-mercaptopurine.

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## Special Considerations

1. Use with caution in patients with abnormal liver function. Dose reduction is required in the setting of liver dysfunction.
2. Because doxorubicin is a strong vesicant, administer slowly with a rapidly flowing IV. Avoid using veins over joints or in extremities with compromised venous and/or lymphatic drainage. Use of a central venous catheter is recommended for patients with difficult venous access and mandatory for prolonged infusions. Careful monitoring is necessary to avoid extravasation. If extravasation is suspected, immediately stop infusion, withdraw fluid, elevate extremity, and apply ice to involved site. May administer local steroids. In severe cases, consult a plastic surgeon.
3. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. Risk of cardiotoxicity is higher in patients >70 years of age, in patients with prior history of hypertension or pre-existing heart disease, in patients previously treated with anthracyclines, or in patients with prior radiation

therapy to the chest. Cumulative doses of  $>450 \text{ mg/m}^2$  are associated with increased risk for cardiotoxicity.

4. Risk of cardiotoxicity is decreased with weekly or continuous infusion schedules. Use of the iron-chelating agent dexrazoxane (ICRF-187) also is effective at reducing the development of cardiotoxicity.
5. Use with caution in patients previously treated with radiation therapy as doxorubicin can cause radiation recall skin reaction. Increased risk of skin toxicity when doxorubicin is given concurrently with radiation therapy.
6. Patients should be cautioned to avoid sun exposure and to wear sun protection when outside.
7. Patients should be warned about the potential for red-orange discoloration of urine for 1–2 days after drug administration.
8. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting toxicity with leukopenia more common than thrombocytopenia or anemia. Nadir usually occurs at days 10–14 with full recovery by day 21.

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#### Toxicity 2

Nausea and vomiting. Usually mild, occurring in 50% of patients within the first 1–2 hours of treatment.

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#### Toxicity 3

Mucositis and diarrhea. Common but not dose-limiting.

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#### Toxicity 4

Cardiotoxicity. Acute form presents within the first 2–3 days as arrhythmias and/or conduction abnormalities, EKG changes, pericarditis, and/or myocarditis. Usually transient and mostly asymptomatic. Not dose-related.

Chronic form results in a dose-dependent, dilated cardiomyopathy associated with congestive heart failure. Risk increases when cumulative doses are greater than  $450 \text{ mg/m}^2$ .

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#### Toxicity 5

Strong vesicant. Extravasation can lead to tissue necrosis and chemical thrombophlebitis at the site of injection.

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#### Toxicity 6

Hyperpigmentation of nails, rarely skin rash, and urticaria. Radiation recall skin reaction can occur at prior sites of irradiation. Increased hypersensitivity to sunlight.

D

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Toxicity 7

Alopecia. Universal but usually reversible within three months after termination of treatment.

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Toxicity 8

Red-orange discoloration of urine. Usually occurs within 1–2 days after drug administration.

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Toxicity 9

Allergic, hypersensitivity reactions are rare.

# Doxorubicin liposome

# D

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## Trade Names

Doxil

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## Classification

Antitumor antibiotic

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## Category

Chemotherapy drug

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## Drug Manufacturer

Ortho-Biotech

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## Mechanism of Action

- Liposomal encapsulation of doxorubicin.
- Protected from chemical and enzymatic degradation, reduced plasma protein binding, and decreased uptake in normal tissues.
- Penetrates tumor tissue into which doxorubicin is released.
- Intercalates into DNA resulting in inhibition of DNA synthesis and function.
- Inhibits transcription through inhibition of DNA-dependent RNA polymerase.
- Inhibits topoisomerase II by forming a cleavable complex with DNA and topoisomerase II. This creates uncompensated DNA helix torsional tension, leading to eventual DNA breaks.
- Formation of cytotoxic oxygen free radicals results in single- and double-stranded DNA breaks and subsequent inhibition of DNA synthesis and function.

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## Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with elevated P170 protein levels. This leads to increased drug efflux and decreased intracellular drug accumulation.
- Decreased expression of topoisomerase II.
- Mutation in topoisomerase II with decreased binding affinity to drug.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-dependent proteins.

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## Absorption

Liposomal doxorubicin is not absorbed orally.

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## Distribution

Mainly confined to the intravascular compartment. In contrast to parent drug, doxorubicin, which has a large  $V_d$  (700–1,100 L/m<sup>2</sup>), liposomal doxorubicin has a small  $V_d$  (2 L/m<sup>2</sup>). Does not cross the blood-brain barrier. Binding to plasma proteins has not been well characterized.

---

## Metabolism

Plasma clearance of doxil is slower than that of doxorubicin, resulting in AUCs that are significantly greater than an equivalent dose of doxorubicin. Prolonged terminal half-life of about 55 hours.

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## Indications

1. AIDS-related Kaposi's sarcoma—Used in patients with disease that has progressed on prior combination chemotherapy and/or in patients who are intolerant to such therapy.
2. Ovarian cancer—Metastatic disease refractory to both paclitaxel and platinum-based chemotherapy regimens.
3. Multiple myeloma—Used in combination with bortezomib in patients who have not previously received bortezomib and who have received at least one prior therapy.

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## Dosage Range

1. Kaposi's sarcoma: 20 mg/m<sup>2</sup> IV every 21 days.
2. Ovarian cancer: 50 mg/m<sup>2</sup> IV every 28 days.
3. Multiple myeloma: 30 mg/m<sup>2</sup> IV on day 4 after bortezomib, which is administered at 1.3 mg/m<sup>2</sup> IV on days 1, 4, 8, and 11, every 21 days.

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## Drug Interactions

None well characterized to date.

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## Special Considerations

1. Liposomal doxorubicin should not be substituted for doxorubicin on a mg-per-mg-basis and should be used only where indicated.
2. Use with caution in patients with abnormal liver function. Dose reduction is required in the setting of liver dysfunction.
3. Infusions of liposomal doxorubicin should be given at an initial rate of 1 mg/min over a period of at least 30 minutes to avoid the risk of infusion-associated reactions. This reaction is thought to be related to the lipid component of liposomal doxorubicin. In the event of such a reaction with flushing, dyspnea, or facial swelling, the infusion should be stopped immediately. If symptoms are minor, can restart infusion at 50% the initial rate. Patients should not be rechallenged in the face of a severe hypersensitivity reaction.

4. Careful monitoring is necessary to avoid extravasation. If extravasation is suspected, immediately stop infusion, withdraw fluid, elevate extremity, and apply ice to involved site. May administer local steroids. In severe cases, consult plastic surgeon.
5. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. Risk of cardiotoxicity is higher in patients >70 years of age, in patients with prior history of hypertension or pre-existing heart disease, in patients previously treated with anthracyclines, or in patients with prior radiation therapy to the chest.
6. Monitor weekly CBC while on therapy.
7. Patients should be cautioned about the risk of hand-foot syndrome.
8. Patients should be warned about the potential for red-orange discoloration of urine for 1–2 days after drug administration.
9. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting toxicity with leukopenia more common than thrombocytopenia or anemia. Nadir usually occurs at days 10–14, with full recovery by day 21.

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#### Toxicity 2

Nausea and vomiting. Usually mild, occurring in 20% of patients.

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#### Toxicity 3

Mucositis and diarrhea. Common but not dose-limiting.

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#### Toxicity 4

Cardiotoxicity. Acute form presents within the first 2–3 days as arrhythmias and/or conduction abnormalities, EKG changes, pericarditis, and/or myocarditis. Usually transient and mostly asymptomatic. Not dose-related.

Chronic form results in a dose-dependent dilated cardiomyopathy associated with congestive heart failure.

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#### Toxicity 5

Skin toxicity manifested as the hand-foot syndrome with skin rash, swelling, erythema, pain, and/or desquamation. Usually mild with onset at 5–6 weeks after the start of treatment. May require subsequent dose reduction. More commonly observed in ovarian cancer patients (37%) than in those with Kaposi's sarcoma (5%).

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#### Toxicity 6

Hyperpigmentation of nails, skin rash, and urticaria. Radiation recall skin reaction can occur at prior sites of irradiation.

# D

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## Toxicity 7

Alopecia. Common but generally reversible within three months after termination of treatment.

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## Toxicity 8

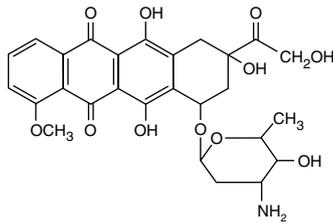
Infusion reaction with flushing, dyspnea, facial swelling, headache, back pain, tightness in the chest and throat, and/or hypotension. Occurs in about 5%–10% of patients, usually with the first treatment. Upon stopping the infusion, resolves within several hours to a day.

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## Toxicity 9

Red-orange discoloration of urine. Usually occurs within 1–2 days after drug administration.

# Epirubicin



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## Trade Names

4 Epi-doxorubicin, Ellence

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## Classification

Antitumor antibiotic

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## Category

Chemotherapy drug

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## Drug Manufacturer

Pfizer

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## Mechanism of Action

- Anthracycline derivative of doxorubicin.
- Intercalates into DNA, which results in inhibition of DNA synthesis and function.
- Inhibits topoisomerase II by forming a cleavable complex with topoisomerase II and DNA.
- Involved in oxidation/reductions by generating cytotoxic oxygen free radicals, which can cause single- and double-stranded DNA breaks.

---

## Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with enhanced drug efflux. This results in decreased intracellular drug accumulation.
- Decreased expression of topoisomerase II.
- Mutation in topoisomerase II with decreased binding affinity to drug.
- Increased expression of glutathione and glutathione-associated enzymes.

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## Absorption

Not orally bioavailable.

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### Distribution

Rapid and extensive distribution to formed blood elements and to body tissues. Does not cross the blood-brain barrier. Epirubicin is extensively bound (about 80%) to plasma proteins. Peak plasma levels are achieved immediately.

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### Metabolism

Extensive metabolism by the liver microsomal P450 system. Both active (epirubicinol) and inactive metabolites are formed. Elimination is mainly through the hepatobiliary route. Renal clearance accounts for only 20% of drug elimination. The half-life is approximately 30–38 hours for the parent compound and 20–31 hours for the epirubicinol metabolite.

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### Indications

1. Breast cancer—FDA-approved as a component of adjuvant therapy in women with axillary node involvement following resection of primary breast cancer.
2. Metastatic breast cancer.
3. Gastric cancer.

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### Dosage Range

1. Usual dose is 100–120 mg/m<sup>2</sup> IV every three weeks.
2. In heavily pretreated patients, consider starting at lower dose of 75–90 mg/m<sup>2</sup> IV every three weeks.
3. Alternative schedule is 12–25 mg/m<sup>2</sup> IV on a weekly basis.

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### Drug Interaction 1

Heparin—Epirubicin is incompatible with heparin as a precipitate will form.

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### Drug Interaction 2

5-FU, cyclophosphamide—Increased risk of myelosuppression when epirubicin is used in combination with 5-FU and cyclophosphamide.

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### Drug Interaction 3

Cimetidine—Cimetidine decreases the AUC of epirubicin by 50% and should be discontinued upon initiation of epirubicin therapy.

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### Special Considerations

1. Use with caution in patients with abnormal liver function. Dose modification should be considered in patients with liver dysfunction.
2. Use with caution in patients with severe renal impairment. Dose should be reduced by at least 50% when serum creatinine >5 mg/dL.

3. Use with caution in elderly patients as they are at increased risk for developing host toxicity.
4. Careful monitoring of drug administration is necessary to avoid extravasation. If extravasation is suspected, stop infusion immediately, withdraw fluid, elevate arm, and apply ice to site. In severe cases, consult plastic surgeon.
5. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. Risk of cardiotoxicity is higher in elderly patients >70 years of age, in patients with prior history of hypertension or pre-existing heart disease, in patients previously treated with anthracyclines, or in patients with prior radiation therapy to the chest. In patients with no prior history of anthracycline therapy, cumulative doses of 900 mg/m<sup>2</sup> are associated with increased risk for cardiotoxicity.
6. Epirubicin may be administered on a weekly schedule to decrease the risk of cardiotoxicity.
7. Monitor weekly CBC while on therapy.
8. Use with caution in patients previously treated with irradiation as epirubicin may induce a radiation recall reaction.
9. Patients may experience red-orange discoloration of urine for 24 hours after drug administration.
10. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting toxicity with leukopenia more common than thrombocytopenia. Nadir typically occurs at 8–14 days after treatment, with recovery of counts by day 21. Risk of myelosuppression greater in elderly patients and in those previously treated with chemotherapy and/or radiation therapy.

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#### Toxicity 2

Mild nausea and vomiting. Occur less frequently than with doxorubicin.

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#### Toxicity 3

Mucositis and diarrhea. Dose-dependent, common, and generally mild.

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#### Toxicity 4

Cardiotoxicity. Cardiac effects are similar to but less severe than those of doxorubicin. Acute toxicity presents as rhythm or conduction disturbances, chest pain, and myopericarditis syndrome that typically occurs within the first 24–48 hours of drug administration. Transient and mostly asymptomatic, not dose-related.

Chronic form of cardiotoxicity presents as a dilated cardiomyopathy with congestive heart failure. Risk of congestive heart failure increases significantly with cumulative doses  $>900 \text{ mg/m}^2$ . Continuous infusion and weekly schedules are associated with decreased risk of cardiotoxicity. Dexrazoxane may be helpful in preventing epirubicin-mediated cardiotoxicity.

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#### Toxicity 5

Alopecia. Onset within 10 days of initiation of therapy and regrowth of hair upon termination of treatment. Occurs much less commonly than with doxorubicin, being observed in only 25%–50% of patients.

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#### Toxicity 6

Potent vesicant. Extravasation can lead to tissue injury, inflammation, and chemical thrombophlebitis at the site of injection.

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#### Toxicity 7

Skin rash, flushing, hyperpigmentation of skin and nails, and photosensitivity. Radiation recall skin reaction can occur at previous sites of irradiation.

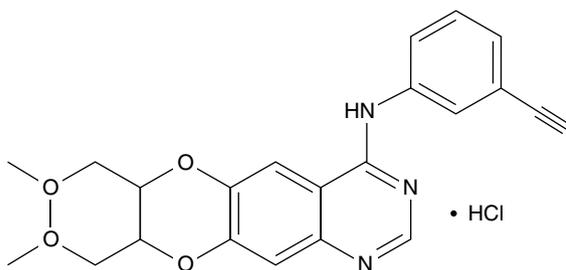
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#### Toxicity 8

Red-orange discoloration of urine for 24 hours after drug administration.

# Erlotinib

E



## Trade Names

Tarceva, OSI-774

## Classification

Signal transduction inhibitor

## Category

Chemotherapy drug

## Drug Manufacturer

OSI, Genentech

## Mechanism of Action

- Potent and selective small molecule inhibitor of the EGFR tyrosine kinase, resulting in inhibition of EGFR autophosphorylation and inhibition of EGFR signaling.
- Inhibition of the EGFR tyrosine kinase results in inhibition of critical mitogenic and anti-apoptotic signals involved in proliferation, growth, metastasis, angiogenesis, and response to chemotherapy and/or radiation therapy.

## Mechanism of Resistance

- Mutation in the EGFR tyrosine kinase leading to decreased binding affinity to erlotinib.
- Presence of K-ras mutations.
- Activation/induction of alternative cellular signaling pathways, such as IGF-1R.

## Absorption

Oral bioavailability is approximately 60% and is increased by food to almost 100%.

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### Distribution

Extensive binding (90%) to plasma proteins, including albumin and  $\alpha_1$ -acid glycoprotein, and extensive tissue distribution. Peak plasma levels are achieved four hours after ingestion. Steady-state drug concentrations are reached in 7–8 days.

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### Metabolism

Metabolism in the liver primarily by the CYP3A4 microsomal enzyme and by CYP1A2 to a lesser extent. Elimination is mainly hepatic with excretion in the feces, and renal elimination of parent drug and its metabolites account for about 8% of an administered dose. The terminal half-life of the parent drug is 36 hours.

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### Indications

1. FDA-approved as monotherapy for the treatment of locally advanced or metastatic non–small cell lung cancer after failure of at least one prior chemotherapy regimen.
2. FDA-approved in combination with gemcitabine for the first-line treatment of patients with locally advanced unresectable or metastatic pancreatic cancer.

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### Dosage Range

1. Non–small cell lung cancer—Recommended dose is 150 mg/day PO.
2. Pancreatic cancer—Recommended dose is 100 mg/day PO in combination with gemcitabine.

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### Drug Interaction 1

Dilantin and other drugs that stimulate the liver microsomal CYP3A4 enzyme, including carbamazepine, rifampicin, phenobarbital, and St. John's Wort—These drugs may increase the rate of metabolism of erlotinib, resulting in its inactivation.

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### Drug Interaction 2

Drugs that inhibit the liver microsomal CYP3A4 enzyme, including ketoconazole, itraconazole, erythromycin, and clarithromycin—These drugs may decrease the rate of metabolism of erlotinib, resulting in increased drug levels and potentially increased toxicity.

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### Drug Interaction 3

Warfarin—Patients receiving Coumarin-derived anticoagulants should be closely monitored for alterations in their clotting parameters (PT and INR) and/or bleeding, as erlotinib may inhibit the metabolism of warfarin by the

liver P450 system. Dose of warfarin may require careful adjustment in the presence of erlotinib therapy.

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### Special Considerations

1. Use with caution in patients with hepatic impairment, and dose reduction and/or interruption should be considered.
2. Nonsmokers and patients with EGFR-positive tumors are more sensitive to erlotinib therapy.
3. Erlotinib should not be used in combination with platinum-based chemotherapy as there is no evidence of clinical benefit.
4. Closely monitor patients for new or progressive pulmonary symptoms, including cough, dyspnea, and fever. Erlotinib therapy should be interrupted pending further diagnostic evaluation.
5. Dose of erlotinib may need to be increased when used in patients with seizure disorders who are receiving phenytoin, as the metabolism of erlotinib by the liver P450 system is enhanced in the presence of phenytoin.
6. Coagulation parameters PT/INR should be closely monitored when patients are receiving both erlotinib and Coumadin, as erlotinib may inhibit the metabolism of Coumadin by the liver P450 system.
7. In patients who develop a skin rash, topical antibiotics such as Cleocin gel or either oral Cleocin and/or oral minocycline may help.
8. Pregnancy category D.

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### Toxicity 1

Pruritus, dry skin with mainly a pustular, acneiform skin rash.

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### Toxicity 2

Diarrhea is most common GI toxicity. Mild nausea/vomiting and mucositis.

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### Toxicity 3

Pulmonary toxicity in the form of ILD manifested by increased cough, dyspnea, fever, and pulmonary infiltrates. Observed in less than 1% of patients and more frequent in patients with underlying pulmonary disease.

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### Toxicity 4

Mild to moderate elevations in serum transaminases. Usually transient and clinically asymptomatic.

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**Toxicity 5**

Anorexia.

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**Toxicity 6**

Conjunctivitis and keratitis.

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**Toxicity 7**

Rare episodes of GI hemorrhage.

# Erythropoietin

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## Trade Names

Procrit, Epogen, EPO, Epoetin alfa

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## Classification

Colony-stimulating growth factor, cytokine

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Ortho Biotech, Amgen

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## Mechanism of Action

- Glycoprotein that is produced by recombinant DNA techniques. Has the same biologic effects as endogenous erythropoietin.
- Stimulates division and differentiation of red blood cells in the bone marrow.
- Does not possess antitumor activity.

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## Absorption

Administered either by the IV or SC route. Absorption is higher after SC injection in the thigh when compared to SC injection in the arm or abdomen. Plasma levels are detectable for 24 hours after injection.

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## Distribution

Distributes into total plasma volume. Binding to plasma proteins is not known.

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## Metabolism

Metabolism is not entirely clear, although catabolism in liver and bone marrow appears to play a role. About 10% of the drug is cleared in urine in unchanged form. The terminal half-life is 4–13 hours in patients with chronic renal failure.

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## Indications

1. Chemotherapy-induced anemia in patients with non-myeloid cancers.
2. Anemia in AZT-treated patients with HIV.
3. Anemia associated with chronic renal failure.
4. Anemia in patients scheduled to undergo elective, noncardiac, nonvascular surgery to reduce the need for allogeneic blood transfusions.

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### Dosage Range

1. Chemotherapy-induced anemia: Usual starting dose is 40,000 units once a week, and if the hemoglobin is not increased  $>1$  g/dL, the dose may be increased to 60,000 units once a week.
2. Anemia in AZT-treated HIV patients: 100 units/kg SC tiw.
3. Chronic renal failure: 50–100 units/kg SC tiw.
4. Surgery: 300 units/day for 10 days prior to surgery, on day of surgery, and for four days after surgery.

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### Drug Interaction 1

Heparin—Erythropoietin decreases the efficacy of heparin when given concurrently.

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### Drug Interaction 2

Aluminum-containing antacids—Efficacy of erythropoietin is decreased in the presence of aluminum-containing antacids.

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### Special Considerations

1. Contraindicated in patients with uncontrolled hypertension. Use with caution in patients with a history of hypertension and/or cardiovascular disease.
2. Contraindicated in patients with known hypersensitivity to mammalian-derived products.
3. Contraindicated in patients with known hypersensitivity to human albumin.
4. Use with caution in patients with known porphyria as exacerbation has been observed in patients treated with erythropoietin.
5. Obtain baseline erythropoietin levels before start of therapy. The optimal response is observed in cancer patients with endogenous levels 200 U/mL. A baseline serum ferritin level and transferrin saturation should also be obtained. Transferrin saturation should be at least 20%, and ferritin should be at least 100 mg/mL.
6. The lowest dose of erythropoietin should be used to increase gradually the need for hemoglobin concentrations to the lowest level sufficient to avoid the need for red blood cell transfusions.

Blood counts should be monitored on a weekly basis during erythropoietin therapy. If the response is not satisfactory in terms of reducing transfusion requirements or increasing hematocrit after 4–8 weeks of therapy, the dose of erythropoietin can be doubled. If patients have not responded to this increase in dose, higher doses are unlikely to be beneficial. Increases in hemoglobin/hematocrit are usually seen after seven days of therapy but may take up to

4–8 weeks. If the hematocrit exceeds 40%, the dose of erythropoietin should be held until the hematocrit falls to 35%. The dose should then be reduced by 25% upon restarting therapy.

7. Patients should be closely monitored to ensure that the hemoglobin levels are not greater than 12 g/dL. An increased risk of death and serious cardiovascular events, including myocardial infarction, heart failure, stroke, and thrombosis, has been observed in this setting (this represents a black-box warning).
8. Patients may benefit from concomitant treatment with iron supplementation, ferrous sulfate 1 tablet PO bid or tid.
9. Pregnancy category C.

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**Toxicity 1**

Diarrhea and occasional nausea and vomiting.

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**Toxicity 2**

Hypertension. Common but usually mild.

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**Toxicity 3**

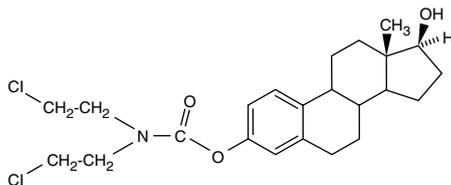
Local pain at injection site.

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**Toxicity 4**

Fever, fatigue, asthenia, and headache.

# Estramustine



## Trade Names

Estracyte, Emcyt

## Classification

Antimicrotubule agent

## Category

Chemotherapy drug

## Drug Manufacturer

Pfizer

## Mechanism of Action

- Conjugate of nornitrogen mustard and estradiol phosphate.
- Cell cycle-specific agent with activity in the mitosis (M) phase.
- Initially designed to target cancer cells expressing estrogen receptors. However, active against estrogen receptor-negative tumor cells.
- Although this compound was initially designed as an alkylating agent, it has no alkylating activity.
- Inhibits microtubule structure and function and the process of microtubule assembly by binding to microtubule-associated proteins (MAPs).

## Mechanism of Resistance

- Mechanisms of cellular resistance are different from those identified for other antimicrotubule agents.
- Estramustine-resistant cells do not express increased levels of P170 glycoprotein and are not cross-resistant to other antimicrotubule agents and/or natural products.
- Estramustine-resistant cells display increased efflux of drug with decreased drug accumulation. The underlying mechanism(s) remains ill-defined.

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### Absorption

Highly bioavailable via the oral route with 70%–75% of an oral dose absorbed.

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### Metabolism

Estramustine is supplied as the estramustine phosphate form, which renders it more water-soluble. Rapidly dephosphorylated in the GI tract so that the dephosphorylated form predominates about 4 hours after ingestion.

Metabolized primarily in the liver. About 15%–20% of the drug is excreted in urine. Only small amounts of unmetabolized drug are found. Biliary and fecal excretion of alkylating and estrogenic metabolites has also been demonstrated. Prolonged half-life of 20–24 hours.

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### Indications

Hormone-refractory, metastatic prostate cancer.

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### Dosage Range

1. Single agent: 14 mg/kg/day PO in 3–4 divided doses.
2. Combination: 600 mg/m<sup>2</sup>/day PO days 1–42 every eight weeks, as part of the estramustine/vinblastine regimen.

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### Drug Interaction

None known.

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### Special Considerations

1. Contraindicated in patients with active thrombophlebitis or thromboembolic disorders. Closely monitor patients with history of heart disease and/or stroke.
2. Contraindicated in patients with known hypersensitivity to estradiol or nitrogen mustard.
3. Contraindicated in patients with peptic ulcer disease, severe liver disease, or cardiac disease.
4. Instruct patients to take estramustine with water one hour before meals or two hours after meals to decrease the risk of GI upset.
5. Administer prophylactic antiemetics to avoid nausea and vomiting.
6. Instruct patients that milk, milk products, and calcium-rich foods may impair absorption of drug.

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### Toxicity 1

Nausea and vomiting. Occur within two hours of ingestion. Usually mild and respond to antiemetic therapy. However, intractable vomiting may occur after prolonged therapy (6–8 weeks).

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**Toxicity 2**

Gynecomastia is reported in up to 50% of patients. Can be prevented by prophylactic breast irradiation.

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**Toxicity 3**

Diarrhea occurs in about 15%–25% of patients.

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**Toxicity 4**

Cardiovascular complications are rare and include congestive heart failure, cardiac ischemia, and thromboembolism.

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**Toxicity 5**

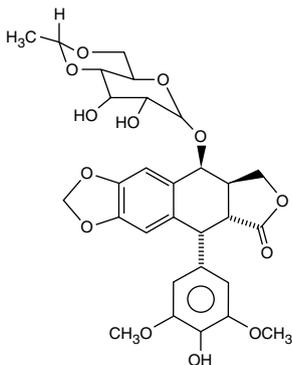
Myelosuppression is rare.

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**Toxicity 6**

Skin rash.

# Etoposide



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## Trade Names

VePesid, VP-16

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## Classification

Epipodophyllotoxin, topoisomerase II inhibitor

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## Category

Chemotherapy drug

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## Drug Manufacturer

Bristol-Myers Squibb

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## Mechanism of Action

- Plant alkaloid extracted from the *Podophyllum peltatum* mandrake plant.
- Cell cycle-specific agent with activity in the late S- and G<sub>2</sub>-phase.
- Inhibits topoisomerase II by stabilizing the topoisomerase II-DNA complex and preventing the unwinding of DNA.

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## Mechanism of Resistance

1. Multidrug-resistant phenotype with increased expression of P170 glycoprotein. Results in enhanced drug efflux and decreased intracellular accumulation of drug. Cross-resistant to vinca alkaloids, anthracyclines, taxanes, and other natural products.
2. Decreased expression of topoisomerase II.
3. Mutations in topoisomerase II with decreased binding affinity to drug.
4. Enhanced activity of DNA repair enzymes.

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### Absorption

Bioavailability of oral capsules is approximately 50%, requiring an oral dose to be twice that of an IV dose. However, oral bioavailability is nonlinear and decreases with higher doses of drug (>200 mg). Presence of food and/or other anticancer agents does not alter drug absorption.

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### Distribution

Rapidly distributed into all body fluids and tissues. Large fraction of etoposide (90%–95%) is protein-bound, mainly to albumin. Decreased albumin levels result in a higher fraction of free drug and a potentially higher incidence of host toxicity.

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### Metabolism

Metabolized primarily by the liver via glucuronidation to hydroxy acid metabolites, which are less active than the parent compound. About 30%–50% of etoposide is excreted in urine, and about 2%–6% is excreted in stool via biliary excretion. The elimination half-life ranges from 3 to 10 hours.

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### Indications

1. Germ cell tumors.
2. Small cell lung cancer.
3. Non-small cell lung cancer.
4. Non-Hodgkin's lymphoma.
5. Hodgkin's lymphoma.
6. Gastric cancer.
7. High-dose therapy in transplant setting for various malignancies, including breast cancer, lymphoma, and ovarian cancer.

---

### Dosage Range

1. IV: Testicular cancer—As part of the PEB regimen, 100 mg/m<sup>2</sup> IV on days 1–5 with cycles repeated every three weeks.
2. IV: Small cell lung cancer—As part of cisplatin/VP-16 regimen, 100–120 mg/m<sup>2</sup> IV on days 1–3 with cycles repeated every three weeks.
3. Small cell lung cancer—50 mg/m<sup>2</sup>/day PO for 21 days.

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### Drug Interactions

Warfarin—Etoposide may alter the anticoagulant effect of warfarin by prolonging the PT and INR. Coagulation parameters (PT and INR) need to be closely monitored and dose of warfarin may require adjustment.

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### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose reduction is recommended in patients with renal dysfunction. Baseline creatinine clearance should be obtained, and renal status should be carefully monitored during therapy.
2. Use with caution in patients with abnormal liver function. Dose reduction is recommended in this setting.
3. Administer drug over a period of at least 30–60 minutes to avoid the risk of hypotension. Should the blood pressure drop, immediately discontinue the drug and administer IV fluids. Rate of administration must be reduced upon restarting therapy.
4. Carefully monitor for anaphylactic reactions. More commonly observed during the initial infusion of therapy and probably related to the polysorbate 80 vehicle in which the drug is formulated. In rare instances, such an allergic reaction can be fatal. The drug should be immediately stopped and treatment with antihistamines, steroids, H<sub>2</sub> blockers such as cimetidine, and pressor agents should be administered.
5. Closely monitor injection site for signs of phlebitis and avoid extravasation.
6. Pregnancy category D.

---

### Toxicity 1

Myelosuppression. Dose-limiting toxicity with leukopenia more common than thrombocytopenia. Nadir usually occurs 10–14 days after therapy with recovery by day 21.

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### Toxicity 2

Nausea and vomiting. Occur in about 30%–40% of patients and generally mild to moderate. More commonly observed with oral administration.

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### Toxicity 3

Anorexia.

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### Toxicity 4

Alopecia observed in nearly two-thirds of patients.

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### Toxicity 5

Mucositis and diarrhea are unusual with standard doses but more often observed with high doses in transplant setting.

E

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**Toxicity 6**

Hypersensitivity reaction with chills, fever, bronchospasm, dyspnea, tachycardia, facial and tongue swelling, and hypotension. Occurs in less than 2% of patients.

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**Toxicity 7**

Metallic taste during infusion of drug.

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**Toxicity 8**

Local inflammatory reaction at injection site.

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**Toxicity 9**

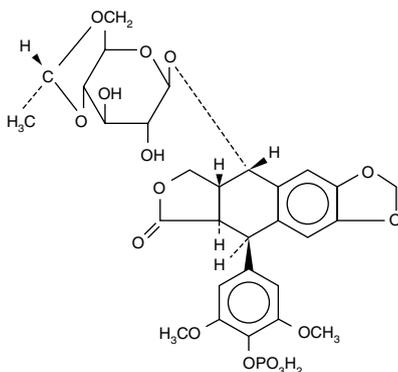
Radiation recall skin changes.

---

**Toxicity 10**

Increased risk of secondary malignancies, especially acute myelogenous leukemia. Associated with 11:23 translocation. Typically develops within 5–8 years of treatment and in the absence of preceding myelodysplastic syndrome.

## Etoposide phosphate



### Trade Names

Etopophos

### Classification

Epipodophyllotoxin, topoisomerase II inhibitor

### Category

Chemotherapy drug

### Drug Manufacturer

Bristol-Myers Squibb

### Mechanism of Action

- Water-soluble prodrug form of etoposide.
- Cell cycle-specific agent with activity in late S- and G<sub>2</sub>-phases.
- Must first be dephosphorylated for etoposide to be active.
- Once activated, it inhibits topoisomerase II by stabilizing the topoisomerase II-DNA complex and preventing the unwinding of DNA.

### Mechanism of Resistance

- Multidrug-resistant phenotype with increased expression of P170 glycoprotein. Results in enhanced drug efflux and decreased intracellular accumulation of drug.
- Decreased expression of topoisomerase II.
- Mutations in topoisomerase II with decreased binding affinity to drug.
- Enhanced activity of DNA repair enzymes.

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### Absorption

Only administered via the IV route.

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### Distribution

Rapidly distributed into all body fluids and tissues. Large fraction of drug (90%–95%) is protein-bound, mainly to albumin. Decreased albumin levels result in a higher fraction of free drug and a potentially higher incidence of host toxicity.

---

### Metabolism

Etoposide phosphate is rapidly and completely converted to etoposide in plasma, which is then metabolized primarily by the liver to hydroxyacid metabolites. These metabolites are less active than the parent compound. The elimination half-life of the drug ranges from 3 to 10 hours. About 15%–20% of the drug is excreted in urine and about 2%–6% is excreted in stool within 72 hours after IV administration.

---

### Indications

1. Germ cell tumors.
  2. Small cell lung cancer.
  3. Non–small cell lung cancer.
- 

### Dosage Range

1. Testicular cancer: 100 mg/m<sup>2</sup> IV on days 1–5 with cycles repeated every three weeks.
  2. Small cell lung cancer: 100 mg/m<sup>2</sup> IV on days 1–3 with cycles repeated every three weeks.
- 

### Drug Interactions

Warfarin—Etoposide may alter the anticoagulant effect of warfarin by prolonging the PT and INR. Coagulation parameters need to be closely monitored and dose of warfarin may require adjustment.

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### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose reduction is recommended in this setting. Baseline creatinine clearance should be obtained and renal status should be closely monitored during therapy.
2. Use with caution in patients with abnormal liver function. Dose reduction is recommended in this setting.
3. Administer drug over a period of at least 30–60 minutes to avoid the risk of hypotension. Should the blood pressure drop, immediately discontinue the drug and administer IV fluids. The rate of administration must be reduced upon restarting therapy.

4. Carefully monitor for anaphylactic reactions. Occur more frequently during the initial infusion of therapy. In rare instances, such an allergic reaction can be fatal. The drug should be immediately stopped and treatment with antihistamines, steroids, H<sub>2</sub> blockers such as cimetidine, and pressor agents should be administered.
5. Closely monitor injection site for signs of phlebitis. Carefully avoid extravasation.
6. Pregnancy category D.

---

#### Toxicity 1

Myelosuppression. Dose-limiting toxicity with leukopenia more common than thrombocytopenia. Nadir usually occurs 10–14 days after therapy with recovery by day 21.

---

#### Toxicity 2

Nausea and vomiting. Occur in about 30%–40% of patients and are generally mild to moderate.

---

#### Toxicity 3

Anorexia.

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#### Toxicity 4

Alopecia.

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#### Toxicity 5

Mucositis and diarrhea are only occasionally seen.

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#### Toxicity 6

Hypersensitivity reaction with chills, fever, bronchospasm, dyspnea, tachycardia, facial and tongue swelling, and hypotension.

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#### Toxicity 7

Metallic taste during infusion of drug.

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#### Toxicity 8

Local inflammatory reaction at the injection site.

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#### Toxicity 9

Radiation recall skin changes.

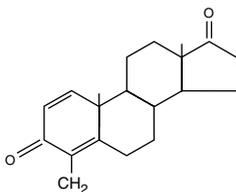
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#### Toxicity 10

Increased risk of secondary malignancies, especially acute myelogenous leukemia. Associated with 11:23 translocation. Typically develops within 5–8 years of treatment and in the absence of preceding myelodysplastic syndrome.

# E

## Exemestane



### Trade Names

Aromasin

### Classification

Steroidal aromatase inactivator

### Category

Hormonal agent

### Drug Manufacturer

Pfizer

### Mechanism of Action

- Permanently binds to and irreversibly inactivates aromatase.
- Inhibits the synthesis of estrogens by inhibiting the conversion of adrenal androgens (androstenedione and testosterone) to estrogens (estrone, estrone sulfate, and estradiol).
- No inhibitory effect on adrenal corticosteroid or aldosterone biosynthesis.

### Mechanism of Resistance

- None characterized.
- Lack of cross-resistance between exemestane and nonsteroidal aromatase inhibitors.

### Absorption

Excellent bioavailability via the oral route with 85% of a dose absorbed within two hours of ingestion. Absorption is not affected by food.

### Distribution

Widely distributed throughout the body. About 90% of drug is bound to plasma proteins.

---

### Metabolism

Extensively metabolized in the liver by the cytochrome P<sub>450</sub> 3A<sub>4</sub> enzyme (up to 85%) to inactive forms. Half-life of drug is about 24 hours. Steady-state levels of drug are achieved after seven days of a once-daily administration. The major route of elimination is fecal with renal excretion accounting for only 10% of drug clearance.

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### Indications

Treatment of advanced breast cancer in postmenopausal women whose disease has progressed following tamoxifen therapy.

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### Dosage Range

Usual dose is 25 mg PO once daily after a meal.

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### Drug Interactions

None known.

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### Special Considerations

1. No dose adjustments are required for patients with either hepatic or renal dysfunction.
2. Should not be administered to premenopausal women.
3. Should not be administered with estrogen-containing agents as they may interfere with antitumor activity.
4. Caution patients about the risk of hot flashes.
5. No need for glucocorticoid and/or mineralocorticoid replacement.
6. Pregnancy category D.

---

### Toxicity 1

Hot flashes.

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### Toxicity 2

Mild nausea.

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### Toxicity 3

Fatigue.

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### Toxicity 4

Headache.

# F

## Filgrastim

### Trade Names

Neupogen, G-CSF

### Classification

Colony-stimulating growth factor, cytokine

### Category

Biologic response modifier agent

### Drug Manufacturer

Amgen

### Mechanism of Action

- Pleiotropic cytokine that binds to specific surface receptors of hematopoietic progenitor cells.
- Stimulates the proliferation, differentiation, and activation of granulocyte progenitor cells and the activity of mature granulocytes.
- Enhances neutrophil chemotaxis and phagocytosis.
- Does not possess antitumor activity.

### Absorption

Filgrastim is rapidly and completely absorbed into the circulation after a SC dose, with peak plasma concentration achieved in 2–8 hours after administration.

### Distribution

Distributes into blood and bone marrow. Binding to plasma proteins is not known.

### Metabolism

Metabolized in both the liver and the kidney. However, drug clearance is unaffected by hepatic and/or renal dysfunction. The terminal half-life is on the order of 3.5 hours.

### Indications

1. Adjunct to myelosuppressive chemotherapy—Prophylactic use in patients receiving chemotherapy with either previous history of drug-related neutropenia and/or fever or in patients receiving drugs associated with a significant incidence of severe neutropenia and fever.
2. High-dose chemotherapy in bone marrow or peripheral stem cell transplant setting—Used to reduce the duration of neutropenia.

3. Mobilization of peripheral blood progenitor cells for collection by leukapheresis.
4. Chronic neutropenia such as congenital neutropenia, cyclic neutropenia, or idiopathic neutropenia.
5. Adjunct to induction or consolidation therapy for acute myelogenous leukemia.

---

### Dosage Range

1. Prevention of chemotherapy-induced neutropenia: 5  $\mu\text{g}/\text{kg}/\text{day}$  SC or IV, administered at least 24 hours after the completion of chemotherapy.
2. High-dose chemotherapy and stem cell transplant: 10  $\mu\text{g}/\text{kg}/\text{day}$  IV infusion of 4 or 24 hours, administered 24 hours after infusion of stem cells. The dose can be reduced to 5  $\mu\text{g}/\text{kg}$  when neutrophil count reaches  $>1,000/\text{mm}^3$  and discontinued when absolute neutrophil count (ANC) remains  $>1,000/\text{mm}^3$  for 3 consecutive days.
3. Stem cell mobilization: 10–20  $\mu\text{g}/\text{kg}/\text{day}$  given at least 4 days before the first apheresis and continued until the last apheresis.

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### Drug Interactions

Steroids, lithium—Caution should be exercised when using these drugs concurrently with filgrastim as they may potentiate the release of neutrophils during filgrastim therapy.

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### Special Considerations

1. Contraindicated in patients with known hypersensitivity to *E. coli*-derived products.
2. Concurrent administration with chemotherapy or radiation therapy is contraindicated as an increased incidence of serious adverse events has been observed. Filgrastim must be given at least 24 hours after the last dose of chemotherapy and 12 hours after radiation therapy as the stimulatory effects of filgrastim on the hematopoietic precursors render them more susceptible to chemotherapy.
3. Instruct patients to rotate the SC injection sites.
4. Blood counts should be monitored at least twice a week during filgrastim therapy. The dose should be adjusted to prevent both persistent neutropenia and excessive leukocytosis. Therapy should be terminated once WBC  $>10,000/\text{mm}^3$  or when ANC  $>1,000/\text{mm}^3$  for 3 consecutive days.
5. Filgrastim is incompatible with saline-containing solutions.
6. Use with caution in patients on steroids or lithium as these drugs may potentiate the release of neutrophils.

7. Premedication with acetaminophen helps to relieve the bone pain that arises due to bone marrow expansion in response to treatment.
8. Pregnancy category C.

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**Toxicity 1**

Transient bone pain occurs in up to 25% of patients. Usually mild to moderate and well-controlled with non-narcotic medications.

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**Toxicity 2**

Hypersensitivity reaction is uncommon.

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**Toxicity 3**

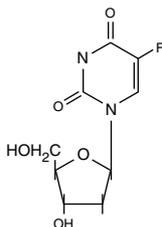
Neutrophilia with WBC counts  $>40,000/\text{mm}^3$  is common with ongoing therapy after normal counts are achieved.

---

**Toxicity 4**

Transient elevations in serum lactate dehydrogenase and alkaline phosphatase.

# Floxuridine



## Trade Names

5-Fluoro-2'-deoxyuridine, FUDR

## Classification

Antimetabolite

## Category

Chemotherapy drug

## Drug Manufacturer

Roche

## Mechanism of Action

- Fluoropyrimidine deoxynucleoside analog.
- Cell cycle-specific with activity in the S-phase.
- Requires activation to cytotoxic metabolite forms. Metabolized to 5-FU metabolite FdUMP, which inhibits thymidylate synthase. This results in inhibition of DNA synthesis, function, and repair.
- Incorporation of 5-FU metabolite FUTP into RNA resulting in alterations in RNA processing and/or translation.
- Incorporation of 5-FU metabolite FdUTP into DNA resulting in inhibition of DNA synthesis and function.
- Inhibition of TS leads to accumulation of dUMP, which becomes misincorporated into DNA in the form of dUTP, resulting in inhibition of DNA synthesis and function.

## Mechanism of Resistance

- Increased expression of thymidylate synthase.
- Decreased levels of reduced folate substrate 5, 10-methylenetetrahydrofolate for thymidylate synthase reaction.
- Decreased incorporation of 5-FU into RNA.

# F

- Decreased incorporation of 5-FU into DNA.
- Increased activity of DNA repair enzymes, uracil glycosylase and dUTPase.
- Increased salvage of physiologic nucleosides including thymidine.
- Increased expression of dihydropyrimidine dehydrogenase.
- Decreased expression of mismatch repair enzymes (hMLH1, hMSH2).
- Alterations in thymidylate synthase with decreased binding affinity of enzyme for FdUMP.

---

## Absorption

Poorly absorbed by the GI tract.

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## Distribution

After IV administration, floxuridine is rapidly extracted by the liver via first-pass metabolism. After hepatic intra-arterial administration, greater than 90% of drug is extracted by hepatocytes. Binding to plasma proteins has not been well characterized.

---

## Metabolism

Undergoes extensive enzymatic metabolism to 5-FU and 5-FU metabolites. Catabolism accounts for >85% of drug metabolism. Dihydropyrimidine dehydrogenase is the main enzyme responsible for 5-FU catabolism, and it is present in liver and extrahepatic tissues, including GI mucosa, WBCs, and kidney. About 30% of an administered dose of drug is cleared in urine mainly as inactive metabolites. The terminal elimination half-life is 20 hours.

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## Indications

1. Metastatic colorectal cancer—Intrahepatic arterial treatment of colorectal cancer metastatic to the liver.
2. Metastatic GI adenocarcinoma—Patients with metastatic disease confined to the liver.

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## Dosage Range

Recommended dose is 0.1–0.6 mg/kg/day IA for 7–14 days via hepatic artery.

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## Drug Interaction 1

Leucovorin—Leucovorin enhances the toxicity and antitumor activity of floxuridine when given first in sequence. Stabilizes the TS-FdUMP-reduced folate ternary complex resulting in maximal inhibition of TS.

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## Drug Interaction 2

Thymidine—Rescues against the host toxic effects of floxuridine.

---

## Special Considerations

1. Contraindicated in patients with poor nutritional status, depressed bone marrow function, or potentially serious infection.
2. No dose adjustments are necessary in patients with mild to moderate liver dysfunction or abnormal renal function. However, patients should be closely monitored as they may be at increased risk of toxicity.
3. Patients should be placed on an H<sub>2</sub> blocker, such as ranitidine 150 mg PO bid, to prevent the onset of peptic ulcer disease while on therapy. Onset of ulcer-like pain is an indication to stop therapy as hemorrhage and/or perforation may occur.
4. Patients who experience unexpected, severe grade 3 or 4 host toxicities with initiation of therapy may have an underlying deficiency in dihydropyrimidine dehydrogenase. Therapy must be discontinued immediately. Further testing to identify the presence of this pharmacogenetic syndrome should be considered.
5. Pregnancy category D. Breast-feeding should be avoided.

---

## Toxicity 1

Hepatotoxicity is dose-limiting. Presents as abdominal pain, elevated alkaline phosphatase, liver transaminases, and bilirubin. Sclerosing cholangitis is a rare event. Other GI toxicities include duodenitis, duodenal ulcer, and gastritis.

---

## Toxicity 2

Nausea and vomiting are mild. Mucositis and diarrhea also observed.

---

## Toxicity 3

Hand-foot syndrome (palmar-plantar erythrodysesthesia). Characterized by tingling, numbness, pain, erythema, dryness, rash, swelling, increased pigmentation, and/or pruritus of the hands and feet.

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## Toxicity 4

Myelosuppression. Nadir occurs at 7–10 days with full recovery by 14–17 days.

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## Toxicity 5

Neurologic toxicity manifested by somnolence, confusion, seizures, cerebellar ataxia, and rarely encephalopathy.

F

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**Toxicity 6**

Cardiac symptoms of chest pain, EKG changes, and serum enzyme elevation. Rare event but increased risk in patients with prior history of ischemic heart disease.

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**Toxicity 7**

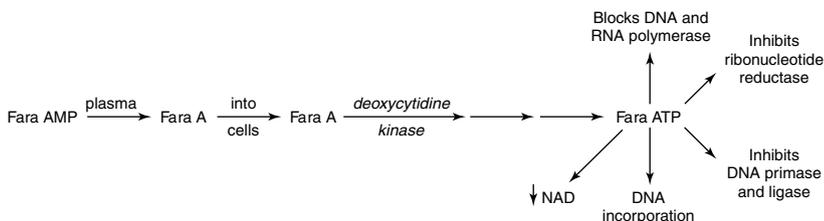
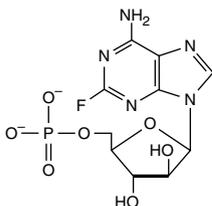
Blepharitis, tear-duct stenosis, acute and chronic conjunctivitis.

---

**Toxicity 8**

Catheter-related complications include leakage, catheter occlusion, perforation, dislodgement, infection, bleeding at catheter site, and thrombosis and/or embolism of hepatic artery.

# Fludarabine



## Trade Names

2-Fluoro-ara-AMP, Fludara

## Classification

Antimetabolite

## Category

Chemotherapy drug

## Drug Manufacturer

Bayer

## Mechanism of Action

- 5-Monophosphate analog of arabinofuranosyladenosine (ara-A) with high specificity for lymphoid cells. Presence of the 2-fluoro group on adenine ring renders fludarabine resistant to breakdown by adenosine deaminase.
- Considered a prodrug. Following administration, it is rapidly dephosphorylated to 2-fluoro-ara-adenosine (F-ara-A). F-ara-A enters cells and is then rephosphorylated first to its monophosphate form and eventually to the active 5-triphosphate metabolite (F-ara-ATP).
- Antitumor activity against both dividing and resting cells.

# F

- Triphosphate metabolite incorporates into DNA resulting in inhibition of DNA chain extension.
- Inhibition of ribonucleotide reductase by the triphosphate metabolite.
- Inhibition of DNA polymerase- $\alpha$  by the triphosphate metabolite resulting in inhibition of DNA synthesis.
- Induction of apoptosis (programmed cell death).

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## Mechanism of Resistance

- Decreased expression of the activating enzyme, deoxycytidine kinase.
- Decreased nucleoside transport of drug.

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## Absorption

Fludarabine is orally bioavailable. However, an oral formulation is not available in the United States.

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## Distribution

Widely distributed throughout the body. Concentrates in high levels in liver, kidney, and spleen. Binding to plasma proteins has not been well characterized.

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## Metabolism

Rapidly converted to 2-fluoro-ara-A, which enters cells via the nucleoside transport system and is rephosphorylated by deoxycytidine kinase to fludarabine monophosphate. This metabolite undergoes two subsequent phosphorylation steps to yield fludarabine triphosphate, the active species. Major route of elimination is via the kidneys, and approximately 25% of 2-fluoro-ara-A is excreted unchanged in urine. The terminal half-life is on the order of 10–20 hours.

---

## Indications

1. Chronic lymphocytic leukemia (CLL).
2. Non-Hodgkin's lymphoma (low-grade).
3. Cutaneous T-cell lymphoma.

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## Dosage Range

Usual dose is 25 mg/m<sup>2</sup> IV on days 1–5 every 4 weeks.

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## Drug Interaction 1

Cytarabine—Fludarabine may enhance the antitumor activity of cytarabine by inducing the expression of deoxycytidine kinase.

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### Drug Interaction 2

Cyclophosphamide, cisplatin, mitoxantrone—Fludarabine may enhance the antitumor activity of cyclophosphamide, cisplatin, and mitoxantrone by inhibiting nucleotide excision repair mechanisms.

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### Drug Interaction 3

Pentostatin—Increased incidence of fatal pulmonary toxicity when fludarabine is used in combination with pentostatin. Use of this combination is absolutely contraindicated.

---

### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose should be reduced in proportion to the creatinine clearance.
2. Use with caution in elderly patients and in those with bone marrow impairment as they are at increased risk of toxicity.
3. Monitor for signs of infection. Patients are at increased risk for opportunistic infections, including herpes, fungus, and *Pneumocystis carinii*. Patients should be empirically placed on Bactrim prophylaxis, 1 DS tablet PO bid three times/week.
4. Monitor for signs of tumor lysis syndrome, especially in patients with a high tumor cell burden. May occur as early as within the first week of treatment.
5. Allopurinol may be given prior to initiation of fludarabine therapy to prevent hyperuricemia.
6. Use irradiated blood products in patients requiring transfusions as transfusion-associated graft-versus-disease can occur rarely after transfusion of non-irradiated products in patients treated with fludarabine.
7. Pregnancy category D. Breast-feeding is not recommended.

---

### Toxicity 1

Myelosuppression. Dose-limiting toxicity. Leukocyte nadir occurs in 10–13 days, with recovery by day 14–21. Autoimmune hemolytic anemia and drug-induced aplastic anemia also occur.

---

### Toxicity 2

Immunosuppression. Decrease in CD4+ and CD8+ T cells occurs in most patients. Increased risk of opportunistic infections, including fungus, herpes, and *Pneumocystis carinii*. Prophylaxis with Bactrim, as outlined above, is required. Recovery of CD4+ count is slow and may take over year to return to normal.

---

**Toxicity 3**

Nausea and vomiting are usually mild.

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**Toxicity 4**

Fever occurs in 20%–30% of patients. Most likely due to release of pyrogens and/or cytokines from tumor cells. Associated with fatigue, malaise, myalgias, arthralgias, and chills.

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**Toxicity 5**

Hypersensitivity reaction with maculopapular skin rash, erythema, and pruritus.

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**Toxicity 6**

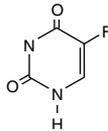
Tumor lysis syndrome. Rarely seen (in less than 1%–2% of patients), and most often in the setting of high tumor-cell burden. However, it can be fatal upon presentation.

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**Toxicity 7**

Transient elevation in serum transaminases. Clinically asymptomatic.

# 5-Fluorouracil



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## Trade Names

5-FU, Efudex

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## Classification

Antimetabolite

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## Category

Chemotherapy drug

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## Drug Manufacturer

Roche

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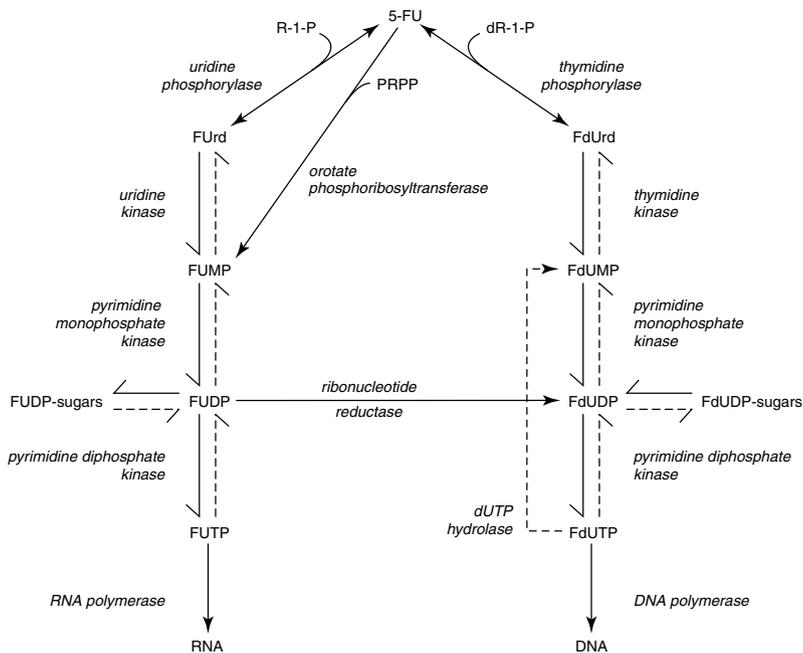
## Mechanism of Action

- Fluoropyrimidine analog.
- Cell cycle-specific with activity in the S-phase.
- Requires activation to cytotoxic metabolite forms. Complex process as outlined in Figure 1.
- Inhibition of the target enzyme thymidylate synthase by the 5-FU metabolite, FdUMP (Figure 2).
- Incorporation of the 5-FU metabolite FUTP into RNA resulting in alterations in RNA processing and/or translation.
- Incorporation of the 5-FU metabolite FdUTP into DNA resulting in inhibition of DNA synthesis and function.
- Inhibition of TS leads to accumulation of dUMP, which then gets misincorporated into DNA in the form of dUTP resulting in inhibition of DNA synthesis and function.

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## Mechanism of Resistance

- Increased expression of thymidylate synthase.
- Decreased levels of reduced folate substrate 5, 10-methylenetetrahydrofolate for thymidylate synthase reaction.

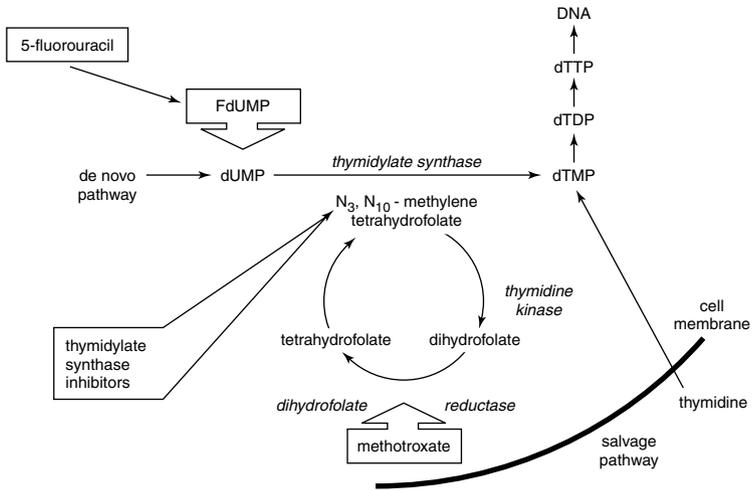


**FIGURE 1** Metabolic activation of 5-FU.

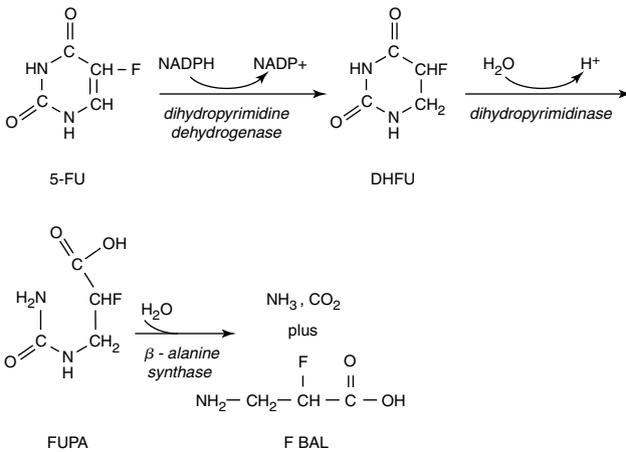
- Decreased incorporation of 5-FU into RNA.
- Decreased incorporation of 5-FU into DNA.
- Increased activity of DNA repair enzymes, uracil glycosylase and dUTPase.
- Increased salvage of physiologic nucleosides including thymidine.
- Increased expression of dihydropyrimidine dehydrogenase.
- Decreased expression of mismatch repair enzymes (hMLH1, hMSH2).
- Alterations in thymidylate synthase with decreased binding affinity of enzyme for FđUMP.

### Absorption

Oral absorption is variable and erratic with a bioavailability that ranges from 40% to 70%.



**FIGURE 2** Inhibition of thymidylate synthase by the 5-FU metabolite FdUMP.



**FIGURE 3** Catabolic breakdown of 5-FU.

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### Distribution

After IV administration, 5-FU is widely distributed to tissues with highest concentration in GI mucosa, bone marrow, and liver. Penetrates into third-space fluid collections such as ascites and pleural effusions. Crosses the blood-brain barrier and distributes into CSF and brain tissue. Binding to plasma proteins has not been well characterized.

---

### Metabolism

Undergoes extensive enzymatic metabolism intracellularly to cytotoxic metabolites. Catabolism accounts for >85% of drug metabolism (see Figure 3). Dihydropyrimidine dehydrogenase is the main enzyme responsible for 5-FU catabolism, and it is highly expressed in liver and extrahepatic tissues such as GI mucosa, WBCs, and kidney. Greater than 90% of an administered dose of drug is cleared in urine and lungs. The terminal elimination half-life is short, ranging from 10 to 20 min.

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### Indications

1. Colorectal cancer—adjuvant setting and advanced disease.
2. Breast cancer—adjuvant setting and advanced disease.
3. GI malignancies, including anal, esophageal, gastric, and pancreatic cancer.
4. Head and neck cancer.
5. Topical use in basal cell cancer of skin and actinic keratoses.
6. Hepatoma.
7. Ovarian cancer.

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### Dosage Range

1. Bolus monthly schedule: 425–450 mg/m<sup>2</sup> IV on days 1–5 every 28 days.
2. Bolus weekly schedule: 500–600 mg/m<sup>2</sup> IV every week for 6 weeks every 8 weeks.
3. 24-hour infusion: 2,400–2,600 mg/m<sup>2</sup> IV every week.
4. 96-hour infusion: 800–1,000 mg/m<sup>2</sup>/day IV.
5. 120-hour infusion: 1,000 mg/m<sup>2</sup>/day IV on days 1–5 every 21–28 days.
6. Protracted continuous infusion: 200–400 mg/m<sup>2</sup>/day IV.

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### Drug Interaction 1

Leucovorin—Leucovorin enhances the toxicity and antitumor activity of 5-FU when given in sequence first. Stabilizes the TS-FdUMP-reduced folate ternary complex resulting in maximal inhibition of TS.

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### Drug Interaction 2

Methotrexate, trimetrexate—Antifolate analogs increase the formation of 5-FU nucleotide metabolites when given 24 hours before 5-FU.

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### Drug Interaction 3

Thymidine—Rescues against the TS- and DNA-mediated host toxic effects of 5-FU.

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### Special Considerations

1. No dose adjustments are necessary in patients with mild to moderate liver or renal dysfunction. However, patients should be closely monitored as they may be at increased risk for host toxicity.
2. Contraindicated in patients with bone marrow depression, poor nutritional status, infection, active ischemic heart disease, or history of myocardial infarction within previous 6 months.
3. Patients should be monitored closely for mucositis and/or diarrhea as there is increased potential for dehydration, fluid imbalance, and infection. Elderly patients are at especially high risk for GI toxicity.
4. Patients who experience unexpected, severe grade 3 or 4 myelosuppression, GI and/or neurologic toxicities with initiation of therapy may have an underlying deficiency in dihydropyrimidine dehydrogenase. Therapy must be discontinued immediately. Further testing to identify the presence of this pharmacogenetic syndrome should be considered.
5. Vitamin B6 (pyridoxine 50 mg PO bid) may be used to prevent and/or reduce the incidence and severity of hand-foot syndrome.
6. Use of ice chips in mouth 10–15 minutes pre- and 10–15 minutes post-IV bolus injections of 5-FU may reduce the incidence and severity of mucositis.
7. Pregnancy category D. Breast-feeding should be avoided.

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### Toxicity 1

Myelosuppression. Dose-limiting for the qd  $\times$  5 or weekly schedules, less frequently observed with infusional therapy. Neutropenia and thrombocytopenia more common than anemia.

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### Toxicity 2

Mucositis and/or diarrhea. May be severe and dose-limiting for infusional schedules. Nausea and vomiting are mild and rare.

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### Toxicity 3

Hand-foot syndrome (palmar-plantar erythrodysesthesia). Characterized by tingling, numbness, pain, erythema, dryness, rash, swelling, increased

F

pigmentation, nail changes, pruritus of the hands and feet, and/or desquamation. Most often observed with infusional therapy. Can be dose-limiting.

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**Toxicity 4**

Neurologic toxicity manifested by somnolence, confusion, seizures, cerebellar ataxia, and rarely encephalopathy.

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**Toxicity 5**

Cardiac symptoms of chest pain, EKG changes, and serum enzyme elevation. Rare event but increased risk in patients with prior history of ischemic heart disease.

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**Toxicity 6**

Blepharitis, tear-duct stenosis, acute and chronic conjunctivitis.

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**Toxicity 7**

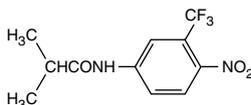
Dry skin, photosensitivity, and pigmentation of the infused vein are common.

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**Toxicity 8**

Metallic taste in mouth during IV bolus injection.

# Flutamide



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## Trade Names

Eulexin

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## Classification

Anti-androgen

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## Category

Hormonal drug

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## Drug Manufacturer

Schering

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## Mechanism of Action

Nonsteroidal, anti-androgen agent binds to androgen receptor and inhibits androgen uptake as well as inhibits androgen binding in nucleus in androgen-sensitive prostate cancer cells.

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## Mechanism of Resistance

- Decreased expression of androgen receptor.
- Mutation in androgen receptor leading to decreased binding affinity to flutamide.

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## Absorption

Rapidly and completely absorbed by the GI tract. Peak plasma levels observed 1–2 hours after oral administration.

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## Distribution

Distribution is not well characterized. Flutamide and its metabolites are extensively bound to plasma proteins (92%–96%).

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## Metabolism

Extensive metabolism by the liver cytochrome P<sub>450</sub> system to both active and inactive metabolites. The main metabolite,  $\alpha$ -hydroxyflutamide, is biologically active. Flutamide and its metabolites are cleared primarily in urine, and only 4% of drug is eliminated in feces. The elimination half-life of flutamide is about 8 hours, whereas the half-life of the hydroxyflutamide metabolite is 8–10 hours.

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### Indications

1. Locally confined stage B2–C prostate cancer.
2. Stage D2 metastatic prostate cancer.

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### Dosage Range

Recommended dose is 250 mg PO tid at 8-hour intervals.

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### Drug Interactions

Warfarin—Flutamide can inhibit metabolism of warfarin by the liver P<sub>450</sub> system leading to increased anticoagulant effect. Coagulation parameters (PT and INR) must be followed closely when warfarin and flutamide are taken concurrently, and dose adjustments may be needed.

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### Special Considerations

1. Monitor LFTs at baseline and during therapy. In the presence of elevated serum transaminases to 2–3 times the upper limit of normal, therapy should be terminated.
2. Caution patients about the risk of diarrhea and, if severe, flutamide may need to be stopped.
3. Caution patients about the potential for hot flashes. Consider the use of clonidine 0.1–0.2 mg PO daily, Megace 20 mg PO bid, or soy tablets, one tablet PO tid for prevention and/or treatment.
4. Instruct patients on the potential risk of altered sexual function and impotence.
5. Pregnancy category D.

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### Toxicity 1

Hot flashes occur in 60% of patients, decreased libido (35%), impotence (30%), gynecomastia (10%), nipple pain, and galactorrhea.

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### Toxicity 2

Nausea, vomiting, and diarrhea.

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### Toxicity 3

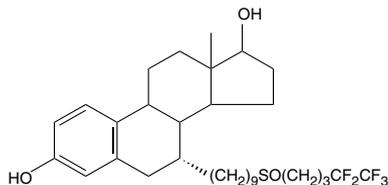
Transient elevations in serum transaminases are rare but may necessitate discontinuation of therapy.

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### Toxicity 4

Amber-green discoloration of urine secondary to flutamide and/or its metabolites.

# Fulvestrant



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## Trade Names

Faslodex

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## Classification

Estrogen receptor antagonist

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## Category

Hormonal agent

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## Drug Manufacturer

AstraZeneca

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## Mechanism of Action

- Potent and selective antagonist of the estrogen receptor (ER) with no known agonist effects. Affinity to the ER is comparable to that of estradiol.
- Downregulates the expression of the ER, presumably through enhanced degradation.

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## Mechanism of Resistance

- None characterized.

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## Absorption

Not absorbed orally. After IM injection, peak plasma levels are achieved in approximately 7 days and are maintained for at least 1 month.

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## Distribution

Rapidly and widely distributed throughout the body. Approximately 99% of drug is bound to plasma proteins, and VLDL, LDL, and HDL are the main binding proteins.

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## Metabolism

Extensively metabolized in the liver by microsomal P450 3A4 enzymes to both active and inactive forms. Steady-state levels of drug are achieved after

7 days of a once-monthly administration and are maintained for at least up to one month. The major route of elimination is fecal (approximately 90%), with renal excretion accounting for only 1% of drug clearance.

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### Indications

Metastatic breast cancer—Treatment of postmenopausal women with ER+, advanced disease with disease progression following antiestrogen therapy.

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### Dosage Range

Recommended dose is 250 mg IM once every month.

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### Drug Interactions

None known.

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### Special Considerations

1. No dose adjustments are required for patients with either renal or mild hepatic dysfunction. The safety and efficacy have not been carefully studied in patients with moderate to severe hepatic impairment.
2. Use with caution in patients with bleeding diatheses, thrombocytopenia, and/or receiving anticoagulation therapy.
3. Pregnancy category D. Women of child-bearing potential should be strongly advised to avoid becoming pregnant. Breast-feeding should be avoided as it is not known whether fulvestrant is excreted in human milk.

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### Toxicity 1

Asthenia occurs in up to 25% of patients.

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### Toxicity 2

Mild nausea and vomiting. Constipation and/or diarrhea can also occur.

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### Toxicity 3

Hot flashes seen in 20% of patients.

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### Toxicity 4

Mild headache.

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### Toxicity 5

Injection site reactions with mild pain and inflammation that are usually transient in nature.

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**Toxicity 6**

Back pain and arthralgias.

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**Toxicity 7**

Flulike syndrome in the form of fever, malaise, and myalgias. Occurs in 10% of patients.

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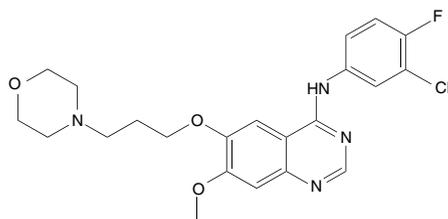
**Toxicity 8**

Dry, scaling skin rash.

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# G

## Gefitinib



### Trade Names

Iressa, ZD1839

### Classification

Signal transduction inhibitor

### Category

Chemotherapy drug

### Drug Manufacturer

AstraZeneca

### Mechanism of Action

- Potent and selective small molecule inhibitor of the EGFR tyrosine kinase, resulting in inhibition of EGFR autophosphorylation and inhibition of EGFR signaling.
- Inhibition of the EGFR tyrosine kinase results in inhibition of critical mitogenic and anti-apoptotic signals involved in proliferation, growth, metastasis, angiogenesis, and response to chemotherapy and/or radiation therapy.

### Mechanism of Resistance

- Mutation in the EGFR tyrosine kinase leading to decreased binding affinity to gefitinib.
- Presence of K-ras mutations.
- Activation/induction of alternative cellular signaling pathways, such as IGF-1R.

### Absorption

Oral absorption is relatively slow, and the oral bioavailability is approximately 60%. Food does not affect drug absorption.

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### Distribution

Extensive binding (90%) to plasma proteins, including albumin and  $\alpha_1$ -acid glycoprotein, and extensive tissue distribution. Steady-state drug concentrations are reached in 7–10 days.

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### Metabolism

Metabolism in the liver primarily by the CYP3A4 microsomal enzyme. Other cytochrome P450 enzymes play a minor role in its metabolism. The main metabolite is the O-desmethyl piperazine derivative, and this metabolite is significantly less potent than the parent drug. Elimination is mainly hepatic with excretion in the feces, and renal elimination of the parent drug and its metabolites accounts for less than 4% of an administered dose. The terminal half-life of the parent drug is 48 hours.

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### Indications

Treatment of non–small cell lung cancer that is refractory to platinum-based chemotherapy and/or second-line docetaxel therapy. FDA-approved for patients who are currently receiving and benefiting or who have previously received and benefited from gefitinib treatment.

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### Dosage Range

Recommended dose is 250 mg/day PO.

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### Drug Interaction 1

Dilantin and other drugs that stimulate the liver microsomal CYP3A4 enzyme, including carbamazepine, rifampicin, phenobarbital, and St. John's Wort—These drugs increase the rate of metabolism of gefitinib, resulting in its inactivation.

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### Drug Interaction 2

Drugs that inhibit the liver microsomal CYP3A4 enzyme, including ketoconazole, itraconazole, erythromycin, and clarithromycin—These drugs decrease the rate of metabolism of gefitinib, resulting in increased drug levels and potentially increased toxicity.

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### Drug Interaction 3

Warfarin—Patients receiving coumarin-derived anticoagulants should be closely monitored for alterations in their clotting parameters (PT and INR) and/or bleeding as gefitinib inhibits the metabolism of warfarin by the liver P450 system. Dose of warfarin may require careful adjustment in the presence of gefitinib therapy.

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### Special Considerations

1. Clinical responses may be observed within the first week of initiation of therapy.

# G

2. Patients with bronchoalveolar non–small cell lung cancer may be more sensitive to gefitinib therapy than other histologic subtypes. Females and nonsmokers also show increased sensitivity to gefitinib therapy.
3. Closely monitor patients with central lesions as they may be at increased risk for complications of hemoptysis.
4. Dose of gefitinib may need to be increased when used in patients with seizure disorders who are receiving phenytoin, as the metabolism of gefitinib by the liver P450 system is enhanced in the presence of phenytoin.
5. Coagulation parameters (PT/INR) should be closely monitored when patients are receiving both gefitinib and Coumadin, as gefitinib inhibits the metabolism of Coumadin by the liver P450 system.
6. In patients who develop a skin rash, topical antibiotics such as Cleocin gel or either oral Cleocin and/or oral minocycline may help.
7. Pregnancy category D.

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#### Toxicity 1

Elevations in blood pressure, especially in those with underlying hypertension.

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#### Toxicity 2

Pruritus, dry skin with mainly a pustular, acneiform skin rash.

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#### Toxicity 3

Mild to moderate elevations in serum transaminases. Usually transient and clinically asymptomatic.

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#### Toxicity 4

Asthenia and anorexia.

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#### Toxicity 5

Mild nausea/vomiting and mucositis.

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#### Toxicity 6

Conjunctivitis, blepharitis, and corneal erosions. Abnormal eyelash growth may occur in some patients.

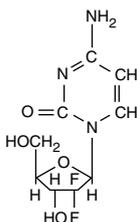
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#### Toxicity 7

Rare episodes of hemoptysis and GI hemorrhage.

# Gemcitabine

G



## Trade Names

Gemzar

## Classification

Antimetabolite

## Category

Chemotherapy drug

## Drug Manufacturer

Eli Lilly

## Mechanism of Action

- Fluorine-substituted deoxycytidine analog.
- Cell cycle-specific with activity in the S-phase.
- Requires intracellular activation by deoxycytidine kinase to the monophosphate form with eventual metabolism to the cytotoxic triphosphate nucleotide metabolite (dFdCTP). Antitumor activity of gemcitabine is determined by a balance between intracellular activation and degradation and the formation of cytotoxic triphosphate metabolites.
- Incorporation of dFdCTP triphosphate metabolite into DNA resulting in chain termination and inhibition of DNA synthesis and function.
- Triphosphate metabolite inhibits several DNA polymerases  $\alpha$ ,  $\beta$ , and  $\delta$ , which, in turn, interferes with DNA chain elongation, DNA synthesis, and DNA repair.
- Difluorodeoxycytidine diphosphate (dFdCDP) metabolite inhibits the enzyme ribonucleotide reductase, resulting in decreased levels of essential deoxyribonucleotides for DNA synthesis and function.
- Incorporation into RNA resulting in alterations in RNA processing and mRNA translation.

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### Mechanism of Resistance

- Decreased activation of drug through decreased expression of the anabolic enzyme deoxycytidine kinase.
- Increased breakdown of drug by the catabolic enzymes cytidine deaminase and dCMP deaminase.
- Decreased nucleoside transport of drug into cells.
- Increased concentration of the competing physiologic nucleotide dCTP, through increased expression of CTP synthetase.

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### Absorption

Poor oral bioavailability as a result of extensive deamination within the GI tract. Administered by the IV route.

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### Distribution

With infusions <70 minutes, drug is not extensively distributed. In contrast, with longer infusions, drug is slowly and widely distributed into body tissues. Does not cross the blood-brain barrier. Binding to plasma proteins is negligible.

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### Metabolism

Undergoes extensive metabolism by deamination to difluorouridine (dFdU) with approximately >90% of drug being recovered in urine as the dFdU metabolite. Deamination occurs in liver, plasma, and peripheral tissues. The principal enzyme involved in drug catabolism is cytidine deaminase. The terminal elimination half-life is dependent on the infusion time. With short infusions <70 minutes, the half-life ranges from 30 to 90 minutes, while for infusions >70 minutes, the half-life is 4–10 hours. Plasma clearance is also dependent on gender and age. Clearance is 30% lower in women and in elderly patients.

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### Indications

1. Pancreatic cancer—FDA-approved as monotherapy or in combination with erlotinib for first-line treatment of locally advanced or metastatic disease.
2. Non-small cell lung cancer—FDA-approved in combination with cisplatin for first-line treatment of inoperable, locally advanced or metastatic disease.
3. Breast cancer—FDA-approved in combination with paclitaxel for first-line treatment of metastatic breast cancer after failure of prior anthracycline-containing adjuvant chemotherapy.
4. Ovarian cancer—FDA-approved in combination with carboplatin for patients with advanced ovarian cancer that has relapsed at least 6 months after completion of platinum-based therapy.

5. Bladder cancer.
6. Soft tissue sarcoma.

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### Dosage Range

1. Pancreatic cancer: 1,000 mg/m<sup>2</sup> IV every week for 7 weeks with 1 week rest. Treatment then continues weekly for 3 weeks followed by 1 week off.
2. Bladder cancer: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15 every 28 days.
3. Non-small cell lung cancer: 1,200 mg/m<sup>2</sup> IV on days 1, 8, and 15 every 28 days.

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### Drug Interaction 1

Cisplatin—Gemcitabine enhances the cytotoxicity of cisplatin by increasing the formation of cytotoxic platinum-DNA adducts.

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### Drug Interaction 2

Radiation therapy—Gemcitabine is a potent radiosensitizer.

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### Special Considerations

1. Monitor complete blood counts on a regular basis during therapy. Dose reduction is recommended based on the degree of hematologic toxicity.
2. Use with caution in patients with abnormal liver and/or renal function. Dose modification should be considered in this setting as there is an increased risk for host toxicity.
3. Prolonged infusion time >60 minutes is associated with higher incidence of toxicity.
4. Use with caution in women and in elderly patients as gemcitabine clearance is decreased.
5. Instruct patients about the potential for changes in the color of urine or difficulty in urination.
6. Pregnancy category D.

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### Toxicity 1

Myelosuppression is dose-limiting. Leukopenia more common than thrombocytopenia. Nadir occurs by days 10–14, with recovery by day 21.

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### Toxicity 2

Nausea and vomiting. Usually mild to moderate, occur in 70% of patients. Diarrhea and/or mucositis observed in 15%–20% of patients.

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### Toxicity 3

Flulike syndrome manifested by fever, malaise, chills, headache, and myalgias. Seen in 20% of patients. Fever, in the absence of infection, develops

# G

in 40% of patients within the first 6–12 hours after treatment but generally is mild.

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## Toxicity 4

Transient hepatic dysfunction with elevation of serum transaminases and bilirubin.

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## Toxicity 5

Pulmonary toxicity in the form of mild dyspnea and drug-induced pneumonitis. ARDS has been reported rarely.

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## Toxicity 6

Infusion reaction presents as flushing, facial swelling, headache, dyspnea, and/or hypotension. Usually related to the rate of infusion and resolves with slowing or discontinuation of infusion.

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## Toxicity 7

Mild proteinuria and hematuria. In rare cases, renal microangiopathy syndromes, including hemolytic-uremic syndrome (HUS) and thrombotic thrombocytopenic purpura (TTP), have been reported.

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## Toxicity 8

Maculopapular skin rash generally involving the trunk and extremities and pruritus. Alopecia is rarely observed.



- CD33 antigen is not expressed on the surface of pluripotent hematopoietic stem cells or on non-myeloid tissues.
- The antibody conjugate is internalized upon binding to the CD33 antigen, and calicheamicin is then released via hydrolysis.

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### Mechanism of Resistance

Not well characterized to date.

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### Absorption

Gemtuzumab is given only by the IV route.

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### Distribution

Within 30 minutes after infusion of gemtuzumab, nearly all of the CD33 sites on peripheral blood leukemic blast cells are bound by the drug conjugate. The AUC increases by nearly 2-fold from the first dose to the second dose of the drug conjugate.

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### Metabolism

Metabolism of gemtuzumab has not been extensively characterized in humans. In vitro studies suggest that the liver microsomal system plays an important role in the formation of various metabolites. While animal studies suggest that gemtuzumab undergoes hepatobiliary elimination, the clearance mechanism(s) in humans remains to be defined. Elimination half-lives of total and unconjugated calicheamicin are 39 and 100 hours, respectively, after the first dose. The half-life of total calicheamicin increases significantly to 63 hours with the second dose.

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### Indications

Relapsed CD33+ AML—Indicated in patients in first relapse who are 60 years of age or older and who are not considered for cytotoxic chemotherapy.

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### Dosage Range

Recommended dose is 9 mg/m<sup>2</sup> IV administered over 2 hours. Usually administer two doses of drug with the second dose being given 14 days after the first dose.

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### Drug Interactions

None known.

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### Special Considerations

1. Contraindicated in patients with known type I hypersensitivity or anaphylactic reactions to gemtuzumab or to any of its components.
2. Gemtuzumab should **NOT** be given by IV push or bolus.

3. Patients should be premedicated with acetaminophen, 650–1,000 mg PO, and diphenhydramine, 50 mg PO, 30 minutes before drug infusion to reduce the incidence of infusion-related reactions.
4. Monitor closely for infusion-related events, which usually occur during the infusion or within 2 hours after infusion. However, grade 3/4 hypotension has been observed several hours after infusion; this is usually transient and reversible with IV fluid support. Pulse, blood pressure, and oral temperature should be measured every 15 to 30 minutes. Immediate institution of diphenhydramine (50 mg IV), acetaminophen (625 mg PO), hydrocortisone (200 mg IV), and/or vasopressors may be required. Resuscitation equipment should be readily available at bedside.
5. Reduction of WBC count to below 30,000 with either hydroxyurea or leukapheresis is highly recommended to reduce the risk of tumor lysis syndrome and pulmonary complications, including acute respiratory distress syndrome (ARDS) in patients treated with gemtuzumab.
6. Monitor CBC and platelet counts on a weekly basis during gemtuzumab therapy.
7. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Infusion-related symptoms, including fever, chills, nausea and vomiting, urticaria, skin rash, fatigue, headache, diarrhea, dyspnea, and/or hypotension. Usually occur during the infusion or within 2 hours after infusion. Transient hypotension can sometimes be observed up to 6 hours after infusion. Incidence decreases with second dose.

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#### Toxicity 2

Myelosuppression is most common dose-limiting toxicity with neutropenia and thrombocytopenia.

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#### Toxicity 3

Hepatotoxicity in the form of increased serum bilirubin and LFTs observed in up to 20% of patients. Usually transient and reversible. Rare cases of veno-occlusive disease (VOD), which can be fatal, most commonly seen in patients previously treated with hematopoietic stem cell transplantation.

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#### Toxicity 4

GI toxicity in the form of nausea, vomiting, and mucositis.

# G

## Goserelin

pyro Glu-His-Trp-Ser-Tyr-D-Ser (tert Butyl)-Leu-Arg-Pro-Azgly  
1 2 3 4 5 6 7 8 9 10

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### Trade Names

Zoladex

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### Classification

LHRH agonist

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### Category

Hormonal drug

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### Drug Manufacturer

AstraZeneca

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### Mechanism of Action

Administration leads to initial release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) followed by suppression of gonadotropin secretion as a result of desensitization of the pituitary to gonadotropin-releasing hormone. This results in decreased secretion of LH and FSH from the pituitary.

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### Absorption

Not orally absorbed because of extensive proteolysis in the GI tract. Bioavailability of subcutaneously administered drug is 75%–90%.

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### Distribution

Distribution is not well characterized. Slowly released over a 28-day period. Peak serum concentrations are achieved 10–15 days after drug administration. About 30% of goserelin is bound to plasma proteins.

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### Metabolism

Metabolism of goserelin occurs mainly via hydrolysis of the C-terminal amino acids. Goserelin is nearly completely eliminated in urine. The elimination half-life is normally 4–5 hours but is prolonged in patients with impaired renal function (12 hours).

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### Indications

Advanced prostate cancer.

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### Dosage Range

Administer 3.6 mg SC every 28 days or 10.8 mg SC every 90 days.

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### Drug Interactions

None known.

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### Special Considerations

1. Initiation of treatment with goserelin may induce a transient tumor flare. Goserelin should not be given in patients with impending ureteral obstruction and/or spinal cord compression or in those with painful bone metastases.
2. Serum testosterone levels decrease to castrate levels within 2–4 weeks after initiation of therapy.
3. Use with caution in patients with abnormal renal function.
4. Caution patients about the potential for hot flashes. Consider the use of soy tablets, one tablet PO tid for prevention and/or treatment.

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### Toxicity 1

Hot flashes occur in 50% of patients, decreased libido (10%), impotence (10%), and gynecomastia (10%).

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### Toxicity 2

Tumor flare. May occur in up to 20% of patients, usually within the first 2 weeks of starting therapy. May observe increased bone pain, urinary retention, or back pain with spinal cord compression. May be prevented by pretreating with an anti-androgen agent such as flutamide, bicalutamide, or nilutamide.

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### Toxicity 3

Local discomfort at the site of injection.

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### Toxicity 4

Elevated serum cholesterol levels.

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### Toxicity 5

Hypersensitivity reaction.

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### Toxicity 6

Nausea and vomiting. Rarely observed.

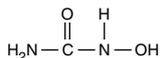
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### Toxicity 7

Myelosuppression. Rarely observed.

# H

## Hydroxyurea



### Trade Names

Hydrea

### Classification

Antimetabolite

### Category

Chemotherapy drug

### Drug Manufacturer

MGI Pharma

### Mechanism of Action

- Cell cycle-specific analog of urea with activity in the S-phase.
- Inhibits the enzyme ribonucleotide reductase, which converts ribonucleotides to deoxyribonucleotides, critical precursors for de novo DNA biosynthesis and DNA repair.

### Mechanism of Resistance

Increased expression of ribonucleotide reductase due to gene amplification, increased transcription, and post-transcriptional mechanisms.

### Absorption

Oral absorption is rapid and nearly complete with a bioavailability ranging between 80% and 100%. Peak plasma concentrations are achieved in 1–1.5 hours.

### Distribution

Widely distributed in all tissues. High concentrations are found in third-space collections, including pleural effusions and ascites. Crosses the blood-brain barrier and enters the CSF. Excreted in significant levels in human breast milk.

### Metabolism

Approximately 50% of drug is metabolized in the liver. About 50% of drug is excreted unchanged in urine. The carbon dioxide that results from drug metabolism is released through the lungs. Plasma half-life on the order of 3–4.5 hours.

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### Indications

1. Chronic myelogenous leukemia.
2. Essential thrombocytosis.
3. Polycythemia vera.
4. Acute myelogenous leukemia, blast crisis.
5. Head and neck cancer (in combination with radiation therapy).
6. Refractory ovarian cancer.

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### Dosage Range

1. Continuous therapy: 20–30 mg/kg PO daily.
2. Intermittent therapy: 80 mg/kg PO every third day.
3. Combination therapy with irradiation of head and neck cancer: 80 mg/kg PO every third day. In this setting, hydroxyurea is used as a radiation sensitizer and initiated at least 7 days before radiation therapy.

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### Drug Interaction 1

5-FU—Hydroxyurea may enhance the risk of 5-FU host toxicity.

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### Drug Interaction 2

Antiretroviral agents—Hydroxyurea may enhance the anti-HIV activity of azidothymidine (AZT), dideoxycytidine (ddC), and dideoxyinosine (ddI).

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### Special Considerations

1. Contraindicated in patients with bone marrow suppression presenting as WBC  $< 2,500/\text{mm}^3$  or platelet count  $< 100,000/\text{mm}^3$ .
2. Monitor CBC on a weekly basis during therapy. Treatment should be stopped if the WBC count falls to less than  $2,500/\text{mm}^3$  or the platelet count drops to less than  $100,000/\text{mm}^3$  and held until the counts rise above these values.
3. Use with caution in patients previously treated with chemotherapy and/or radiation therapy as there is an increased risk of myelosuppression.
4. Use with caution in patients with abnormal renal function. Doses should be reduced in the setting of renal dysfunction.
5. Pregnancy category D. Use with caution in women who are breast-feeding as the drug is excreted in human breast milk.

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### Toxicity 1

Myelosuppression with leukopenia is dose-limiting. Median onset 7–10 days with recovery of WBC counts 7–10 days after stopping the drug. Median onset of thrombocytopenia and anemia usually by day 10. Effect



on bone marrow may be more severe in patients previously treated with chemotherapy and/or radiation therapy.

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**Toxicity 2**

Nausea and vomiting. Generally mild. Incidence can be reduced by dividing the daily dose into two or three doses. Stomatitis also occurs.

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**Toxicity 3**

Maculopapular rash, facial and acral erythema, hyperpigmentation, dry skin with atrophy, and pruritus.

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**Toxicity 4**

Radiation recall skin reaction.

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**Toxicity 5**

Headache, drowsiness, and confusion.

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**Toxicity 6**

Transient elevations of serum transaminases and bilirubin.

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**Toxicity 7**

Teratogenic. Carcinogenic potential is not known.

# Ibritumomab

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## Trade Names

Zevalin, IDEC-Y2B8

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## Classification

Monoclonal antibody

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## Category

Biologic response modifier agent

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## Drug Manufacturer

IDEC Pharmaceuticals

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## Mechanism of Action

- Immunoconjugate consisting of a stable thiourea covalent bond between the monoclonal antibody ibritumomab and the linker-chelator tiuxetan. This linker-chelator provides a high-affinity conformationally restricted site for Indium-111 and/or Yttrium-90.
- The antibody moiety is ibritumomab, which targets the CD20 antigen, a 35 kDa cell surface non-glycosylated phosphoprotein expressed during early pre-B cell development until the plasma cell stage. Binding of antibodies to CD20 induces a transmembrane signal that blocks cell activation and cell cycle progression.
- CD20 is expressed on more than 90% of all B-cell, non-Hodgkin's lymphomas and leukemias. CD20 is not expressed on early pre-B cells, plasma cells, normal bone marrow stem cells, antigen-presenting dendritic reticulum cells, or other normal tissues.
- The beta emission from Yttrium-90 induces cellular damage by the formation of free radicals in the target and neighboring cells.

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## Absorption

Ibritumomab is given only by the IV route.

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## Distribution

Peak and trough levels of rituximab correlate inversely with the number of circulating CD20-positive B cells. When In-111-ibritumomab is administered without unlabeled ibritumomab, only 18% of known sites of disease are imaged. In contrast, when In-111-ibritumomab administration is preceded by unlabeled ibritumomab, up to 90% of known sites of disease can be imaged.

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## Metabolism

The mean effective half-life of Yttrium-90 in blood is 30 hours, and the mean area under the fraction of injected activity (FIA) vs. time curve in blood

is 39 hours. Over a period of 7 days, a median of 7.2% of the injected activity is excreted in urine.

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### Indications

Relapsed and/or refractory low-grade, follicular, or transformed B-cell non-Hodgkin's lymphoma, including patients refractory to rituximab therapy.

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### Dosage Range

The regimen consists of two low doses of rituximab, an imaging dose, two or three whole body scans, and a therapeutic dose, all of which are delivered on an outpatient basis over a period of 8 days. The recommended dose is 0.4 mCi/kg for patients with platelet counts greater than 150,000 and 0.3 mCi/kg for patients with platelet counts between 100,000 and 149,000. In either case, the maximum dose is 32 mCi.

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### Drug Interactions

None characterized to date.

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### Special Considerations

1. Contraindicated in patients with known type I hypersensitivity, anaphylactic reactions to murine proteins or to any component of the product, including rituximab, yttrium chloride, and indium chloride.
2. Should not be administered to patients with an altered biodistribution of In-111 ibritumomab.
3. The prescribed and administered dose of Yttrium-90 should not exceed the absolute maximum allowable dose of 32 mCi.
4. This therapy should be used only by physicians and health care professionals who are qualified and experienced in the safe use and handling of radioisotopes.
5. Patients should be premedicated with acetaminophen and diphenhydramine before each infusion of rituximab to reduce the incidence of infusion-related reactions.
6. Rituximab infusion should be started at an initial rate of 50 mg/hour. If no toxicity is observed during the first hour, the infusion rate can be escalated by increments of 50 mg/hour every 30 minutes to a maximum of 400 mg/hour. If the first treatment is well tolerated, the starting infusion rate for the second infusion can be administered at 100 mg/hour with 100 mg/hour increments at 30-minute intervals up to 400 mg/hour. Rituximab should NOT be given by IV push.
7. Monitor for infusion-related events resulting from rituximab infusion, which usually occur 30–120 minutes after the start of the first infusion. Infusion should be immediately stopped if signs or symptoms of an allergic reaction are observed. Immediate institution of

diphenhydramine, acetaminophen, corticosteroids, IV fluids, and/or vasopressors may be necessary. In most instances, the infusion can be restarted at a reduced rate (50%) once symptoms have completely resolved. Resuscitation equipment should be readily available at bedside.

8. Infusion-related deaths within 24 hours of rituximab infusions have been reported.
9. Ibritumomab therapy should not be given to patients with >25% involvement of the bone marrow by lymphoma and/or impaired bone marrow reserve.
10. Ibritumomab therapy should not be given to patients with platelet counts below 100,000.
11. Complete blood counts and platelet counts should be monitored weekly following ibritumomab therapy and should continue until levels recover.
12. The ibritumomab regimen should be given only as a single-course treatment.
13. The ibritumomab regimen may have direct toxic effects on the male and female reproductive organs, and effective contraception should be used during therapy and for up to 12 months following the completion of therapy.
14. Pregnancy category D. Breast-feeding should be avoided as it is not known whether ibritumomab is excreted in human milk.

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### Toxicity 1

Infusion-related symptoms, including fever, chills, urticaria, flushing, fatigue, headache, bronchospasm, rhinitis, dyspnea, angioedema, nausea, and/or hypotension. Severe symptoms include pulmonary infiltrates, acute respiratory distress syndrome, myocardial infarction, ventricular fibrillation, and/or cardiogenic shock. Usually occur within 30 minutes to 2 hours after the start of the first infusion. Usually resolve upon slowing or interrupting the infusion and with supportive care.

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### Toxicity 2

Myelosuppression is most common side effect. Thrombocytopenia observed more frequently than neutropenia. The median duration of cytopenias ranges from 22 to 35 days, and the median time to nadir is 7–9 weeks. In <5% of patients, severe cytopenias were extended beyond 12 weeks after therapy.

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### Toxicity 3

Mild asthenia occurs in up to 40% of patients.

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**Toxicity 4**

Infections develop in nearly 30% of patients during the first 3 months after therapy.

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**Toxicity 5**

Mild nausea and vomiting.

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**Toxicity 6**

Cough, rhinitis, dyspnea, and sinusitis are observed in up to 35% of patients.

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**Toxicity 7**

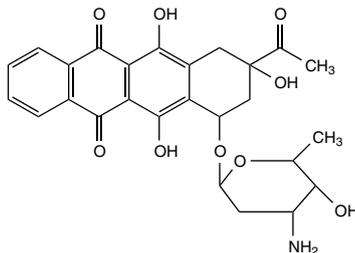
Secondary malignancies occur in about 2% of patients. Acute myelogenous leukemia and myelodysplastic syndrome have been reported at range of 8–34 months following therapy.

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**Toxicity 8**

Development of human anti-mouse (HAMA) and human anti-chimeric antibodies (HACA). Rare event in less than 1%–2% of patients.

# Idarubicin



## Trade Names

Idamycin, 4-Demethoxydaunorubicin

## Classification

Antitumor antibiotic

## Category

Chemotherapy drug

## Drug Manufacturer

Pfizer

## Mechanism of Action

- Semisynthetic anthracycline glycoside analog of daunorubicin.
- Intercalates into DNA, which results in inhibition of DNA synthesis and function.
- Inhibits topoisomerase II by forming a cleavable complex with topoisomerase II and DNA.
- In the presence of iron, drug forms oxygen free radicals, which cause single- and double-stranded DNA breaks.
- Specificity, in part, for the late S- and G<sub>2</sub>-phases of the cell cycle.

## Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with enhanced drug efflux. This results in decreased intracellular drug accumulation.
- Decreased expression of topoisomerase II.
- Mutation in topoisomerase II with decreased binding affinity to drug.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-associated enzymes.

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### Absorption

Administered only by the IV route.

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### Distribution

Rapid and extensive tissue distribution. Peak concentrations in nucleated blood and bone marrow cells are achieved within minutes of administration and are 100-fold greater than those in plasma. Drug and its major metabolite, idarubicinol, are extensively bound (>90%) to plasma proteins.

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### Metabolism

Significant metabolism in liver and in extrahepatic tissues. Metabolism by the liver microsomal system yields the active metabolite, idarubicinol, which may be responsible for the cardiotoxic effects. Idarubicin is eliminated mainly by biliary excretion into feces, with renal clearance accounting for only about 15% of drug elimination. The half-life of the parent drug is on the order of 20 hours, while the half-life of drug metabolites may exceed 45 hours.

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### Indications

1. Acute myelogenous leukemia.
  2. Acute lymphoblastic leukemia.
  3. Chronic myelogenous leukemia in blast crisis.
  4. Myelodysplastic syndromes.
- 

### Dosage Range

Acute myelogenous leukemia, induction therapy: 12 mg/m<sup>2</sup> IV on days 1–3 in combination with cytarabine, 100 mg/m<sup>2</sup>/day IV continuous infusion for 7 days.

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### Drug Interaction 1

Probenecid—Avoid concomitant use of probenecid and sulfapyrazone as these are uricosuric agents and may lead to uric acid nephropathy.

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### Drug Interaction 2

Heparin—Idarubicin is incompatible with heparin as it forms a precipitate.

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### Special Considerations

1. Use with caution in patients with abnormal liver function. Dose modification should be considered in patients with liver dysfunction. Dose reduction by 50% is recommended for serum bilirubin in the range of 2.6–5.0 mg/dL. Absolutely contraindicated in patients with bilirubin >5.0 mg/dL.

2. Careful administration of drug, usually through a central venous catheter, is necessary as it is a strong vesicant. If peripheral venous access is used, careful monitoring of drug administration is necessary to avoid extravasation. If extravasation is suspected, stop infusion immediately, withdraw fluid, elevate arm, and apply ice to site. In severe cases, consult a plastic surgeon.
3. Alkalinization of the urine, allopurinol, and vigorous IV hydration are recommended to prevent tumor lysis syndrome in patients with acute myelogenous leukemia.
4. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. Risk of cardiotoxicity is higher in elderly patients >70 years of age, in patients with prior history of hypertension or pre-existing heart disease, in patients previously treated with anthracyclines, or in patients with prior radiation therapy to the chest. While maximum dose of idarubicin that may be administered safely is not known, cumulative doses of >150 mg/m<sup>2</sup> have been associated with decreased LVEF.
5. Caution patients against sun exposure and to wear sun protection when outside.
6. Caution patients about the potential for red discoloration of urine for 1–2 days after drug administration.
7. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting toxicity. Leukocytes more commonly affected than platelets. Nadir typically occurs at 10–14 days after treatment, with recovery of counts by day 21. Risk of myelosuppression is greater in elderly patients and in those previously treated with chemotherapy and/or radiation therapy.

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#### Toxicity 2

Nausea and vomiting. Usually mild and occurs in up to 80%–90% of patients.

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#### Toxicity 3

Cardiotoxicity. Cardiac effects are similar to but less severe than those of doxorubicin. Acute toxicity presents as atrial arrhythmias, chest pain, and myopericarditis syndrome that typically occurs within the first 24–48 hours of drug administration. Dilated cardiomyopathy with congestive heart failure can occur, usually with higher cumulative doses above 150 mg/m<sup>2</sup>.

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#### Toxicity 4

Alopecia. Nearly universal but reversible.

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**Toxicity 5**

Generalized skin rash, increased sensitivity to sunlight, hyperpigmentation of nails and at the injection site. Rarely, radiation recall skin reaction.

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**Toxicity 6**

Strong vesicant. Extravasation can lead to extensive tissue damage.

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**Toxicity 7**

Mucositis and diarrhea. Common but usually not severe.

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**Toxicity 8**

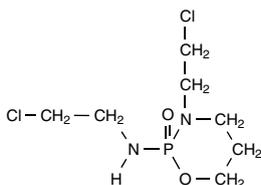
Reversible effects on liver enzymes, including SGOT and SGPT.

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**Toxicity 9**

Red discoloration of urine. Usually within the first 1–2 days after drug administration.

# Ifosfamide



## Trade Names

Ifex, Isophosphamide

## Classification

Alkylating agent

## Category

Chemotherapy drug

## Drug Manufacturer

Bristol-Myers Squibb

## Mechanism of Action

- Inactive in its parent form.
- Activated by the liver cytochrome P<sub>450</sub> microsomal system to various cytotoxic metabolites, including ifosfamide mustard and acrolein.
- Cytotoxic metabolites form cross-links with DNA resulting in inhibition of DNA synthesis and function.
- Cell cycle–nonspecific agent, active in all phases of the cell cycle.

## Mechanism of Resistance

- Decreased cellular uptake of drug.
- Decreased expression of liver P<sub>450</sub> activating enzymes.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-associated enzymes.
- Increased expression of aldehyde dehydrogenase resulting in enhanced inactivation of drug.
- Enhanced activity of DNA repair enzymes.

## Absorption

Well-absorbed by the GI tract with a bioavailability of nearly 100%. However, only IV form is available commercially because oral form is highly neurotoxic.

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### Distribution

Widely distributed into body tissues. About 20% of drug is bound to plasma protein.

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### Metabolism

Extensively metabolized in the liver by the cytochrome P<sub>450</sub> system. Activated at a 4-fold slower rate than cyclophosphamide because of lower affinity to the liver P<sub>450</sub> system. For this reason, about 4-fold more drug is required to produce equitoxic antitumor effects with cyclophosphamide. The half-life of the drug is 3–10 hours for standard therapy and up to 14 hours for high-dose therapy. Approximately 50%–70% of the drug and its metabolites is excreted in urine.

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### Indications

1. Recurrent germ cell tumors.
  2. Soft tissue sarcoma, osteogenic sarcoma.
  3. Non-Hodgkin's lymphoma.
  4. Hodgkin's disease.
  5. Non-small cell and small cell lung cancer.
  6. Bladder cancer.
  7. Head and neck cancer.
  8. Cervical cancer.
  9. Ewing's sarcoma.
- 

### Dosage Range

1. Testicular cancer: 1,200 mg/m<sup>2</sup> IV on days 1–5 every 21 days, as part of the VeIP salvage regimen.
  2. Soft tissue sarcoma: 2,000 mg/m<sup>2</sup> IV continuous infusion on days 1–3 every 21 days, as part of the MAID regimen.
  3. Non-Hodgkin's lymphoma: 1,000 mg/m<sup>2</sup> on days one and 2 every 28 days, as part of the ICE regimen.
  4. Head and neck cancer: 1,000 mg/m<sup>2</sup> on days 1–3 every 21–28 days, as part of the TIC regimen.
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### Drug Interaction 1

Phenobarbital, phenytoin, and other drugs that stimulate the liver P<sub>450</sub> system—Increase the rate of metabolic activation of ifosfamide to its toxic metabolites resulting in enhanced toxicity.

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### Drug Interaction 2

Cimetidine and allopurinol—Increase the formation of ifosfamide metabolites resulting in increased toxicity.

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### Drug Interaction 3

Cisplatin—Increases ifosfamide-associated renal toxicity.

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### Drug Interaction 4

Warfarin—Ifosfamide may enhance the anticoagulant effects of warfarin.

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### Special Considerations

1. Administer prophylactic antiemetics to avoid nausea and vomiting.
  2. Contraindicated in patients with a history of thrombophlebitis or thromboembolic disorders.
  3. Use with caution in patients with abnormal renal function. Dose reduction is necessary in this setting. Baseline creatinine clearance must be obtained, and renal function should be monitored during therapy.
  4. Uroprotection with mesna and hydration must be used to prevent bladder toxicity. Pre- and post-hydration (1,500–2,000 mL/day) or continuous bladder irrigations are recommended to prevent hemorrhagic cystitis. Important to monitor urine for presence of gross and/or microscopic hematuria before each cycle of therapy.
  5. Monitor coagulation parameters, including PT and INR, when ifosfamide is used concurrently with warfarin, as ifosfamide may enhance its anticoagulant effects.
  6. Contraindicated in patients with peptic ulcer disease, severe liver disease, and/or cardiac disease.
  7. Pregnancy category D.
- 

### Toxicity 1

Myelosuppression is dose-limiting. Mainly leukopenia and to a lesser extent thrombocytopenia. Nadir occurs at 10–14 days with recovery in 21 days.

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### Toxicity 2

Bladder toxicity can be dose-limiting and manifested by hemorrhagic cystitis, dysuria, and increased urinary frequency. Chronic fibrosis of bladder leads to an increased risk of secondary bladder cancer. Uroprotection with mesna and hydration must be used to prevent bladder toxicity.

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### Toxicity 3

Nausea and vomiting. Usually occurs within 3–6 hours of therapy and may last up to 3 days. Anorexia is fairly common.

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### Toxicity 4

Neurotoxicity in the form of lethargy, confusion, seizure, cerebellar ataxia, weakness, hallucinations, cranial nerve dysfunction, and rarely stupor and

coma. Incidence may be higher in patients receiving high-dose therapy and in those with impaired renal function.

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**Toxicity 5**

Alopecia is common (>80%). Skin rash, hyperpigmentation, and nail changes are occasionally seen.

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**Toxicity 6**

Syndrome of inappropriate secretion of antidiuretic hormone (SIADH).

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**Toxicity 7**

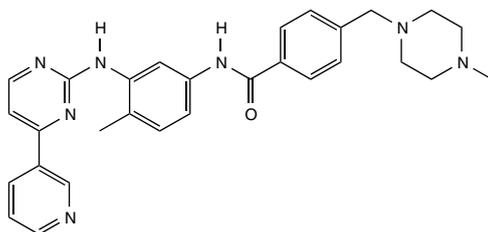
Amenorrhea, oligospermia, and infertility.

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**Toxicity 8**

Mutagenic, teratogenic, and carcinogenic.

# Imatinib



## Trade Names

STI571, Gleevec

## Classification

Signal transduction inhibitor

## Category

Chemotherapy drug

## Drug Manufacturer

Novartis

## Mechanism of Action

- Phenylaminopyrimidine methanesulfonate compound that occupies the ATP binding site of the BCR-ABL protein and other related tyrosine kinases. Binding in this ATP pocket results in subsequent inhibition of substrate phosphorylation.
- Potent and selective inhibitor of the P210 BCR-ABL tyrosine kinase resulting in inhibition of clonogenicity and tumorigenicity of BCR-ABL and Ph<sup>+</sup> cells.
- Induces apoptosis in BCR-ABL positive cells without causing cell differentiation.
- Inhibits other activated ABL tyrosine kinases, including P185 BCR-ABL, and inhibits other receptor tyrosine kinases for platelet-derived growth factor receptor (PDGFR), stem cell factor (SCF), and c-kit.

## Mechanism of Resistance

- Increased expression of BCR-ABL tyrosine kinase through amplification of the BCR-ABL gene.
- Alterations in the binding affinity of the BCR-ABL tyrosine kinase to the drug as a result of mutations in the protein.

- Increased expression of P170 glycoprotein resulting in enhanced drug efflux and decreased intracellular drug accumulation.
- Increased degradation and/or metabolism of the drug through as yet undefined mechanisms.

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### Absorption

Oral bioavailability is nearly 100%.

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### Distribution

Extensive binding (95%) to plasma proteins, including albumin and  $\alpha$ -acid glycoprotein. Steady-state drug concentrations are reached in 2–3 days.

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### Metabolism

Metabolism in the liver primarily by the CYP3A4 microsomal enzyme. Other cytochrome P450 enzymes play a minor role in its metabolism. The main metabolite is the N-desmethylated piperazine derivative, and this metabolite shows in vitro potency similar to that of the parent drug. Elimination is mainly in the feces, predominantly as metabolites. The terminal half-life of the parent drug is 18 hours, while that of its main metabolite, the N-desmethyl derivative, is on the order of 40 hours.

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### Indications

1. Chronic phase of CML—first-line therapy in adult patients, FDA-approved.
2. Chronic phase of CML after failure on interferon- $\alpha$  therapy—FDA-approved.
3. CML in accelerated phase and/or in blast crisis—FDA-approved.
4. Chronic phase Ph+ CML in pediatric patients whose disease has recurred after stem cell transplant or is resistant to interferon- $\alpha$ .
5. Myelodysplastic/myeloproliferative diseases (MDS/MPD) associated with PDGFR gene rearrangements.
6. Hypereosinophilic syndrome/chronic eosinophilic leukemia (HES/CEL).
7. Relapsed/refractory Ph+ acute lymphocytic leukemia (PH+ ALL).
8. Gastrointestinal stromal tumors (GIST) expressing c-kit (CD117).

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### Dosage Range

1. Recommended starting dose is 400 mg/day for patients in chronic phase CML and 600 mg/day for patients in accelerated phase or blast crisis. Dose increases from 400 mg to 600 mg or 800 mg in patients with chronic phase disease, or from 600 mg to a maximum of 800 mg (given as 400 mg twice daily) in patients with accelerated phase or blast crisis may be considered in the absence of severe

adverse drug reaction and severe nonleukemia-related neutropenia or thrombocytopenia in the following circumstances: disease progression (at any time); failure to achieve a satisfactory hematological response after at least 3 months of treatment; failure to achieve a cytogenetic response after 12 months of treatment; or loss of a previously achieved hematological and/or cytogenetic response. Patients should be monitored closely following dose escalation given the potential for an increased incidence of adverse reactions at higher dosages.

2. Recommended starting dose is 400 mg/day for patients with GIST. Limited data exist on the effect of dose increases from 400 mg to 600 mg or 800 mg in patients progressing at the lower dose.
3. Recommended starting dose is 400 mg/day for patients with MDS/MPD.
4. Recommended starting dose is 400 mg/day for patients with HES/CEL.
5. Recommended starting dose is 600 mg/day for patients with Ph+ ALL.

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#### Drug Interaction 1

Dilantin and other drugs that stimulate the liver microsomal CYP3A4 enzyme, including carbamazepine, rifampin, phenobarbital, and St. John's Wort—These drugs increase the rate of metabolism of imatinib resulting in its inactivation.

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#### Drug Interaction 2

Drugs that inhibit the liver microsomal CYP3A4 enzyme, including ketoconazole, itraconazole, erythromycin, and clarithromycin—These drugs decrease the rate of metabolism of imatinib resulting in increased drug levels and potentially increased toxicity.

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#### Drug Interaction 3

Warfarin—Patients on coumarin-derived anticoagulants should be closely monitored for alterations in their clotting parameters (PT and INR) and/or bleeding as imatinib inhibits the metabolism of warfarin by the liver P450 system. Dose of warfarin may require careful adjustment in the presence of imatinib therapy.

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#### Special Considerations

1. Patients should be weighed and monitored regularly for signs and symptoms of fluid retention. The risk of fluid retention and edema is increased with higher drug doses and in patients whose age >65 years.
2. Use with caution in patients with underlying hepatic impairment. At this time, there is no specific recommendation regarding initial dose adjustment in the setting of liver dysfunction.

3. Monitor CBC on a weekly basis for the first month, biweekly for the second month, and periodically thereafter.
4. Imatinib should be taken with food and large glass of water to decrease the risk of GI irritation.
5. Hematologic responses typically occur within 2 weeks after initiation of therapy while complete hematologic responses are observed within 4 weeks after starting therapy.
6. Cytogenetic responses are observed as early as 2 months and up to ten months after starting therapy. The median time to best cytogenetic response is about 5 months.
7. Carefully monitor dose of drug when used in patients with seizure disorders on phenytoin. Dose of drug may need to be increased as the metabolism of imatinib by the CYP<sub>3A4</sub> enzyme is enhanced in the presence of phenytoin.
8. Patients who require anticoagulation should receive low-molecular weight or standard heparin as imatinib inhibits the metabolism of warfarin.
9. Monitor cardiac function before (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. The diagnosis of CHF should be considered in patients who experience edema while on imatinib.
10. Pregnancy category D.

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#### Toxicity 1

Nausea and vomiting occur in 40%–50% of patients. Usually related to the swallowing of capsules and relieved when the drug is taken with food.

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#### Toxicity 2

Transient ankle and periorbital edema. Usually mild to moderate in nature.

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#### Toxicity 3

Occasional myalgias.

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#### Toxicity 4

Fluid retention with pleural effusion, ascites, pulmonary edema, and weight gain. Usually dose-related and more common in elderly patients and in those in blast crisis and the accelerated phase of CML. CHF is a rare but serious adverse event.

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#### Toxicity 5

Diarrhea is observed in 25%–30% of patients.

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**Toxicity 6**

Myelosuppression with neutropenia and thrombocytopenia.

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**Toxicity 7**

Mild, transient elevation in serum transaminases. Clinically asymptomatic in most cases.

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**Toxicity 8**

Skin toxicity in the form of bullous reactions, including erythema multiforme and Stevens-Johnson syndrome.

# Interferon- $\alpha$

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## Trade Names

$\alpha$ -interferon, IFN- $\alpha$ , Interferon- $\alpha$  2a, Roferon Interferon- $\alpha$  2b, Intron A

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## Classification

Immunotherapy

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Roche (Roferon), Schering (Intron A)

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## Mechanism of Action

- Precise mechanism of antitumor action remains unknown.
- Direct antiproliferative effects on tumor cell mediated by: induction of 2'5'-oligoadenylate synthetase and protein kinase leading to decreased translation and inhibition of tumor cell protein synthesis. Induction of differentiation. Prolongation of the cell cycle. Modulation of oncogene expression.
- Indirect induction of host antitumor mechanisms mediated by: induced activity of at least four immune effector cells, including cytotoxic T cells, helper T cells, NK cells, and macrophages. Enhancement of tumor surface expression of critical antigens that are recognized by the immune system. Inhibition of angiogenesis through decreased expression of various angiogenic factors:

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## Mechanism of Resistance

- Development of neutralizing antibodies to interferon- $\alpha$ .
- Decreased expression of cell surface receptors to interferon- $\alpha$ .

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## Absorption

Not available for oral use and is administered only via the parenteral route. Approximately 80%–90% of interferon- $\alpha$  is absorbed into the systemic circulation after IM or SC injection. Peak plasma levels are achieved in 4 hours after intramuscular injection and 7 hours after subcutaneous administration.

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## Distribution

Does not cross the blood-brain barrier. Binding to plasma proteins has not been well characterized.

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### Metabolism

Interferon- $\alpha$  is catabolized by renal tubule cells to various breakdown products. The major route of elimination is through the kidneys by both glomerular filtration and tubular secretion. Hepatic metabolism and biliary excretion play only a minor role in drug clearance. The elimination half-life is approximately 2–7 hours and depends on the specific route of drug administration.

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### Indications

1. Malignant melanoma—adjuvant therapy.
2. Chronic myelogenous leukemia—chronic phase.
3. Hairy cell leukemia.
4. AIDS-related Kaposi's sarcoma.
5. Cutaneous T-cell lymphoma.
6. Multiple myeloma.
7. Low-grade, non-Hodgkin's lymphoma.
8. Renal cell cancer.
9. Hemangioma.

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### Dosage Range

1. Chronic myelogenous leukemia: 9 million IU SC or IM daily.
2. Hairy cell leukemia: 3 million IU SC or IM daily for 16–24 weeks.
3. Malignant melanoma: 20 million IU/m<sup>2</sup> IV, five times weekly for 4 weeks, then 10 million IU/m<sup>2</sup> SC, three times weekly for 48 weeks.
4. Kaposi's sarcoma: 36 million IU SC or IM daily for 12 weeks.

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### Drug Interaction 1

Phenytoin, phenobarbital—Effects of phenytoin and phenobarbital may be increased as interferon- $\alpha$  inhibits the liver P450 system. Drug levels must be monitored closely and dose adjustments made accordingly.

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### Drug Interaction 2

Live vaccines—Vaccination with live vaccines is contraindicated during and for at least 3 months after completion of interferon therapy.

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### Special Considerations

1. Use with caution in patients with pre-existing cardiac, pulmonary, CNS, hepatic, and/or renal impairment as they are at increased risk for developing serious and sometimes fatal reactions.
2. Contraindicated in patients with history of autoimmune disease, autoimmune hepatitis, or in those who have received immunosuppressive therapy for organ transplants.

3. Contraindicated in patients with a known allergy to benzyl alcohol as the injectable solution form contains benzyl alcohol.
4. Use with caution in patients with myelosuppression or those who are receiving concurrent agents known to cause myelosuppression.
5. Use with caution in patients with a history of depression and/or other psychological disorders. Routine neuropsychiatric monitoring of all patients on interferon- $\alpha$  is recommended.
6. Use with caution in older patients (>65 years of age) as they are at increased risk for developing fatigue and neurologic toxicities secondary to interferon- $\alpha$ .
7. Premedicate patient with acetaminophen to reduce the risk and/or severity of flulike symptoms, including fever and chills. In the event that acetaminophen is unsuccessful, indomethacin can be used.
8. Pregnancy category C.

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#### Toxicity 1

Flu-like symptoms with fever, chills, headache, myalgias, and arthralgias. Occur in 80%–90% of patients, usually beginning a few hours after the first injection and lasting for up to 8–9 hours. Incidence decreases with subsequent injections. Can be controlled with acetaminophen and/or indomethacin.

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#### Toxicity 2

Fatigue and anorexia are dose-limiting with chronic administration.

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#### Toxicity 3

Somnolence, confusion, or depression. Patients >65 years of age are much more susceptible to the neurologic sequelae of interferon- $\alpha$ .

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#### Toxicity 4

Myelosuppression with mild leukopenia and thrombocytopenia. Reversible upon discontinuation of therapy.

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#### Toxicity 5

Mild, transient elevations in serum transaminases. Dose-dependent toxicity observed more frequently in the presence of pre-existing liver abnormalities.

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#### Toxicity 6

Renal toxicity is uncommon and is manifested by mild proteinuria and hypocalcemia. Acute renal failure and nephrotic syndrome have been reported in rare instances.

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**Toxicity 7**

Alopecia, skin rash, pruritus with dry skin, and irritation at the injection site.

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**Toxicity 8**

Cardiotoxicity in the form of chest pain, arrhythmias, and congestive heart failure. Uncommon and almost always reversible.

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**Toxicity 9**

Impotence, decreased libido, menstrual irregularities, and an increased incidence of spontaneous abortions.

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**Toxicity 10**

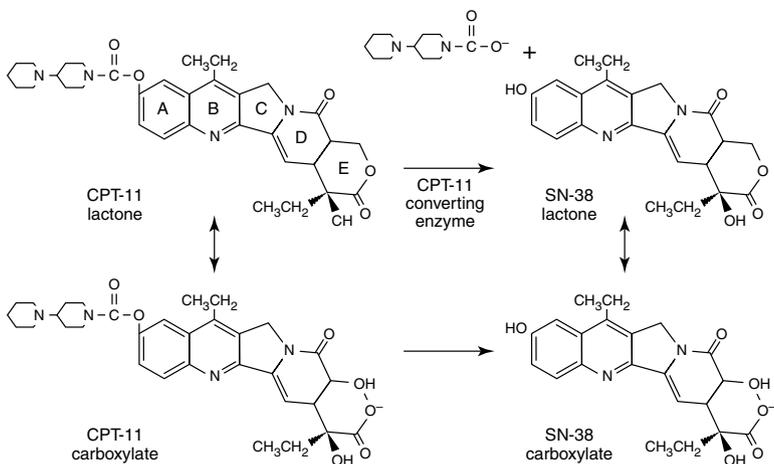
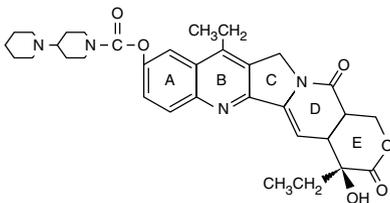
Rare cases of autoimmune disorders, including thrombocytopenia, vasculitis, Raynaud's disease, lupus, rheumatoid arthritis, and rhabdomyolysis.

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**Toxicity 11**

Retinopathy with cotton-wool spots and small hemorrhages. Usually asymptomatic and resolves upon termination of therapy.

# Irinotecan



## Trade Names

Camptosar, CPT-11

## Classification

Topoisomerase I inhibitor

## Category

Chemotherapy drug

## Drug Manufacturer

Pfizer

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### Mechanism of Action

- Semisynthetic derivative of camptothecin, an alkaloid extract from the *Camptotheca acuminata* tree.
- Inactive in its parent form. Converted by the carboxylesterase enzyme to its active metabolite form, SN-38.
- SN-38 binds to and stabilizes the topoisomerase I-DNA complex and prevents the relegation of DNA after it has been cleaved by topoisom-erase I. The collision between this stable complex (“cleavable complex”) and the advancing replication fork results in double-strand DNA breaks and cellular death.
- Antitumor activity of drug requires the presence of ongoing DNA synthesis.
- Cell cycle–nonspecific agent with activity in all phases of the cell cycle.
- Colorectal tumors express higher levels of topoisomerase I than normal colonic mucosa, making this an attractive target for chemotherapy.

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### Mechanism of Resistance

- Decreased expression of topoisomerase I.
- Mutations in topoisomerase I enzyme with decreased affinity for the drug.
- Increased expression of the multidrug-resistant phenotype with over-expression of P170 glycoprotein. Results in enhanced efflux of drug and decreased intracellular accumulation of drug.
- Decreased formation of the cytotoxic metabolite SN-38 through decreased activity and/or expression of the carboxylesterase enzyme.
- Decreased accumulation of drug into cells by mechanisms not well identified.

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### Absorption

Irinotecan is not given by the oral route.

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### Distribution

Widely distributed in body tissues. Irinotecan exhibits moderate binding to plasma proteins (30%–60%). In contrast, SN-38 shows extensive plasma protein binding (95%). Peak levels of SN-38 are achieved within one hour after drug administration.

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### Metabolism

The conversion of irinotecan to the active metabolite SN-38 occurs primarily in the liver. However, this conversion can also take place in plasma

and in intestinal mucosa. SN-38 subsequently undergoes conjugation in the liver to the glucuronide metabolite, which is essentially inactive. In aqueous solution, the lactone ring undergoes rapid hydrolysis to the carboxylate form. Only about 34%–44% of CPT-11 and 45%–64% of the active metabolite SN-38 are present in the active lactone form at one hour after drug administration. The major route of elimination of both irinotecan and SN-38 is in bile and feces, accounting for 50%–70% of drug clearance. Only 10%–14% of CPT-11 and <1% of SN-38 is cleared in urine. The half-lives of irinotecan and SN-38 are 8 and 14 hours, respectively.

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### Indications

1. Colorectal cancer—Irinotecan is FDA-approved in combination with 5-FU and leucovorin as first-line treatment of patients with metastatic colorectal cancer.
2. Colorectal cancer—Irinotecan is FDA-approved as a single agent for second-line treatment of patients with metastatic colorectal cancer after failure to 5-FU–based chemotherapy.
3. Non–small cell lung cancer.
4. Small cell lung cancer.

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### Dosage Range

1. In the United States, the recommended starting dose of irinotecan is 125 mg/m<sup>2</sup> IV weekly for 4 weeks, followed by a 2-week rest. This schedule can be modified to 2 weeks, followed by a 1-week rest.
2. In Europe, the recommended dose is 300–350 mg/m<sup>2</sup> IV on an every-3-week schedule.
3. Irinotecan can be administered at 180 mg/m<sup>2</sup> IV as monotherapy or in combination with infusional 5-FU/LV on an every-2-week schedule.

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### Drug Interaction 1

Dilantin and other drugs that stimulate the liver microsomal CYP3A4 enzyme, including carbamazepine, rifampin, phenobarbital, and St. John's Wort—These drugs increase the rate of metabolism of irinotecan and SN-38, resulting in its inactivation.

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### Drug Interaction 2

Drugs that inhibit the liver microsomal CYP3A4 enzyme, including ketoconazole, itraconazole, erythromycin, and clarithromycin—These drugs decrease the rate of metabolism of irinotecan and SN-38, resulting in increased drug levels and potentially increased toxicity.

## Special Considerations

1. Irinotecan is an emetogenic drug. Patients should routinely receive antiemetic prophylaxis with a 5-HT<sub>3</sub> antagonist, such as ondansetron or granisetron, in combination with dexamethasone.
2. Treatment with irinotecan is complicated by a syndrome of “early diarrhea,” which consists of diarrhea, diaphoresis, and abdominal cramping during the infusion or within 24 hours of drug administration. This complication is thought to be due to a cholinergic effect. The recommended treatment is atropine (0.25–1.0 mg) administered IV unless clinically contraindicated. The routine use of atropine for prophylaxis is not recommended. However, atropine prophylaxis should be administered if a cholinergic event has been experienced.
3. Instruct patients about the possibility of late diarrhea (starting after 24 hours of drug administration), which can lead to serious dehydration and/or electrolyte imbalances if not managed promptly. This side effect is thought to be due to a direct irritation of the gastrointestinal mucosa by SN-38, although other as yet unidentified mechanisms may be involved. Loperamide should be taken immediately after the first loose bowel movement. The recommended dose is 4 mg PO as a loading dose, followed by 2 mg every 2 hours around the clock (4 mg every 4 hours during the night). Loperamide can be discontinued once the patient is diarrhea-free for 12 hours. If diarrhea should continue without improvement in the first 24 hours, an oral fluoroquinolone should be added. Hospitalization with IV antibiotics and IV hydration should be considered with continued diarrhea.
4. Irinotecan should be held for grade 3 (7–9 stools/day, incontinence, or severe cramping) and/or grade 4 (<10 stools/day, grossly bloody stool, or need for parenteral support) diarrhea. Dose of drug must be reduced upon recovery by the patient.
5. Patients should be warned against taking laxatives while on therapy.
6. Carefully monitor administration of drug as it is a moderate vesicant. The site of infusion should be carefully inspected for extravasation, in which case flushing with sterile water, elevation of the extremity, and local application of ice are recommended.
7. Use with caution in patients >65 years of age, in patients with poor performance status, and in those previously treated with pelvic and/or abdominal irradiation as they are at increased risk for myelosuppression and diarrhea.

8. Careful monitoring of patients on a weekly basis, especially during the first treatment cycle. Monitor complete blood cell count and platelet count on a weekly basis.
9. Patients with the UGT1A1 7/7 genotype may be at increased risk for developing GI toxicity and myelosuppression. Approximately 10% of the North American population is homozygous for this genotype. Dose reduction should be considered in this setting.
10. Patients should be warned to be off St. John's Wort for at least 2 weeks before starting irinotecan therapy and should remain off until after the completion of irinotecan therapy. St. John's Wort has been shown to reduce irinotecan chemotherapy by inhibiting metabolism of irinotecan to the active SN-38 metabolite.
11. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting with neutropenia being most commonly observed. Patients with prior history of abdominal/pelvic irradiation are particularly prone to developing myelosuppression after treatment with irinotecan. Typical nadir occurs at days 7–10 with full recovery by days 21–28.

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#### Toxicity 2

Diarrhea. Dose-limiting with two different forms, early and late. Early form occurs within 24 hours of drug treatment and is thought to be a cholinergic event. Characterized by flushing, diaphoresis, abdominal pain, and diarrhea.

Late-form diarrhea occurs after 24 hours, typically at 3–10 days after treatment, can be severe and prolonged, and can lead to dehydration and electrolyte imbalance. Up to 80%–90% of patients may experience some aspect of late diarrhea, although only 10%–20% of patients will experience grade 3 or 4 diarrhea. Anorexia, nausea, and vomiting are usually mild and dose-related.

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#### Toxicity 3

Mild alopecia.

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#### Toxicity 4

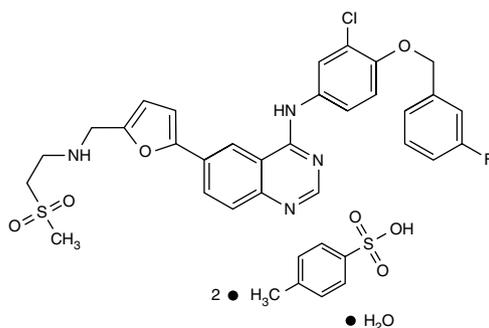
Transient elevation in serum transaminases, alkaline phosphatase, and bilirubin.

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#### Toxicity 5

Asthenia and fever.

# Lapatinib



## Trade Names

Tykerb, GW572016

## Classification

Signal transduction inhibitor

## Category

Chemotherapy drug

## Drug Manufacturer

GlaxoSmithKline

## Mechanism of Action

- Potent small molecule inhibitor of the tyrosine kinases associated with epidermal growth factor receptor (ErbB1) and HER2 (ErbB2), resulting in inhibition of phosphorylation and downstream signaling.
- Inhibition of the EGFR and HER2 tyrosine kinases results in inhibition of critical mitogenic and antiapoptotic signals involved in proliferation, growth, invasion/metastasis, angiogenesis, and response to chemotherapy and/or radiation therapy.

## Mechanism of Resistance

None well characterized to date.

## Absorption

Oral absorption is incomplete and variable and is increased when administered with food.

## Distribution

Extensive binding (99%) to plasma proteins, including albumin and  $\alpha$ 1-acid glycoprotein, and extensive tissue distribution. Peak plasma levels are achieved 4 hours after ingestion. Steady-state drug concentrations are reached in 6 to 7 days.

## Metabolism

Metabolism in the liver primarily by the CYP3A4 and CYP3A5 microsomal enzymes and by CYP2C19 and CYP2C8 to a lesser extent. Elimination is mainly hepatic with excretion in the feces, and renal elimination of parent drug and its metabolites accounts for less than 2% of an administered dose. The terminal half-life of the parent drug is 14 hours, and with repeat dosing, the effective half-life is 24 hours.

## Indications

FDA-approved in combination with capecitabine for the treatment of patients with advanced or metastatic breast cancer whose tumors overexpress HER2 and who have received prior therapy, including an anthracycline, a taxane, and trastuzumab.

## Dosage Range

Recommended dose is 1,250 mg PO daily on days 1 to 21 continuously in combination with capecitabine 1,000 mg/m<sup>2</sup> PO bid on days 1 to 14, with each cycle repeated every 21 days.

## Drug Interaction 1

Dilantin and other drugs that stimulate the liver microsomal CYP3A4 enzyme, including carbamazepine, rifampicin, phenobarbital, and St. John's Wort. These drugs may increase the rate of metabolism of lapatinib, resulting in its inactivation.

## Drug Interaction 2

Drugs that inhibit the liver microsomal CYP3A4 enzyme, including ketoconazole, itraconazole, erythromycin, and clarithromycin. These drugs may decrease the rate of metabolism of erlotinib, resulting in increased drug levels and potentially increased toxicity.

## Drug Interaction 3

Warfarin—Patients receiving coumarin-derived anticoagulants should be closely monitored for alterations in their clotting parameters (PT and INR) and/or bleeding, as lapatinib may inhibit the metabolism of warfarin by the liver P450 system. The dose of warfarin may require careful adjustment in the presence of erlotinib therapy.

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### Special Considerations

1. Use with caution in patients with hepatic impairment, and dose reduction and/or interruption should be considered.
2. Monitor cardiac function at baseline and periodically during therapy with either MUGA or echocardiogram to assess LVEF. The majority of LVEF decreases occur within the first 9 weeks of therapy. Use with caution in patients with pre-existing conditions that could impair LVEF.
3. Monitor EKG with QT measurement at baseline and periodically during therapy, as QT prolongation has been observed. Use with caution in patients at risk of developing QT prolongation, including hypokalemia, hypomagnesemia, congenital long QT syndrome, patients taking antiarrhythmic medications or any other products that may cause QT prolongation, and cumulative high-dose anthracycline therapy.
4. Lapatinib should be taken 1 hour before or after a meal, and the daily dose should not be divided. When capecitabine is coadministered, capecitabine should be taken with a glass of water within 30 minutes after a meal.
5. Avoid grapefruit products while on therapy.
6. Closely monitor patients for diarrhea, as even severe diarrhea may develop while on therapy. Aggressive management with antidiarrheal agents as well as replacement of fluids and electrolytes should be followed.
7. Pregnancy category D.

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### Toxicity 1

Diarrhea is the most common dose-limiting toxicity and occurs in 65% of patients. Mild nausea/vomiting may also occur.

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### Toxicity 2

Cardiac toxicity with reduction in LVEF. QT prolongation observed in <1% of patients.

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### Toxicity 3

Myelosuppression with anemia more common than thrombocytopenia or neutropenia.

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### Toxicity 4

Fatigue and anorexia.

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### Toxicity 5

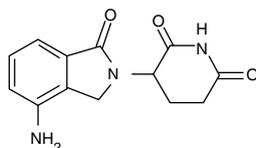
Mild to moderate elevation of serum transaminases and serum bilirubin.

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### Toxicity 6

Hand-foot syndrome (palmar-plantar erythrodysesthesia) and skin rash.

# Lenalidomide



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## Trade Name

Revlimid, CC-5013

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## Classification

Immunomodulatory analog of thalidomide, anti-angiogenic agent

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## Category

Unclassified therapeutic agent, biologic response modifier agent

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## Drug Manufacturer

Celgene

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## Mechanism of Action

- Mechanism of action is not fully characterized.
- Immunomodulatory drug (IMid) that stimulates T-cell proliferation as well as IL-2 and IFN- $\gamma$  production.
- Inhibition of TNF- $\alpha$  and IL-6 synthesis and down-modulation of cell surface adhesion molecules similar to thalidomide.
- May exert anti-angiogenic effect through inhibition of basic fibroblast growth (bFBG) and vascular endothelial growth factor (VEGF) as well as through as yet undefined mechanisms.
- Overcomes cellular drug resistance to thalidomide.

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## Mechanism of Resistance

None characterized to date.

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## Absorption

Lenalidomide is rapidly absorbed following oral administration with peak plasma concentrations at 60–90 minutes post ingestion. Co-administration with food does not alter the extent of absorption (AUC) but does reduce maximal plasma concentration ( $C_{max}$ ) by 36%.

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## Distribution

Not well characterized.

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## Metabolism

Lenalidomide does not appear to be metabolized or induced by the cytochrome P<sub>450</sub> pathway. Approximately 66% of an administered dose is excreted unchanged in the urine. The elimination half-life of the drug is approximately 3 hours.

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## Indications

1. FDA-approved for the treatment of low- or intermediate-risk myelodysplastic syndromes (MDS) associated with the deletion 5q (del 5q) cytogenetic abnormality with or without additional cytogenetic abnormalities.
2. FDA-approved for the treatment of multiple myeloma in combination with dexamethasone for patients who have received at least one prior therapy.

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## Dosage Range

1. Myelodysplastic syndrome: 10 mg PO daily.
2. Multiple myeloma: 25 mg PO daily on days 1–21 and 40 mg Decadron PO on days 1–4, 9–12, and 17–20 of a 28-day cycle.

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## Drug Interactions

None well characterized to date.

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## Special Considerations

1. Pregnancy category X. Lenalidomide is a thalidomide analog, a known human teratogen that causes severe or life-threatening birth defects. As such, women who are pregnant or who wish to become pregnant should not take lenalidomide. Severe fetal malformations can occur if even one capsule is taken by a pregnant woman. All women should have a baseline  $\beta$ -human chorionic gonadotropin ( $\beta$ -HCG) before starting lenalidomide therapy. Women of reproductive age must have two negative pregnancy tests before starting therapy: one should be 10 to 14 days before therapy is begun, and the second should be 24 hours before therapy.
2. All women of childbearing potential should practice two forms of birth control throughout therapy with lenalidomide: one highly effective form (intrauterine device, hormonal contraception [patch, implant, pill, injection], partner's vasectomy, or tubal ligation) and one additional barrier method (latex condom, diaphragm, or cervical cap). It is strongly recommended that these precautionary measures be taken 1 month before initiation of therapy, continue while on therapy, and continue at least 1 month after therapy is discontinued.
3. Lenalidomide is only available under a special restricted distribution program called "RevAssist<sup>SM</sup>." Only prescribers and pharmacists

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registered with the RevAssist<sup>SM</sup> program are able to prescribe and dispense the drug. Lenalidomide should only be dispensed to those patients who are registered and meet all the conditions of the RevAssist<sup>SM</sup> program.

4. Breast-feeding while on therapy should be avoided, as it remains unknown if lenalidomide is excreted in breast milk.
5. Men taking lenalidomide must use latex condoms for every sexual encounter with a woman of child-bearing potential, as the drug may be present in semen.
6. Patients taking lenalidomide should not donate blood or semen while receiving treatment, and for at least 1 month after stopping this drug.
7. Monitor complete blood counts while on therapy as lenalidomide is toxic to the bone marrow.
8. Use with caution in patients with impaired renal function, as the risk of toxicity may be greater.
9. There is a significantly increased risk of thromboembolic complications, including deep venous thrombosis (DVT) and pulmonary embolism (PE), especially in myeloma patients treated with lenalidomide and Decadron. Prophylaxis with low molecular weight heparin, warfarin, or aspirin [325 mg PO qd] can help prevent and/or reduce this risk.

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#### Toxicity 1

Potentially severe or fatal teratogenic effects.

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#### Toxicity 2

Myelosuppression with neutropenia and thrombocytopenia that is usually reversible.

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#### Toxicity 3

Increased risk of thromboembolic complications, such as DVT and PE.

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#### Toxicity 4

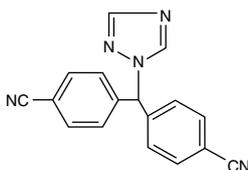
Nausea/vomiting, diarrhea, and constipation are most common GI side effects.

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#### Toxicity 5

Neurotoxic side effects are rare with almost no sedation.

# Letrozole



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## Trade Names

Femara

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## Classification

Aromatase inhibitor

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## Category

Hormonal agent

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## Drug Manufacturer

Novartis

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## Mechanism of Action

- Nonsteroidal, competitive inhibitor of aromatase. Nearly 200-fold more potent than aminoglutethimide.
- Inhibits synthesis of estrogens by inhibiting the conversion of adrenal androgens (androstenedione and testosterone) to estrogens (estrone, estrone sulfate, and estradiol). Serum estradiol levels are suppressed by 90% within 14 days, and nearly completely suppressed after 6 weeks of therapy.
- No inhibitory effect on adrenal corticosteroid biosynthesis.

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## Absorption

Rapidly and completely absorbed after oral administration. Food does not interfere with oral absorption.

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## Distribution

Significant uptake in peripheral tissues and in breast cancer cells. Minimal binding to plasma proteins.

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## Metabolism

Metabolism occurs in the liver by the cytochrome P450 system. Process of glucuronidation leads to inactive metabolites. Parent drug and metabolites are excreted via the kidneys with over 75%–90% cleared in urine.

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### Indications

1. First-line treatment of postmenopausal women with hormone-receptor positive or hormone-receptor unknown locally advanced or metastatic breast cancer.
2. Second-line treatment of postmenopausal women with advanced breast cancer after progression on tamoxifen therapy.
3. Adjuvant treatment of postmenopausal women with hormone-receptor positive early stage breast cancer.
4. Extended adjuvant treatment of early-stage breast cancer in postmenopausal women who have received 5 years of adjuvant tamoxifen therapy.

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### Dosage Range

Usual dose is 2.5 mg PO qd until disease progression.

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### Drug Interactions

None known.

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### Special Considerations

1. Letrozole is indicated only for postmenopausal women. Efficacy in premenopausal women has not been established, and there may be an increased risk of benign ovarian tumors and cystic ovarian disease in this population.
2. Use with caution in patients with abnormal liver function. Monitor liver function at baseline and periodically during therapy. The dose should be reduced by 50% in patients with cirrhosis and severe hepatic dysfunction.
3. No need for glucocorticoid and/or mineralocorticoid replacement.
4. Closely monitor women with osteoporosis or at risk of osteoporosis by performing bone densitometry at the start of therapy and at regular intervals. Treatment or prophylaxis for osteoporosis should be initiated when appropriate.
5. Letrozole can be taken with or without food.
6. Pregnancy category D.

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### Toxicity 1

Mild musculoskeletal pains and arthralgias are the most common adverse events.

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**Toxicity 2**

Headache and fatigue.

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**Toxicity 3**

Mild nausea with less frequent vomiting and anorexia. Thromboembolic events are rare, and less common than with megestrol acetate.

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**Toxicity 4**

Hot flashes occur in about 6% of patients.

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**Toxicity 5**

Mild elevation in serum transaminases and serum bilirubin. Most often seen in patients with established metastatic disease in the liver.

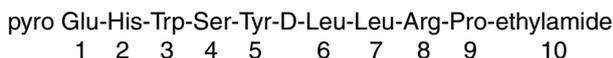
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**Toxicity 6**

Thromboembolic events are rarely observed.



# Leuprolide



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## Trade Names

Lupron

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## Classification

LHRH agonist

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## Category

Hormonal agent

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## Drug Manufacturer

TAP Pharmaceuticals

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## Mechanism of Action

Administration of this LHRH agonist leads to initial release of FSH and LH followed by suppression of gonadotropin secretion as a result of desensitization of the pituitary to gonadotropin-releasing hormone. This eventually leads to decreased secretion of LH and FSH from the pituitary, resulting in castration levels of testosterone. Plasma levels of testosterone fall to castrate levels after 2–4 weeks of therapy.

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## Absorption

Leuprolide is not orally absorbed. After SC injection, approximately 90% of a dose is absorbed into the systemic circulation.

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## Distribution

Distribution is not well characterized. Leuprolide is slowly released over a 28-day period. Peak serum concentrations are achieved 10–15 days after drug administration. About 45%–50% of drug is bound to plasma proteins.

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## Metabolism

Metabolism of leuprolide occurs mainly via hydrolysis of the C-terminal amino acids. Leuprolide is nearly completely eliminated in its parent form in urine (>90%) with an elimination half-life of 3–4 hours. The half-life is prolonged in patients with impaired renal function.

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### Indications

1. Advanced prostate cancer.
2. Neoadjuvant therapy of early-stage prostate cancer.

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### Dosage Range

Administer 22.5 mg SC every 3 months.

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### Drug Interactions

None known.

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### Special Considerations

1. Initiation of treatment with leuprolide may induce a transient tumor flare due to the initial release of LH and FSH. Patients with impending ureteral obstruction and/or spinal cord compression or in those with painful bone metastases are at especially high risk. To prevent tumor flare, patients should be started on anti-androgen therapy at least 2 weeks before starting leuprolide.
2. Serum testosterone levels decrease to castrate levels within 2–4 weeks after initiation of therapy.
3. Use with caution in patients with abnormal renal function.
4. Caution patients about the possibility of hot flashes. Consider the use of clonidine 0.1–0.2 mg PO daily, Megace 20 mg PO bid, or soy tablets, one tablet PO tid for prevention and/or treatment.

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### Toxicity 1

Hot flashes, impotence, and gynecomastia. Decreased libido occurs less commonly.

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### Toxicity 2

Tumor flare. May occur in up to 20% of patients, usually within the first 2 weeks of starting therapy. May observe increased bone pain, urinary retention, or back pain with spinal cord compression. May be prevented by pretreating with an antiandrogen agent such as flutamide, bicalutamide, or nilutamide.

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### Toxicity 3

Local discomfort at the site of injection.

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### Toxicity 4

Elevated serum cholesterol levels.

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### Toxicity 5

Nausea and vomiting. Rarely observed.

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**Toxicity 6**

Hypersensitivity reaction.

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**Toxicity 7**

Myelosuppression. Rarely observed.

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**Toxicity 8**

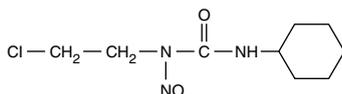
Peripheral edema. Results from sodium retention.

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**Toxicity 9**

Asthenia.

# Lomustine



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## Trade Names

CCNU

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## Classification

Alkylating agent

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## Category

Chemotherapy drug

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## Drug Manufacturer

Bristol-Myers Squibb

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## Mechanism of Action

- Cell cycle–nonspecific nitrosourea analog.
- Alkylation and carbamoylation by lomustine metabolites interfere with the synthesis and function of DNA, RNA, and proteins.
- Antitumor activity appears to correlate best with formation of intra-strand cross-linking of DNA.

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## Mechanism of Resistance

- Decreased cellular uptake of drug.
- Increased intracellular thiol content due to glutathione and/or glutathione-related enzymes.
- Enhanced activity of DNA repair enzymes.

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## Absorption

Readily and completely absorbed orally. Peak plasma concentrations are observed within 3 hours after oral administration.

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## Distribution

Lipid-soluble drug with broad tissue distribution. Well-absorbed after oral administration and crosses the blood-brain barrier. CNS levels approach 15%–30% of plasma levels.

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## Metabolism

Metabolized by the liver microsomal P<sub>450</sub> system to active metabolites. The elimination half-life of the drug is about 72 hours, and excretion mainly occurs via the kidneys. Approximately 50% of a dose is excreted in urine within the first 12–24 hours, while 60% of a dose is excreted after 48 hours.

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## Indications

1. Brain tumors—primary or metastatic.
2. Hodgkin's disease.
3. Non-Hodgkin's lymphoma.

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## Dosage Range

As a single agent, the recommended dose in previously untreated patients is 130 mg/m<sup>2</sup> PO every 6 weeks. In patients with compromised bone marrow function, the dose should be reduced to 100 mg/m<sup>2</sup> PO every 6 weeks.

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## Drug Interaction 1

Cimetidine—Cimetidine enhances the toxicity of lomustine.

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## Drug Interaction 2

Alcohol—Ingestion of alcohol should be avoided for at least 1 hour before and after administration of lomustine.

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## Special Considerations

1. Monitor CBC while on therapy. Subsequent cycles should not be given before 6 weeks, given the delayed and potentially cumulative effects of the drug. Platelet and leukocyte counts must return to normal before starting the next course of therapy.
2. PFTs should be obtained at baseline and monitored periodically during therapy. There is an increased risk of pulmonary toxicity in patients with a prior history of lung disease and a baseline FVC or DLCO below 70% of predicted.
3. Administer drug on an empty stomach as food may inhibit absorption.
4. Pregnancy category D.

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## Toxicity 1

Myelosuppression. Dose-limiting toxicity. In contrast to most other anticancer agents, myelosuppression involving all elements is delayed and cumulative. Nadirs typically occur 4–6 weeks after therapy and may persist for 1–3 weeks.

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**Toxicity 2**

Nausea and vomiting may occur within 2–6 hours after a dose of drug and can last for up to 24 hours.

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**Toxicity 3**

Anorexia may be present but short-lived. Mucositis is unusual.

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**Toxicity 4**

Impotence, male sterility, amenorrhea, ovarian suppression, menopause, and infertility. Gynecomastia is occasionally observed.

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**Toxicity 5**

Pulmonary toxicity is uncommon at doses lower than 1,100 mg/m<sup>2</sup>.

Interstitial lung disease and pulmonary fibrosis in the form of an insidious cough, dyspnea, pulmonary infiltrates, and/or respiratory failure may be observed.

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**Toxicity 6**

Renal toxicity is uncommon at total cumulative doses of lower than 1,000 mg/m<sup>2</sup>. Usually manifested by progressive azotemia and decrease in kidney size, which can progress to renal failure.

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**Toxicity 7**

Neurotoxicity in the form of confusion, lethargy, dysarthria, and ataxia.

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**Toxicity 8**

Increased risk of secondary malignancies with long-term use, especially acute myelogenous leukemia and myelodysplasia.

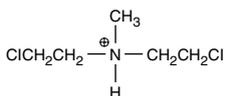
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**Toxicity 9**

Alopecia is rarely seen.

# M

## Mechlorethamine



### Trade Names

Mustargen, Nitrogen mustard

### Classification

Alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

Merck

### Mechanism of Action

- Analog of mustard gas.
- Classic alkylating agent that forms interstrand and intrastrand cross-links with DNA resulting in inhibition of DNA synthesis and function.
- Cell cycle–nonspecific with activity in all phases of the cell cycle.

### Mechanism of Resistance

- Decreased cellular uptake of drug.
- Increased inactivation of cytotoxic species through increased expression of sulfhydryl proteins, including glutathione and glutathione-associated enzymes.
- Enhanced activity of DNA repair enzymes.

### Absorption

Not orally bioavailable.

### Distribution

Distribution of drug is not well characterized.

### Metabolism

Undergoes rapid hydrolysis in plasma to reactive metabolites. Extremely short plasma half-life on the order of 15–20 minutes. No significant organ metabolism. Greater than 50% of inactive drug metabolites are excreted in urine within 24 hours.

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### Indications

1. Hodgkin's disease.
2. Non-Hodgkin's lymphoma.
3. Cutaneous T-cell lymphoma (topical use).
4. Intrapleural, intrapericardial, and intraperitoneal treatment of metastatic disease resulting in pleural effusion.

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### Dosage Range

1. Hodgkin's disease: Administer 6 mg/m<sup>2</sup> IV on days 1 and 8 every 28 days, as part of the MOPP regimen.
2. Cutaneous T-cell lymphoma: Dilute 10 mg in 60 mL sterile water and apply topically to skin lesions.
3. Intracavitary use: Administer 0.2–0.4 mg/kg into the pleural and/or peritoneal cavity.

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### Drug Interactions

Sodium thiosulfate—Sodium thiosulfate inactivates the activity of mechlorethamine.

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### Special Considerations

1. Mechlorethamine is a potent vesicant, and caution should be exercised in preparing and administering the drug.
2. Administer drug into either a new IV site or one that is less than 24 hours old to decrease the risk of extravasation.
3. In the event of drug extravasation, inflammation and necrosis may be prevented by the immediate instillation of 2.6% sodium thiosulfate solution into the area to neutralize the active drug. Elevate arm and apply ice packs for 6–12 hours. May need to consult a plastic surgeon for further evaluation.
4. Pregnancy category D.

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### Toxicity 1

Myelosuppression. Dose-limiting toxicity. Leukopenia and thrombocytopenia are equally affected. Nadirs occur at day 7–10 and recover by day 21.

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### Toxicity 2

Nausea and vomiting. Usually occur within the first 3 hours after drug administration, lasting for 4–8 hours and up to 24 hours, and often severe. Can be dose limiting in some patients.

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### Toxicity 3

Potent vesicant. Pain, inflammation, erythema, induration, and necrosis can be observed at the injection site.

M

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**Toxicity 4**

Alopecia.

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**Toxicity 5**

Amenorrhea and azoospermia.

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**Toxicity 6**

Hyperuricemia.

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**Toxicity 7**

CNS toxicities, including weakness, sleepiness, and headache, are rare.

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**Toxicity 8**

Hypersensitivity reactions. Rarely observed.

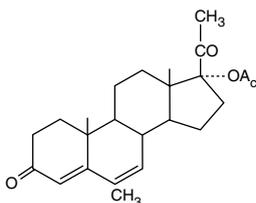
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**Toxicity 9**

Increased risk of secondary malignancies including acute myelogenous leukemia with IV administration and basal cell and squamous cell cancers of the skin with topical application.

# Megestrol acetate

M



## Trade Names

Megace

## Classification

Progestational agent

## Category

Hormonal agent

## Drug Manufacturer

Bristol-Myers Squibb

## Mechanism of Action

- Synthetic derivative of the naturally occurring steroid hormone progesterone.
- Possesses anti-estrogenic effects. Induces the activity of 17-hydroxysteroid dehydrogenase, which then oxidizes estradiol to the less active metabolite estrone. Also activates estrogen sulfatransferase, which metabolizes estrogen to less potent metabolites.
- Inhibits release of luteinizing hormone receptors resulting in a decrease in estrogen levels.
- Inhibits stability, availability, and turnover of estrogen receptors.

## Mechanism of Resistance

None known.

## Absorption

Rapidly and completely absorbed after an oral dose. Peak plasma concentration is reached within 1–3 hours after oral administration.

## Distribution

Large fraction of megestrol is distributed into body fat.

# M

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## Metabolism

About 70% of drug is metabolized in the liver to inactive steroid metabolites. The drug is primarily eliminated in urine in the form of parent drug and metabolites, and 60%–80% of the drug is renally excreted within 10 days after administration. Elimination half-life is quite variable and ranges from 15 to 105 hours with a mean of 34 hours.

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## Indications

1. Breast cancer.
2. Endometrial cancer.
3. Renal cell cancer.
4. Appetite stimulant in cancer and HIV patients.

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## Dosage Range

1. Breast cancer: 40 mg PO qid.
2. Endometrial cancer: 40 mg PO qid.
3. Appetite stimulant: 80–200 mg PO qid.

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## Drug Interactions

Aminoglutethimide—Aminoglutethimide enhances the hepatic metabolism of megestrol resulting in decreased serum levels.

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## Special Considerations

1. Use with caution in patients with either a history of thromboembolic or hypercoagulable disorders as megestrol acetate has been associated with an increased incidence of thromboembolic events.
2. Use with caution in patients with diabetes mellitus as megestrol may exacerbate this condition.
3. Use with caution in patients with abnormal liver function. Dose reduction is recommended in this setting.
4. Caution patients on the risk of weight gain and fluid retention. Patients should be advised to go on a low-salt diet.
5. Pregnancy category D.

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## Toxicity 1

Weight gain results from a combination of fluid retention and increased appetite.

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## Toxicity 2

Thromboembolic events are rarely observed.

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## Toxicity 3

Nausea and vomiting.

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**Toxicity 4**

Break-through menstrual bleeding.

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**Toxicity 5**

Tumor flare.

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**Toxicity 6**

Hyperglycemia.

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**Toxicity 7**

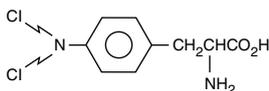
Hot flashes, sweating, and mood changes.



M

# M

## Melphalan



### Trade Names

Alkeran, Phenylalanine mustard, L-PAM

### Classification

Alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

GlaxoSmithKline

### Mechanism of Action

- Analog of nitrogen mustard.
- Classic bifunctional alkylating agent that forms interstrand and intrastrand cross-links with DNA resulting in inhibition of DNA synthesis and function.
- Cell cycle–nonspecific as it acts at all stages of the cell cycle.

### Mechanism of Resistance

- Decreased cellular uptake of drug.
- Increased inactivation of cytotoxic species through increased expression of sulfhydryl proteins, including glutathione and glutathione-associated enzymes.
- Enhanced activity of DNA repair enzymes.

### Absorption

Oral absorption is poor and incomplete. Oral bioavailability ranges between 25% and 90% with a mean of 60%, and oral absorption is decreased when taken with food.

### Distribution

Widely distributed in all tissues. Approximately 80%–90% of drug is bound to plasma proteins.

---

### Metabolism

Undergoes rapid hydrolysis in plasma to reactive metabolites. Short plasma half-life on the order of 60–90 minutes. No significant organ metabolism. About 25%–30% of drug is excreted in urine within 24 hours after administration, with the majority of the drug being cleared in feces (up to 50%) over 6 days.

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### Indications

1. Multiple myeloma.
2. Breast cancer.
3. Ovarian cancer.
4. High-dose chemotherapy and transplant setting.
5. Polycythemia vera.

---

### Dosage Range

1. Multiple myeloma: Administer 9 mg/m<sup>2</sup> IV on days 1–4 every 4 weeks as part of the melphalan-prednisone regimen.
2. Transplant setting: Administer 140 mg/m<sup>2</sup> as a single agent in bone marrow/stem cell transplant setting.

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### Drug Interaction 1

Cimetidine—Cimetidine decreases the oral bioavailability of melphalan by up to 30%.

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### Drug Interaction 2

Steroids—Steroids enhance the antitumor effects of melphalan.

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### Drug Interaction 3

Cyclosporine—Cyclosporine enhances the risk of renal toxicity secondary to melphalan.

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### Special Considerations

1. Use with caution in patients with abnormal renal function. Although the drug has been used in high doses in the transplant setting in the face of renal dysfunction without increased toxicity, dose reduction should be considered in the setting of renal dysfunction.
2. When administered orally, drug should be taken on an empty stomach to maximize absorption.
3. IV administration may cause hypersensitivity reaction.
4. Monitor complete blood cell count as melphalan therapy is associated with delayed and prolonged nadir.

5. Monitor injection site for erythema, pain, and/or burning.
6. Pregnancy category D.

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**Toxicity 1**

Myelosuppression. Dose-limiting toxicity with leukopenia and thrombocytopenia equally affected. Effect may be prolonged and cumulative with a nadir 4–6 weeks after therapy.

---

**Toxicity 2**

Nausea and vomiting, mucositis, and diarrhea. Generally mild with conventional doses, but severe with high-dose therapy.

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**Toxicity 3**

Hypersensitivity reactions are rare with oral form. Observed in about 10% of patients treated with IV form of drug, and manifested as diaphoresis, urticaria, skin rashes, bronchospasm, dyspnea, tachycardia, and hypotension.

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**Toxicity 4**

Alopecia is uncommon.

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**Toxicity 5**

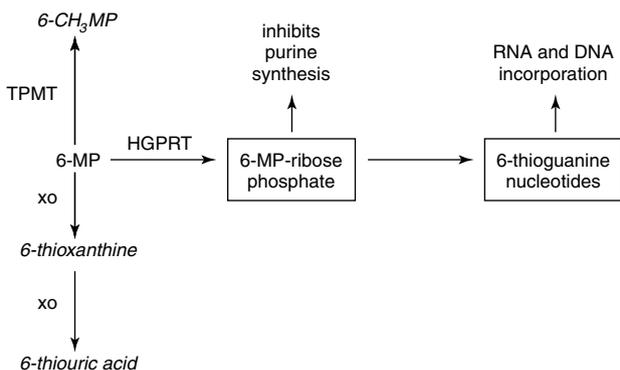
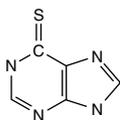
Skin ulcerations and other skin reactions at the injection site are uncommon.

---

**Toxicity 6**

Increased risk of secondary malignancies including acute myelogenous leukemia and myelodysplasia with prolonged use. Mutagenic and teratogenic.

# Mercaptopurine



## Trade Names

6-MP, Purinethol

## Classification

Antimetabolite

## Category

Chemotherapy drug

## Drug Manufacturer

GlaxoSmithKline

## Mechanism of Action

- Cell cycle-specific purine analog with activity in the S phase.
- Parent drug is inactive. Requires intracellular phosphorylation by the enzyme hypoxanthine-guanine phosphoribosyltransferase (HGPRT) to the cytotoxic monophosphate form, which is then metabolized to the eventual triphosphate metabolite.
- Inhibits de novo purine synthesis by inhibiting 5-phosphoribosyl-1-pyrophosphate (PRPP) amidotransferase.

- Incorporation of thiopurine triphosphate nucleotides into DNA resulting in inhibition of DNA synthesis and function.
- Incorporation of thiopurine triphosphate nucleotides into RNA resulting in alterations in RNA processing and/or translation.

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### Mechanism of Resistance

- Decreased expression of the activating enzyme HGPRT.
- Increased expression of the catabolic enzyme alkaline phosphatase or the conjugating enzyme thiopurine methyltransferase (TPMT).
- Decreased transmembrane transport of drug.
- Decreased expression of mismatch repair enzymes (e.g., hMLH1, hMSH2).
- Cross-resistance observed between mercaptopurine and thioguanine.

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### Absorption

Oral absorption is erratic and incomplete. Only 50% of an oral dose is absorbed.

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### Distribution

Widely distributed in total body water. Does not cross the blood-brain barrier. About 20%–30% of drug is bound to plasma proteins.

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### Metabolism

Metabolized in the liver by methylation to active metabolites and via oxidation by xanthine oxidase to inactive metabolites. About 50% of parent drug and metabolites are eliminated in urine within the first 24 hours. Plasma half-life after oral administration is 1.5 hours in contrast to the plasma half-life after IV administration, which ranges between 20 and 50 minutes.

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### Indications

Acute lymphoblastic leukemia.

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### Dosage Range

1. Induction therapy: 2.5 mg/kg PO daily.
2. Maintenance therapy: 1.5–2.5 mg/kg PO daily.

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### Drug Interaction 1

Coumadin—Anticoagulant effects of coumadin are inhibited by mercaptopurine through an unknown mechanism. Monitor coagulation parameters (PT and INR), and adjust dose accordingly.

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### Drug Interaction 2

Allopurinol—Allopurinol inhibits xanthine oxidase and the catabolic breakdown of mercaptopurine, resulting in enhanced toxicity. Dose of

mercaptopurine must be reduced by 50%–75% when given concurrently with allopurinol.

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### Drug Interaction 3

Bactrim DS may enhance the myelosuppressive effects of mercaptopurine when given concurrently.

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### Special Considerations

1. Dose reduction of 50%–75% is required when mercaptopurine is given concurrently with allopurinol. This is because allopurinol inhibits the catabolic breakdown of mercaptopurine by xanthine oxidase.
2. Use with caution in patients with abnormal liver and/or renal function. Dose reduction should be considered in this setting.
3. Use with caution in the presence of other hepatotoxic drugs as risk of mercaptopurine-associated hepatic toxicity is increased.
4. Patients with a deficiency in the metabolizing enzyme 6-thiopurine methyltransferase (TPMT) are at increased risk for developing severe toxicities. This enzyme deficiency is a pharmacogenetic syndrome.
5. Administer on an empty stomach to facilitate oral absorption. Advise patient to take mercaptopurine at bedtime.
6. Pregnancy category D.

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### Toxicity 1

Myelosuppression. Mild to moderate with leukopenia more common than thrombocytopenia. Leukopenia nadir at days 10–14 with recovery by day 21.

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### Toxicity 2

Mucositis and/or diarrhea. Usually seen with higher doses.

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### Toxicity 3

Hepatotoxicity in the form of elevated serum bilirubin and transaminases, presenting as jaundice. Usually occurs 2–3 months after therapy.

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### Toxicity 4

Mild nausea and vomiting.

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### Toxicity 5

Dry skin, urticaria, and photosensitivity.

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### Toxicity 6

Immunosuppression. Increased risk of bacterial, fungal, and parasitic infections.

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### Toxicity 7

Mutagenic, teratogenic, and carcinogenic.

# M

## Mesna

### Trade Names

Mesnex, 2-Mercaptoethanesulfonic acid

### Classification

Sulfhydryl compound

### Category

Chemoprotective agent

### Drug Manufacturer

Bristol-Myers Squibb

### Mechanism of Action

- Synthetic sulfhydryl compound with no intrinsic antitumor activity.
- Used to prevent ifosfamide- and cyclophosphamide-induced hemorrhagic cystitis.
- Mesna is initially metabolized to the dimesna form (mesna disulfide). In the kidneys, dimesna is reduced back to mesna, which then binds to and detoxifies the urotoxic ifosfamide metabolites, acrolein and 4-hydroxy ifosfamide.
- Identical mode of action to detoxify urotoxic cyclophosphamide metabolites.

### Absorption

About 75% of mesna is bioavailable after an oral dose.

### Distribution

Distributed in total body water and in the intravascular compartment.

### Metabolism

Rapidly metabolized in plasma via oxidation to its sole metabolite, dimesna. Rapidly eliminated in the kidneys, where it is reduced to mesna, the free thiol compound. Mesna then binds to acrolein and other urotoxic metabolites, and the soluble complexes are excreted in urine. Most of given dose is eliminated within 4 hours of administration, and approximately 32% of the drug is eliminated as mesna and 33% as dimesna. The half-lives of mesna and dimesna are 0.36 and 1.1 hours, respectively.

### Indications

1. Prevention of ifosfamide-induced hemorrhagic cystitis.
2. Prevention of high-dose cyclophosphamide-induced hemorrhagic cystitis.

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### Dosage Range

1. Dose of mesna is based on the administered dose of ifosfamide and/or cyclophosphamide.
2. Usually given as IV bolus three times daily at a total dose that is 60% of the administered dose of ifosfamide and/or cyclophosphamide. The first dose of mesna is given 15 minutes before ifosfamide, the second dose is given 4 hours after ifosfamide, and the third dose is given 8 hours after ifosfamide.
3. Alternative regimen is to combine equivalent doses of ifosfamide and mesna in same IV bag.
4. Mesna can be administered via a combination of intravenous and oral dosing. Mesna is given as IV bolus at a dose equal to 20% of the ifosfamide dose at the time of ifosfamide administration. Mesna tablets are given orally at a dose equal to 40% of the ifosfamide dose at 2 and 6 hours after each dose of ifosfamide. The total daily dose of mesna is 100% of the ifosfamide dose.

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### Drug Interaction 1

Cisplatin, carboplatin—Mesna is incompatible with cisplatin and carboplatin.

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### Drug Interaction 2

Epirubicin—Mesna is incompatible with epirubicin.

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### Drug Interaction 3

Ifosfamide, cyclophosphamide—Mesna decreases the risk of bladder toxicity associated with ifosfamide and cyclophosphamide but does not alter their antitumor activity.

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### Special Considerations

1. Use with caution in patients with diabetes mellitus as treatment with mesna can cause false-positive results on urinalysis for ketones.
2. Monitoring of urine for hematuria is recommended for early detection of hemorrhagic cystitis. Urinalysis should be checked for gross and/or microscopic hematuria before each dose of ifosfamide. Mesna does not prevent drug-induced hemorrhagic cystitis in all patients, especially in those receiving high doses of ifosfamide (>2–4 mg/m<sup>2</sup>).
3. Use with caution in patients with known allergies to thiol-containing compounds.
4. Patients who vomit within 2 hours of taking oral mesna should repeat the dose or receive IV mesna.

M

5. Mesna does not prevent and/or reduce any of the non-bladder adverse reactions associated with ifosfamide therapy.
6. Pregnancy category B.

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**Toxicity 1**

Mild nausea and vomiting, diarrhea.

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**Toxicity 2**

Allergic reaction in the form of skin rash or pruritus. Usually mild.

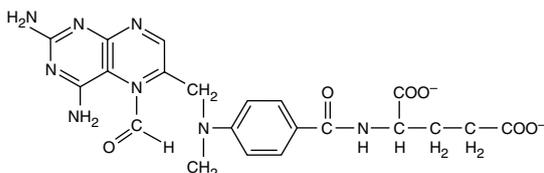
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**Toxicity 3**

Flulike symptoms, including fever, flushing, and sore throat.

# Methotrexate

M



## Trade Names

MTX, Amethopterin

## Classification

Antimetabolite

## Category

Chemotherapy drug

## Drug Manufacturer

Lederle Laboratories and Immunex

## Mechanism of Action

- Cell cycle-specific antifolate analog, active in S-phase of the cell cycle.
- Enters cells through specific transport systems mediated by the reduced folate carrier and the folate receptor protein.
- Requires polyglutamation by the enzyme folylpolyglutamate synthase (FPGS) for its cytotoxic activity.
- Inhibition of dihydrofolate reductase (DHFR) resulting in depletion of critical reduced folates.
- Inhibition of de novo thymidylate synthesis.
- Inhibition of de novo purine synthesis.
- Incorporation of dUTP into DNA resulting in inhibition of DNA synthesis and function.

## Mechanism of Resistance

- Increased expression of the target enzyme DHFR through either gene amplification or increased transcription, translation, and/or post-translational events.
- Alterations in the binding affinity of DHFR for methotrexate.

- Decreased carrier-mediated transport of drug into cell through decreased expression and/or activity of reduced folate carrier (RFC) or folate-receptor protein.
- Decreased formation of cytotoxic MTX polyglutamates through either decreased expression of FPGS or increased expression of gamma-glutamyl hydrolase (GGH).
- Decreased expression of MMR enzymes may contribute to the development of resistance.

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### Absorption

Oral bioavailability is saturable and erratic at doses greater than 25 mg/m<sup>2</sup>. Peak serum levels are achieved within 1–2 hours of oral administration. Methotrexate is completely absorbed from parenteral routes of administration, and peak serum concentrations are reached in 30–60 minutes after IM injection.

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### Distribution

Widely distributed throughout the body. At conventional doses, CSF levels are only about 5%–10% of those in plasma. High-dose MTX yields therapeutic concentrations in the CSF. Distributes into third-space fluid collections such as pleural effusion and ascites. Only about 50% of drug bound to plasma proteins, mainly to albumin.

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### Metabolism

Extensive metabolism in liver and in cells by FPGS to higher polyglutamate forms. About 10%–20% of parent drug and the 7-hydroxymetabolite are eliminated in bile and then reabsorbed via enterohepatic circulation. Renal excretion is the main route of elimination and is mediated by glomerular filtration and tubular secretion. About 80%–90% of an administered dose is eliminated unchanged in urine within 24 hours. Terminal half-life of drug is on the order of 8–10 hours.

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### Indications

1. Breast cancer.
2. Head and neck cancer.
3. Osteogenic sarcoma.
4. Acute lymphoblastic leukemia.
5. Non-Hodgkin's lymphoma.
6. Meningeal leukemia and carcinomatous meningitis.
7. Bladder cancer.
8. Gestational trophoblastic cancer.

---

### Dosage Range

1. Low dose: 10–50 mg/m<sup>2</sup> IV every 3–4 weeks.
2. Low dose weekly: 25 mg/m<sup>2</sup> IV weekly.
3. Moderate dose: 100–500 mg/m<sup>2</sup> IV every 2–3 weeks.
4. High dose: 1–12 gm/m<sup>2</sup> IV over a 3- to 24-hour period every 1–3 weeks.
5. Intrathecal: 10–15 mg IT two times weekly until CSF is clear, then weekly dose for 2–6 weeks, followed by monthly dose.
6. Intramuscular: 25 mg/m<sup>2</sup> IM every 3 weeks.

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### Drug Interaction 1

Aspirin, penicillins, probenecid, nonsteroidal anti-inflammatory agents, cephalosporins, and phenytoin—These drugs inhibit the renal excretion of methotrexate leading to enhanced drug effect and toxicity.

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### Drug Interaction 2

Warfarin—Methotrexate may enhance the anticoagulant effect of warfarin through competitive displacement from plasma proteins.

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### Drug Interaction 3

5-Fluorouracil—Methotrexate enhances the antitumor activity of 5-fluorouracil when given 24 hours before fluoropyrimidine treatment.

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### Drug Interaction 4

Leucovorin—Leucovorin rescues the host toxic effects of methotrexate and may also impair the antitumor activity.

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### Drug Interaction 5

Thymidine—Thymidine rescues the host toxic effects of methotrexate and may also impair the antitumor activity.

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### Drug Interaction 6

Folic acid supplements—Folic acid supplements may counteract the antitumor effects of methotrexate and should be discontinued while on therapy.

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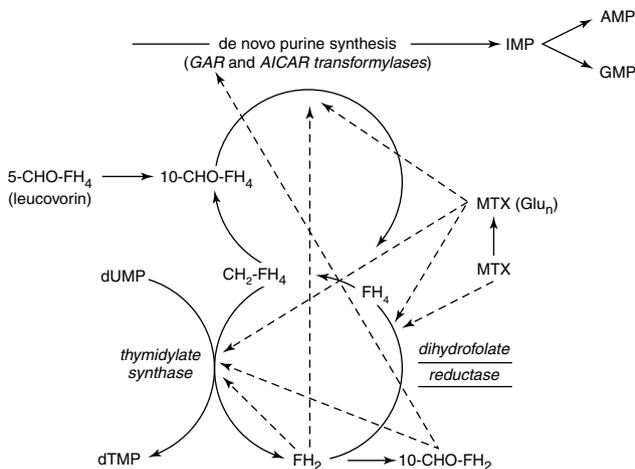
### Drug Interaction 7

Omeprazole—Omeprazole increases serum methotrexate levels, leading to enhanced antitumor activity and host toxicity.

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### Drug Interaction 8

L-Asparaginase—L-Asparaginase antagonizes the antitumor activity of methotrexate.



Compound	Inhibits
MTX	dihydrofolate reductase
MTX (Glu <sub>n</sub> )	{ dihydrofolate reductase thymidylate synthase AICAR transformylase GAR transformylase
FH <sub>2</sub> (Glu <sub>n</sub> )	{ thymidylate synthase AICAR transformylase GAR transformylase
10-CHO-FH <sub>2</sub> (Glu <sub>n</sub> )	{ thymidylate synthase GAR transformylase

### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose should be reduced in proportion to the creatinine clearance. Important to obtain baseline creatinine clearance and to monitor renal status during therapy.
2. Instruct patients to stop folic acid supplements during therapy as they may counteract the effects of methotrexate.
3. Monitor complete blood counts on a weekly basis and more frequently with high-dose therapy.
4. Use with caution in patients with third-space fluid collections such as pleural effusion and ascites, as the half-life of methotrexate is prolonged, leading to enhanced clinical toxicity. Fluid collections should be drained before methotrexate therapy.



5. Use with caution in patients with bladder cancer status post cystectomy and ileal conduit diversion as they are at increased risk for delayed elimination of methotrexate and subsequent toxicity.
6. With high-dose therapy, methotrexate doses  $>1 \text{ gm/m}^2$ , important to vigorously hydrate the patient with 2.5–3.5 liters/ $\text{m}^2$ /day of IV 0.9% sodium chloride starting 12 hours before and for 24–48 hours after methotrexate infusion. Sodium bicarbonate (1–2 amps/L solution) should be included in the IV fluid to ensure that the urine pH is greater than 7.0 at the time of drug infusion and ideally for up to 48–72 hours after drug is given.
7. Methotrexate blood levels should be monitored in patients receiving high-dose therapy, patients with renal dysfunction (creatinine clearance  $<60 \text{ mL/min}$ ) regardless of dose, and patients who have experienced excessive toxicity with prior treatment with methotrexate.
8. With high-dose therapy, methotrexate blood levels should be monitored every 24 hours starting at 24 hours after methotrexate infusion. Leucovorin rescue should begin at 24 hours after drug infusion and should continue until the methotrexate drug level is  $<50 \text{ nM}$ .
9. Patients should be instructed to lie on their side for at least 1 hour after intrathecal administration of methotrexate. This will ensure adequate delivery of drug throughout the CSF.
10. Intrathecal administration of methotrexate may lead to myelosuppression and/or mucositis as therapeutic blood levels can be achieved.
11. Methotrexate overdose can be treated with leucovorin and/or thymidine.
12. Instruct patients to avoid sun exposure for at least 1 month after therapy.
13. Pregnancy category D.

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#### Toxicity 1

Myelosuppression. Dose-limiting toxicity with leukocyte nadir at days 4–7 and recovery usually by day 14.

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#### Toxicity 2

Mucositis. Can be dose-limiting. Typical onset is 3–7 days after methotrexate therapy and precedes the decrease in leukocyte and platelet count. Nausea and vomiting are dose-dependent.

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#### Toxicity 3

Acute renal failure, azotemia, urinary retention, and uric acid nephropathy. Renal toxicity results from the intratubular precipitation of methotrexate

and its metabolites. Methotrexate itself may exert a direct toxic effect on the renal tubules.

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#### Toxicity 4

Transient elevation in serum transaminases and bilirubin are often observed with high-dose therapy. May occur within the first 12–24 hours after start of infusion and returns to normal within 10 days.

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#### Toxicity 5

Poorly defined pneumonitis characterized by fever, cough, and interstitial pulmonary infiltrates.

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#### Toxicity 6

Acute chemical arachnoiditis with severe headaches, nuchal rigidity, seizures, vomiting, fever, and an inflammatory cell infiltrate in the CSF observed immediately after intrathecal administration. Chronic, demyelinating encephalopathy observed in children months to years after intrathecal methotrexate and presents as dementia, limb spasticity, and in advanced cases, coma.

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#### Toxicity 7

Acute cerebral dysfunction with paresis, aphasia, behavioral abnormalities, and seizures observed in 5%–15% of patients receiving high-dose methotrexate. Usually occurs within 6 days of treatment and resolves within 48–72 hours. A chronic form of neurotoxicity manifested as an encephalopathy with dementia and motor paresis can develop 2–4 months after treatment.

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#### Toxicity 8

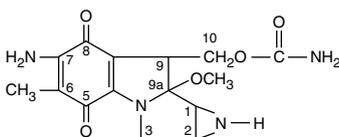
Erythematous skin rash, pruritus, urticaria, photosensitivity, and hyperpigmentation. Radiation recall skin reaction is also observed.

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#### Toxicity 9

Menstrual irregularities, abortion, and fetal deaths in women. Reversible oligospermia with testicular failure reported in men with high-dose therapy.

# Mitomycin-C



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## Trade Names

Mutamycin, Mitomycin

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## Classification

Antitumor antibiotic

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## Category

Chemotherapy drug

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## Drug Manufacturer

Bristol-Myers Squibb

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## Mechanism of Action

- Isolated from the broth of *Streptomyces caespitosus* species.
- Acts as an alkylating agent to cross-link DNA resulting in inhibition of DNA synthesis and function.
- Inhibits transcription by targeting DNA-dependent RNA polymerase.
- Bioreductive activation by NADPH cytochrome P450 reductase, NADH cytochrome B450 reductase, and DT-diaphorase to oxygen free radical forms, semiquinone or hydroquinone species, which target DNA and inhibit DNA synthesis and function.
- Preferential activation of mitomycin-C in hypoxic tumor cells.

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## Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with elevated P170 protein levels. This leads to increased drug efflux and decreased intracellular drug accumulation. Cross-resistance to anthracyclines, vinca alkaloids, and other natural products.
- Decreased bioactivation through decreased expression of DT-diaphorase.
- Increased activity of DNA excision repair enzymes.
- Increased expression of glutathione and glutathione-dependent detoxifying enzymes.



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### Absorption

Not available for oral use and is administered only by the IV route.

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### Distribution

Rapidly cleared from plasma after IV administration and widely distributed to tissues. Does not cross the blood-brain barrier.

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### Metabolism

Metabolism in the liver with formation of both active and inactive metabolites. Mediated by the liver cytochrome P<sub>450</sub> system and DT-diaphorase. Bioactivation can also occur in spleen, kidney, and heart. Parent compound and its metabolites are excreted mainly through the hepatobiliary system into feces. Renal clearance accounts for only 8%–10% of drug elimination. Elimination half-life of about 50 minutes.

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### Indications

1. Gastric cancer.
2. Pancreatic cancer.
3. Breast cancer.
4. Non–small cell lung cancer.
5. Cervical cancer.
6. Head and neck cancer (in combination with radiation therapy).
7. Superficial bladder cancer.

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### Dosage Range

1. Gastric cancer: 10 mg/m<sup>2</sup> IV every 8 weeks, as part of the FAM regimen.
2. Breast cancer: Usual dose in various combination regimens is 10 mg/m<sup>2</sup> IV every 8 weeks.
3. Intravesicular therapy: Usual dose for intravesicular instillation is 40 mg administered in 20 mL of water.

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### Drug Interactions

None well characterized.

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### Special Considerations

1. Use with caution in patients with abnormal liver function. Dose reduction is required in the setting of liver dysfunction.
2. Because mitomycin-C is a potent vesicant, administer slowly over 30–60 minutes with a rapidly flowing IV. Administer drug carefully, usually through a central venous catheter. Careful monitoring is necessary to avoid extravasation. If extravasation is suspected,



immediately stop infusion, withdraw fluid, elevate extremity, and apply ice to involved site. May administer local steroids. In severe cases, consult a plastic surgeon.

3. Monitor complete blood cell counts on a weekly basis. Mitomycin-C therapy results in delayed and cumulative myelosuppression.
4. Monitor patients for acute dyspnea and severe bronchospasm following drug administration. Bronchodilators, steroids, and/or oxygen may help to relieve symptoms. Risk of pulmonary toxicity increased with cumulative doses of mitomycin-C  $>60$  mg.
5. FIO<sub>2</sub> concentrations in the perioperative period should be maintained below 50% as patients receiving mitomycin-C concurrently with other anticancer agents are at increased risk for developing ARDS. Careful attention to fluid status is important.
6. Monitor for signs of hemolytic-uremic syndrome (anemia with fragmented cells on peripheral blood smear, thrombocytopenia, and renal dysfunction), especially when total cumulative doses of mitomycin-C are  $>60$  mg.
7. Monitor when used in combination with other myelosuppressive anticancer agents.
8. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting and cumulative toxicity with leukopenia being more common than thrombocytopenia. Nadir counts are delayed at about 4–6 weeks.

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#### Toxicity 2

Nausea and vomiting. Usually mild and occurs within 1–2 hours of treatment, lasting for up to 3 days.

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#### Toxicity 3

Mucositis is common but not dose-limiting. Observed within the first week of treatment.

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#### Toxicity 4

Potent vesicant. Extravasation can lead to tissue necrosis and chemical thrombophlebitis at the site of injection.

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#### Toxicity 5

Anorexia and fatigue are common.

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#### Toxicity 6

Hemolytic-uremic syndrome. Consists of microangiopathic hemolytic anemia (hematocrit  $<25\%$ ), thrombocytopenia ( $<100,000/\text{mm}^3$ ), and renal



failure (serum creatinine  $>1.6$  mg/dL). Other complications include pulmonary edema, neurologic abnormalities, and hypertension. Rare event, seen in  $<2\%$  of patients treated. Can occur at any time during treatment but usually occurs at total doses  $>60$  mg. Syndrome can be fatal.

---

#### Toxicity 7

Interstitial pneumonitis. Presents with dyspnea, nonproductive cough, and interstitial infiltrates on chest x-ray. Occurs more frequently with total cumulative doses  $>60$  mg.

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#### Toxicity 8

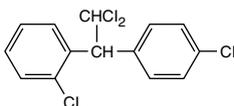
Hepatic veno-occlusive disease. Presents with abdominal pain, hepatomegaly, and liver failure. Occurs only with high-dose therapy in transplant setting.

---

#### Toxicity 9

Chemical cystitis and bladder contraction. Observed only in setting of intravesicular therapy.

# Mitotane



## Trade Names

Lysodren

## Classification

Adrenolytic agent

## Category

Chemotherapy drug

## Drug Manufacturer

Bristol-Myers Squibb

## Mechanism of Action

- Dichloro derivative of the insecticide DDD.
- Direct toxic effect on mitochondria of adrenal cortical cells resulting in inhibition of adrenal steroid production.
- Alters the peripheral metabolism of steroids resulting in decreased levels of 17-OH corticosteroid.

## Absorption

About 35%–45% of an oral dose is absorbed. Peak plasma levels are achieved in 3–5 hours.

## Distribution

Widely distributed to tissues. Highly fat-soluble with large amounts of drug distributed in adipose tissues. Mitotane is slowly released with drug levels being detectable for up to 10 weeks. Does not cross the blood-brain barrier.

## Metabolism

Metabolism in the liver with formation of both active and inactive metabolites. Parent compound and its metabolites are excreted mainly through the hepatobiliary system into feces (60%). Renal clearance accounts for only 10%–25% of drug elimination. Variable elimination half-life of up to 160 hours due to storage of drug in adipose tissue.

# M

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## Indications

Adrenocortical cancer.

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## Dosage Range

Usual dose is 2–10 gm/day PO in three or four divided doses.

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## Drug Interaction 1

Warfarin—Mitotane alters the metabolism of warfarin, leading to an increased requirement for warfarin. Coagulation parameters, including PT and INR, should be monitored closely, and dose adjustments made accordingly.

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## Drug Interaction 2

Barbiturates, phenytoin, cyclophosphamide—Mitotane alters the metabolism of various drugs that are metabolized by the liver microsomal P450 system, including barbiturates, phenytoin, and cyclophosphamide.

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## Drug Interaction 3

Steroids—Mitotane interferes with steroid metabolism. If steroid replacement is required, doses higher than those for physiologic replacement may be needed.

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## Special Considerations

1. Use with caution in patients with abnormal liver function. Dose reduction is required in the setting of liver dysfunction.
  2. Adrenal insufficiency may develop, and adrenal steroid replacement with glucocorticoid and/or mineralocorticoid therapy is indicated.
  3. Stress-dose IV steroids are required in the event of infection, stress, trauma, and/or shock.
  4. Patients should be cautioned about driving, operating complicated machinery, and/or other activities that require increased mental alertness as mitotane causes lethargy and somnolence.
  5. Concurrent use of mitotane and warfarin requires careful monitoring of coagulation parameters, including PT and INR, as mitotane can alter warfarin metabolism.
  6. Pregnancy category C.
- 

## Toxicity 1

Mild nausea and vomiting. Dose-limiting, occur in 80% of patients.

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## Toxicity 2

Lethargy, somnolence, vertigo, and dizziness. CNS side effects occur in 40% of patients.

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**Toxicity 3**

Mucositis is common but not dose-limiting. Observed within the first week of treatment.

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**Toxicity 4**

Transient skin rash and hyperpigmentation.

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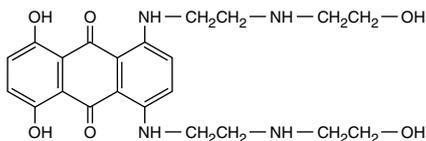
**Toxicity 5**

Adrenal insufficiency. Rarely occurs with steroid replacement therapy.

M

# M

## Mitoxantrone



### Trade Names

Novantrone

### Classification

Antitumor antibiotic

### Category

Chemotherapy drug

### Drug Manufacturer

OSI

### Mechanism of Action

- Synthetic planar anthracenedione analog.
- Intercalates into DNA resulting in inhibition of DNA synthesis and function.
- Inhibits topoisomerase II by forming a cleavable complex with topoisomerase II and DNA.

### Mechanism of Resistance

- Increased expression of the multidrug-resistant gene with enhanced drug efflux, resulting in decreased intracellular drug accumulation.
- Decreased expression of topoisomerase II.
- Mutation in topoisomerase II with decreased binding affinity to drug.
- Increased expression of sulphhydryl proteins, including glutathione and glutathione-associated enzymes.

### Absorption

Not orally bioavailable.

### Distribution

Rapid and extensive distribution to formed blood elements and to body tissues. Distributes in high concentrations in liver, bone marrow, heart, lung, and kidney. Does not cross the blood-brain barrier. Extensively bound

(about 80%) to plasma proteins. Peak plasma levels are achieved immediately after IV injection.

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### Metabolism

Metabolism by the liver microsomal P<sub>450</sub> system. Elimination is mainly through the hepatobiliary route with 25% of the drug excreted in feces. Renal clearance accounts for only 6%–10% of drug elimination, mainly as unchanged drug. The elimination half-life ranges from 23 to 215 hours with a median of 75 hours.

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### Indications

1. Advanced, hormone-refractory prostate cancer—Used in combination with prednisone as initial chemotherapy.
2. Acute myelogenous leukemia.
3. Breast cancer.
4. Non-Hodgkin's lymphoma.

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### Dosage Range

1. Acute myelogenous leukemia, induction therapy: 12 mg/m<sup>2</sup> IV on days 1–3, given in combination with ara-C, 100 mg/m<sup>2</sup>/day IV continuous infusion for 5–7 days.
2. Prostate cancer: 12 mg/m<sup>2</sup> IV on day 1 every 21 days, given in combination with prednisone 5 mg PO bid.
3. Non-Hodgkin's lymphoma: 10 mg/m<sup>2</sup> IV on day 1 every 21 days, given as part of the CNOP or FND regimens.

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### Drug Interactions

Heparin—Mitoxantrone is incompatible with heparin as a precipitate will form.

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### Special Considerations

1. Use with caution in patients with abnormal liver function. Dose modification should be considered in patients with liver dysfunction.
2. Carefully monitor the IV injection site as mitoxantrone is a vesicant. Skin may turn blue at site of injection. Avoid extravasation, but ulceration and tissue injury are rare when drug is properly diluted.
3. Alkalinization of the urine, allopurinol, and vigorous IV hydration are recommended to prevent tumor lysis syndrome in patients with acute myelogenous leukemia.
4. Monitor cardiac function prior to (baseline) and periodically during therapy with either MUGA radionuclide scan or echocardiogram to assess LVEF. Risk of cardiac toxicity is higher in elderly patients >70 years of age, in patients with prior history of hypertension

M

or preexisting heart disease, in patients previously treated with anthracyclines, or in patients with prior radiation therapy to the chest. Cumulative doses of 140 mg/m<sup>2</sup> in patients with no prior history of anthracycline therapy and 120 mg/m<sup>2</sup> in patients with prior anthracycline therapy are associated with increased risk for cardiotoxicity. A decrease in LVEF by 15%–20% is an indication to discontinue treatment.

5. Monitor complete blood counts while on therapy.
6. Patients may experience blue-green urine for up to 24 hours after drug administration.
7. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting toxicity. Leukocytes more commonly affected than platelets. Nadir typically occurs at 10–14 days after treatment but may occur earlier in acute leukemia, with recovery of counts by day 21. Risk of myelosuppression is greater in elderly patients and in those previously treated with chemotherapy and/or radiation therapy.

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#### Toxicity 2

Nausea and vomiting are observed in 70% of patients. Usually mild, occurs less frequently than with doxorubicin.

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#### Toxicity 3

Mucositis and diarrhea. Common but usually not severe.

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#### Toxicity 4

Cardiotoxicity. Cardiac effects are similar to but less severe than those of doxorubicin. Acute toxicity presents as atrial arrhythmias, chest pain, and myopericarditis syndrome that typically occurs within the first 24–48 hours of drug administration. Transient and mostly asymptomatic.

Chronic toxicity is manifested in the form of a dilated cardiomyopathy with congestive heart failure. Cumulative doses of 140 mg/m<sup>2</sup> in patients with no prior history of anthracycline therapy and 120 mg/m<sup>2</sup> in patients with prior anthracycline therapy are associated with increased risk for developing congestive cardiomyopathy.

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#### Toxicity 5

Allopecia. Observed in 40% of patients but less severe than with doxorubicin.

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#### Toxicity 6

Transient and reversible effects on liver enzymes including SGOT and SGPT.

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**Toxicity 7**

Blue discoloration of fingernails, sclera, and urine for 1–2 days after treatment.

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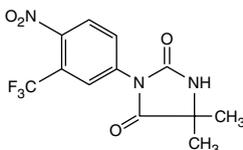
**Toxicity 8**

Secondary acute myelogenous leukemia.

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# N

## Nilutamide



### Trade Names

Nilandron

### Classification

Anti-androgen

### Category

Hormonal drug

### Drug Manufacturer

Sanofi-Aventis

### Mechanism of Action

Nonsteroidal, anti-androgen agent that binds to androgen receptor and inhibits androgen uptake. It also inhibits androgen binding in the nucleus of androgen-sensitive prostate cancer cells.

### Mechanism of Resistance

- Decreased expression of androgen receptor.
- Mutation in androgen receptor leading to decreased binding affinity to nilutamide.

### Absorption

Rapidly and completely absorbed by the GI tract. Absorption is not affected by food.

### Distribution

Distribution is not well characterized. Moderate binding of nilutamide to plasma proteins.

### Metabolism

Extensive metabolism occurs in the liver to both active and inactive metabolites. About 60% of the drug is excreted in urine, mainly in metabolite form, and only minimal clearance in feces. The elimination half-life is approximately 41–49 hours.

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### Indications

Stage D2 metastatic prostate cancer in combination with surgical castration.

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### Dosage Range

Recommended dose is 300 mg PO daily for 30 days, then 150 mg PO daily.

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### Drug Interaction 1

Warfarin—Nilutamide can inhibit metabolism of warfarin by the liver P<sub>450</sub> system leading to increased anticoagulant effect. Coagulation parameters, PT and INR, must be followed routinely, and dose adjustments may be needed.

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### Drug Interaction 2

Drugs metabolized by the liver P<sub>450</sub> system—Nilutamide inhibits the activity of liver cytochrome P<sub>450</sub> enzymes and may therefore reduce the metabolism of various compounds, including phenytoin and theophylline. Enhanced toxicity of these agents may be observed, requiring dose adjustment.

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### Drug Interaction 3

Alcohol—Increased risk of alcohol intolerance following treatment with nilutamide.

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### Special Considerations

1. Should be given on the same day or on the day after surgical castration to achieve maximal benefit.
2. Nilutamide can be taken with or without food.
3. Should be used with caution in patients with abnormal liver function and is contraindicated in patients with severe liver impairment. Monitor liver function tests at baseline and during therapy.
4. Contraindicated in patients with severe respiratory insufficiency. Baseline PFTs and chest x-ray should be obtained in all patients and periodically during therapy. If findings of interstitial pneumonitis appear on chest x-ray or there is a significant decrease by 20%–25% in DLCO and FVC on PFTs, treatment with nilutamide should be terminated.
5. Caution patients about the potential for hot flashes. Consider the use of clonidine 0.1–0.2 mg PO daily, Megace 20 mg PO bid, or soy tablets one tablet PO tid for prevention and/or treatment.
6. Instruct patients on the potential risk of altered sexual function and impotence.

7. Patients should be advised to abstain from alcohol while on nilutamide as there is an increased risk of intolerance (facial flushes, malaise, hypotension) to alcohol.
8. Pregnancy category C.

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#### Toxicity 1

Hot flashes, decreased libido, impotence, gynecomastia, nipple pain, and galactorrhea.

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#### Toxicity 2

Visual disturbances in the form of impaired adaptation to dark, abnormal vision, and alterations in color vision. Occurs in up to 57% of patients and results in treatment discontinuation in 1%–2% of patients.

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#### Toxicity 3

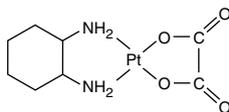
Anorexia, nausea, and constipation. Transient elevations in serum transaminases are uncommon.

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#### Toxicity 4

Cough, dyspnea, and interstitial pneumonitis occur rarely in about 2% of patients. Usually observed within the first 3 months of treatment. Incidence may be higher in patients of Asian descent.

# Oxaliplatin



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## Trade Names

Diaminocyclohexane platinum, DACH-platinum, Eloxatin

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## Classification

Platinum analog

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## Category

Chemotherapy drug

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## Drug Manufacturer

Sanofi-Aventis

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## Mechanism of Action

- Third-generation platinum compound.
- Cell cycle–nonspecific with activity in all phases of the cell cycle.
- Covalently binds to DNA with preferential binding to the N-7 position of guanine and adenine.
- Reacts with two different sites on DNA to produce cross-links, either intrastrand (>90%) or interstrand (<5%). Formation of DNA adducts results in inhibition of DNA synthesis and function as well as inhibition of transcription.
- DNA mismatch repair enzymes are unable to recognize oxaliplatin-DNA adducts in contrast with other platinum-DNA adducts as a result of their bulkier size.
- Binding to nuclear and cytoplasmic proteins may result in additional cytotoxic effects.

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## Mechanism of Resistance

- Decreased drug accumulation due to alterations in cellular transport.
- Increased inactivation by thiol-containing proteins such as glutathione and glutathione-related enzymes.
- Increased DNA repair enzyme activity (e.g., ERCC-1).
- Non–cross-resistant to cisplatin and carboplatin in tumor cells that are deficient in MMR enzymes (e.g., hMHL1, hMSH2).

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### Absorption

Not orally bioavailable.

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### Distribution

Widely distributed to all tissues with a 50-fold higher volume of distribution than cisplatin. About 40% of drug is sequestered in red blood cells within 2–5 hours of infusion. Extensively binds to plasma proteins in time-dependent manner (up to 98%).

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### Metabolism

Oxaliplatin undergoes extensive nonenzymatic conversion to its active cytotoxic species. As observed with cisplatin, oxaliplatin undergoes aquation reaction in the presence of low concentrations of chloride. The major species are monochloro-DACH, dichloro-DACH, and mono-diaquo-DACH platinum. Renal excretion accounts for >50% of oxaliplatin clearance. More than 20 different metabolites have been identified in the urine. Only 2% of drug is excreted in feces. Prolonged terminal half-life of up to 240 hours.

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### Indications

1. Metastatic colorectal cancer—FDA-approved as second-line therapy in combination with 5-FU/LV (FOLFOX<sub>4</sub>) in patients whose disease has recurred or progressed during or within 6 months of completion of first-line therapy with the combination of bolus 5-FU/LV and irinotecan (IFL Saltz regimen).
  2. Metastatic colorectal cancer—FDA-approved as first-line therapy in combination with 5-FU/LV (FOLFOX<sub>4</sub>).
  3. Early-stage colon cancer—FDA-approved as adjuvant therapy in combination with 5-FU/LV (FOLFOX<sub>4</sub>) in patients with stage III colon cancer and in those with high-risk stage II disease.
  4. Pancreatic cancer.
  5. Gastric cancer.
- 

### Dosage Range

Recommended dose is 85 mg/m<sup>2</sup> IV over 2 hours, on an every-2-week schedule. Can also administer 130 mg/m<sup>2</sup> IV on an every-3-week schedule.

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### Drug Interactions

None known.

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### Special Considerations

1. Use with caution in patients with abnormal renal function, especially when CrCl <20 mL/min. Baseline creatinine clearance should be obtained, and renal status should be closely monitored during treatment.

2. Oxaliplatin should not be administered with basic solutions (e.g., solutions containing 5-FU) as it may be partially degraded.
3. Careful neurologic evaluation should be performed before starting therapy and at the beginning of each cycle as the dose-limiting toxicity of oxaliplatin is neurotoxicity.
4. Caution patients to avoid exposure to cold following drug administration, which can trigger and/or worsen acute neurotoxicity.
5. Calcium/magnesium infusions prior to and at the completion of the oxaliplatin infusion should not be used to reduce the incidence of acute neurotoxicity, as they may impair the clinical activity of oxaliplatin-based chemotherapy.

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### Toxicity 1

Neurotoxicity with acute and chronic forms. Acute toxicity is seen in 80%–85% of patients and is characterized by a peripheral sensory neuropathy with distal paresthesias, visual and voice changes, often triggered or exacerbated by cold. Dysesthesias in the upper extremities and laryngopharyngeal region with episodes of difficulty breathing or swallowing are also observed usually within hours or 1–3 days after therapy. Risk increases upon exposure to cold and usually is spontaneously reversible. Chronic toxicity is dose-dependent with a 15% and >50% risk of impairment in proprioception and neurosensory function at cumulative doses of 850 and 1,200 mg/m<sup>2</sup>, respectively. In contrast to cisplatin-induced neurotoxicity, oxaliplatin-induced neuropathy is reversible, usually within 3–4 months of discontinuation of oxaliplatin.

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### Toxicity 2

Nausea and vomiting. Occur in 65% of patients treated with single-agent oxaliplatin and in 90% of patients treated with the combination of 5-FU/LV and oxaliplatin. Well-controlled with antiemetic therapy.

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### Toxicity 3

Diarrhea.

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### Toxicity 4

Myelosuppression. Relatively mild with thrombocytopenia and anemia more common than neutropenia.

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### Toxicity 5

Allergic reactions with facial flushing, rash, urticaria, and less frequently, bronchospasm and hypotension.

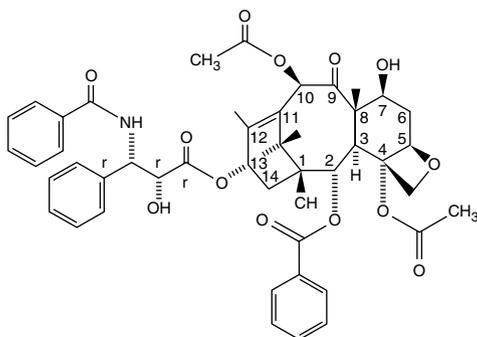
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### Toxicity 6

Renal toxicity is uncommon with only 5% of patients experiencing grade 1 toxicity.

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# Paclitaxel



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## Trade Names

Taxol

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## Classification

Taxane, antimicrotubule agent

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## Category

Chemotherapy drug

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## Drug Manufacturer

Bristol-Myers Squibb

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## Mechanism of Action

- Isolated from the bark of the Pacific yew tree, *Taxus brevifolia*.
- Cell cycle-specific, active in the mitosis (M) phase of the cell cycle.
- High-affinity binding to microtubules enhances tubulin polymerization. Normal dynamic process of microtubule network is inhibited, leading to inhibition of mitosis and cell division.

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## Mechanism of Resistance

- Alterations in tubulin with decreased binding affinity for drug.
- Multidrug-resistant phenotype with increased expression of P170 glycoprotein. Results in enhanced drug efflux with decreased intracellular accumulation of drug. Cross-resistant to other natural products, including vinca alkaloids, anthracyclines, taxanes, and VP-16.

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## Absorption

Poorly soluble and not orally bioavailable.

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### Distribution

Distributes widely to all body tissues, including third-space fluid collections such as ascites. Negligible penetration into the CNS. Extensive binding (>90%) to plasma and cellular proteins.

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### Metabolism

Metabolized extensively by the hepatic P<sub>450</sub> microsomal system. About 70%–80% of drug is excreted via fecal elimination. Less than 10% is eliminated as the parent form with the majority being eliminated metabolites. Renal clearance is relatively minor with less than 10% of drug cleared via the kidneys. Terminal elimination half-life ranges from 9 to 50 hours depending on the schedule of administration.

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### Indications

1. Ovarian cancer.
  2. Breast cancer.
  3. Non–small cell and small cell lung cancer.
  4. Head and neck cancer.
  5. Esophageal cancer.
  6. Prostate cancer.
  7. Bladder cancer.
  8. AIDS-related Kaposi's sarcoma.
- 

### Dosage Range

1. Ovarian cancer: 135–175 mg/m<sup>2</sup> IV as a 3-hour infusion every 3 weeks.
  2. Breast cancer: 175 mg/m<sup>2</sup> IV as a 3-hour infusion every 3 weeks.
  3. Bladder cancer, head and neck cancer: 250 mg/m<sup>2</sup> IV as a 24-hour infusion every 3 weeks.
  4. Weekly schedule: 80–100 mg/m<sup>2</sup> IV each week for 3 weeks with 1 week rest.
  5. Infusional schedule: 140 mg/m<sup>2</sup> as a 96-hour infusion.
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### Drug Interaction 1

Radiation therapy—Paclitaxel is a radiosensitizing agent.

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### Drug Interaction 2

Concomitant use of inhibitors and/or activators of the liver cytochrome P<sub>450</sub> CYP<sub>3A4</sub> enzyme system may affect paclitaxel metabolism and its subsequent antitumor and host toxic effects.

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### Drug Interaction 3

Phenytoin, phenobarbital—Accelerate the metabolism of paclitaxel resulting in lower plasma levels of drug.

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### Drug Interaction 4

Cisplatin, carboplatin—Myelosuppression is greater when platinum compound is administered before paclitaxel. Platinum compounds inhibit plasma clearance of paclitaxel. When a platinum analog is used in combination, paclitaxel must be given first.

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### Drug Interaction 5

Cyclophosphamide—Myelosuppression is greater when cyclophosphamide is administered before paclitaxel.

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### Drug Interaction 6

Doxorubicin—Paclitaxel reduces the plasma clearance of doxorubicin by 30%–35%, resulting in increased severity of myelosuppression.

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### Special Considerations

1. Contraindicated in patients with history of severe hypersensitivity reaction to paclitaxel or to other drugs formulated in Cremophor EL, including cyclosporine, etoposide, or teniposide.
2. Use with caution in patients with abnormal liver function. Dose reduction is required in this setting. Patients with abnormal liver function are at significantly higher risk for host toxicity. Contraindicated in patients with severe hepatic dysfunction.
3. Use with caution in patients with prior history of diabetes mellitus and chronic alcoholism or prior therapy with known neurotoxic agents such as cisplatin.
4. Use with caution in patients with previous history of ischemic heart disease, with myocardial infarction within the preceding 6 months, conduction system abnormalities, or on medications known to alter cardiac conduction (beta blockers, calcium channel blockers, and digoxin).
5. Patients should receive premedication to prevent the incidence of hypersensitivity reactions (HSR). Give dexamethasone 20 mg PO at 12 and 6 hours before drug administration, diphenhydramine 50 mg IV, and cimetidine 300 mg IV at 30 minutes before drug administration. Patients experiencing major HSR may be rechallenged after receiving multiple high doses of steroids, dexamethasone 20 mg IV every 6 hr for 4 doses. Patients should also be treated with diphenhydramine 50 mg IV and cimetidine 300 mg IV 30 minutes before the rechallenge.

6. Medical personnel should be readily available at the time of drug administration. Emergency equipment, including Ambu bag, EKG machine, IV fluids, pressors, and other drugs for resuscitation, must be at bedside before initiation of treatment.
7. Monitor patient's vital signs every 15 minutes during the first hour of drug administration. HSR usually occurs within 2–3 minutes of start of infusion and almost always within the first 10 minutes.
8. Patients who have received >6 courses of weekly paclitaxel should be advised to avoid exposure of their skin as well as their fingernails and toenails to the sun as they are at increased risk for developing onycholysis. This side effect is not observed with the every-3-week schedule.
9. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting neutropenia with nadir at day 8–10 and recovery by day 15–21. Decreased incidence of neutropenia with 3-hour schedule when compared to 24-hour schedule.

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#### Toxicity 2

HSR. Occurs in up to 20%–40% of patients. Characterized by generalized skin rash, flushing, erythema, hypotension, dyspnea, and/or bronchospasm. Usually occurs within the first 2–3 minutes of an infusion and almost always within the first 10 minutes. Incidence of HSR is the same with 3- and 24-hour schedules. Premedication regimen, as outlined in Special Considerations, has significantly decreased incidence.

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#### Toxicity 3

Neurotoxicity mainly in the form of sensory neuropathy with numbness and paresthesias. Dose-dependent effect. Other risk factors include prior exposure to known neurotoxic agents (e.g., cisplatin) and pre-existing medical disorders such as diabetes mellitus and chronic alcoholism. Also more frequent with longer infusions and at doses >175 mg/m<sup>2</sup>. Motor and autonomic neuropathy observed at high doses. Optic nerve disturbances with scintillating scotomata observed rarely.

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#### Toxicity 4

Transient asymptomatic sinus bradycardia is most commonly observed cardiotoxicity. Occurs in 30% of patients. Other rhythm disturbances are seen, including Mobitz type I, Mobitz type II, and third-degree heart block, as well as ventricular arrhythmias.

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#### Toxicity 5

Alopecia. Occurs in nearly all patients, with loss of total body hair.

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**Toxicity 6**

Mucositis and/or diarrhea seen in 30%–40% of patients. Mucositis is more common with the 24-hour schedule. Mild to moderate nausea and vomiting, usually of brief duration.

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**Toxicity 7**

Transient elevations in serum transaminases, bilirubin, and alkaline phosphatase.

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**Toxicity 8**

Onycholysis. Mainly observed in those receiving >6 courses on the weekly schedule. Not seen with the every-3-week schedule.

# Panitumumab

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## Trade Name

Vectibix

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## Classification

Monoclonal antibody, anti-EGFR antibody

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Amgen

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## Mechanism of Action

- Fully human IgG<sub>2</sub> monoclonal antibody directed against the EGFR.
- Precise mechanism(s) of action remains unknown.
- Binds with nearly 40-fold higher affinity to EGFR than normal ligands EGF and TGF- $\alpha$ , which results in inhibition of EGFR. Prevents both homodimerization and heterodimerization of the EGFR which leads to inhibition of autophosphorylation and inhibition of EGFR signaling.
- Inhibition of the EGFR signaling pathway results in inhibition of critical mitogenic and anti-apoptotic signals involved in proliferation, growth, invasion/metastasis, and angiogenesis.
- Inhibition of the EGFR pathway enhances the response to chemotherapy and/or radiation therapy.

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## Mechanism of Resistance

- Mutation in the EGFR leading to decreased binding affinity to panitumumab.
- Decreased expression of EGFR.

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## Distribution

Distribution in the body is not well characterized.

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## Metabolism

Metabolism of panitumumab has not been extensively characterized. Pharmacokinetic studies showed clearance of antibody was saturated at a weekly dose of 2 mg/kg. Half-life is on the order of 6 to 7 days with minimal clearance by the liver or kidneys.

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### Indications

1. FDA-approved as monotherapy for the treatment of advanced colorectal cancer following fluoropyrimidine-, oxaliplatin-, and irinotecan-containing regimens.

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### Dosage Range

1. Recommended dose for the treatment of advanced colorectal cancer is 6 mg/kg IV on an every 2 week schedule.
2. An alternative schedule is 2.5 mg/kg IV every week.

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### Drug Interactions

No formal drug interactions have been characterized to date.

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### Special Considerations

1. The incidence of infusion reactions is lower when compared with cetuximab anti-EGFR therapy, as panitumumab is a fully human antibody.
2. The level of EGFR expression does not correlate with clinical activity, and as such, EGFR testing should not be required for clinical use.
3. Development of skin toxicity appears to be a surrogate marker for panitumumab clinical activity.
4. Use with caution in patients with underlying interstitial lung disease as these patients are at increased risk for developing worsening of their interstitial lung disease.
5. In patients who develop a skin rash, topical antibiotics such as Cleocin gel or either oral Cleocin and/or oral minocycline may help. Topical steroids and/or oral steroid treatment do not appear to be helpful in this setting. Patients should be warned to avoid sunlight exposure.
6. Electrolyte status (magnesium and calcium) should be periodically monitored during therapy and for up to 8 weeks after completion of therapy.
7. Pregnancy category C. Breast-feeding should be avoided.

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### Toxicity 1

Pruritus, dry skin with mainly a pustular, acneiform skin rash. Presents mainly on the face and upper trunk. Improves with continued treatment and resolves upon cessation of therapy.

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### Toxicity 2

Infusion-related symptoms with fever, chills, urticaria, flushing, and headache. Usually minor in severity and observed most commonly with administration of the first infusion.

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**Toxicity 3**

Pulmonary toxicity in the form of ILD manifested by increased cough, dyspnea, and pulmonary infiltrates. Observed rarely in less than 1% of patients and more frequent in patients with underlying pulmonary disease.

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**Toxicity 4**

Hypomagnesemia.

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**Toxicity 5**

Diarrhea.

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**Toxicity 6**

Asthenia and generalized malaise observed in up to 10% to 15%.

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**Toxicity 7**

Paronychia inflammation with swelling of the lateral nail folds of the toes and fingers. Usually occurs with prolonged use of panitumumab.

# Pegfilgrastim

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## Trade Names

Neulasta, PEG-rHuG-CSF

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## Classification

Colony-stimulating growth factor, cytokine

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Amgen

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## Mechanism of Action

- Covalent conjugate of recombinant methionyl human G-CSF (filgrastim) and monomethoxypolyethylene glycol. The molecular weight of pegfilgrastim is approximately 39 kDa.
- Pleiotropic cytokine that binds to specific surface receptors of hematopoietic progenitor cells.
- Stimulates the proliferation, differentiation, and activation of granulocyte progenitor cells and the activity of mature granulocytes.
- Enhances neutrophil chemotaxis and phagocytosis.
- Does not possess antitumor activity.

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## Absorption

Pegfilgrastim is rapidly and completely absorbed into the circulation after an SC dose, with peak plasma concentration achieved 2–8 hours after administration.

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## Distribution

Distributes into blood and bone marrow. Binding to plasma proteins not known.

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## Metabolism

Metabolized in both the liver and the kidney. Pegfilgrastim has reduced renal clearance and prolonged persistence in vivo when compared with filgrastim. The terminal half-life ranges from 15 to 80 hours.

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## Indications

Adjunct to myelosuppressive chemotherapy—Prophylactic use in patients with non-myeloid malignancies receiving chemotherapy with either previous history of drug-related neutropenia and/or fever or in patients receiving drugs associated with a significant incidence of severe neutropenia and fever.

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### Dosage Range

1. Prevention of chemotherapy-induced neutropenia: single SC injection of 6 mg, administered once per chemotherapy cycle.

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### Drug Interactions

Steroids, lithium—Caution should be exercised when using these drugs concurrently with pegfilgrastim as they may potentiate the release of neutrophils during pegfilgrastim therapy.

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### Special Considerations

1. Contraindicated in patients with known hypersensitivity to *E. coli*-derived products, pegfilgrastim, filgrastim, and/or any component contained within the product.
2. Concurrent administration with chemotherapy is contraindicated as an increased incidence of serious adverse events has been observed. Pegfilgrastim should **NOT** be administered in the period between 14 days before and 24 hours after administration of chemotherapy as the stimulatory effects of G-CSF on the hematopoietic precursors render them more susceptible to chemotherapy.
3. Blood counts should be monitored closely following pegfilgrastim therapy.
4. Pegfilgrastim is incompatible with saline-containing solutions.
5. Use with caution in patients receiving steroids or lithium as these drugs may potentiate the release of neutrophils.
6. Use with caution in patients with sickle cell disease as severe sickle cell crises have been observed in patients receiving filgrastim therapy. Patients with sickle cell disease who receive pegfilgrastim should be well hydrated and closely monitored.
7. Pegfilgrastim is **NOT** indicated for mobilization of peripheral blood progenitor cells.
8. Rare cases of splenic rupture have been reported following filgrastim therapy. Patients who report left upper quadrant abdominal pain and/or shoulder pain should be immediately evaluated for an enlarged spleen and/or splenic rupture.
9. Closely monitor patients for the onset of fever, pulmonary infiltrates, or respiratory distress as ARDS has been reported in neutropenic patients with sepsis receiving filgrastim, the parent compound of pegfilgrastim.
10. Premedication with acetaminophen helps to relieve the bone pain that arises due to bone marrow expansion in response to treatment.
11. Pregnancy category C. Breast-feeding should be avoided.

P

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**Toxicity 1**

Transient bone pain occurs in up to 25% of patients. Usually mild to moderate and well controlled with non-narcotic medications.

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**Toxicity 2**

HSR in the form of skin rash, urticaria, and anaphylaxis is uncommon.

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**Toxicity 3**

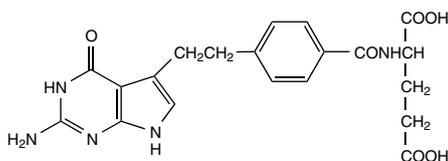
Leukocytosis observed in less than 1% of patients and usually not associated with any adverse effects.

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**Toxicity 4**

Transient elevations in serum lactate dehydrogenase, alkaline phosphatase, and uric acid.

# Pemetrexed



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## Trade Names

Alimta, LY231514

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## Classification

Antimetabolite

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## Category

Chemotherapy drug

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## Drug Manufacturer

Eli Lilly

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## Mechanism of Action

- Pyrimidopyrimidine antifolate analog with activity in the S-phase of the cell cycle.
- Transported into the cell primarily via the RFC and to a smaller extent by the folate-receptor protein (FRP).
- Metabolized intracellularly to higher polyglutamate forms by the enzyme folylpolyglutamate synthase (FPGS). The pentaglutamate form is the predominant intracellular species. Pemetrexed polyglutamates are approximately 60-fold more potent than the parent monoglutamate compound, and they exhibit prolonged cellular retention.
- Inhibition of the folate-dependent enzyme thymidylate synthase (TS) resulting in inhibition of de novo thymidylate and DNA synthesis. This represents the main site of action of the drug.
- Inhibition of TS leads to accumulation of dUMP and subsequent incorporation of dUTP into DNA, resulting in inhibition of DNA synthesis and function.
- Inhibition of dihydrofolate reductase, resulting in depletion of reduced folates and of critical one-carbon carriers for cellular metabolism.
- Inhibition of de novo purine biosynthesis through inhibition of glycinamide ribonucleotide formyltransferase (GART) and aminoimidazole carboxamide ribonucleotide formyltransferase (AICART).

# P

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## Mechanism of Resistance

- Increased expression of the target enzyme TS.
- Alterations in the binding affinity of TS for pemetrexed.
- Decreased transport of drug into cells through decreased expression of the RFC and/or FRP.
- Decreased polyglutamation of drug, resulting in decreased formation of cytotoxic metabolites.

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## Absorption

Pemetrexed is given only by the IV route.

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## Distribution

Peak plasma levels are reached in less than 30 minutes. Widely distributed throughout the body. Tissue concentrations highest in liver, kidneys, small intestine, and colon.

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## Metabolism

Significant intracellular metabolism of drug to the polyglutamated species. Metabolism in the liver through as yet undefined mechanisms. Principally cleared by renal excretion with as much as 90% of the drug in the urine unchanged during the first 24 hours after administration. Short distribution half-life in plasma with a mean of 3 hours (range, 1.2–3.9 hours). However, relatively prolonged terminal half-life of about 20 hours and a prolonged intracellular half-life as a result of pemetrexed polyglutamates.

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## Indications

1. Mesothelioma—FDA-approved in combination with cisplatin.
2. Non–small cell lung cancer—FDA-approved as second-line monotherapy.
3. Colorectal cancer.
4. Breast cancer.
5. Pancreas cancer.
6. Bladder cancer.

---

## Dosage Range

1. Recommended dose as a single agent is 500 mg/m<sup>2</sup> IV every 3 weeks.
2. When used in combination with cisplatin, recommended dose is 500 mg/m<sup>2</sup> IV every 3 weeks.

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### Drug Interaction 1

Thymidine—Thymidine rescues against the host toxic effects of pemetrexed.

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### Drug Interaction 2

5-FU—Pemetrexed may enhance the antitumor activity of 5-FU. Precise mechanism of interaction remains unknown.

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### Drug Interaction 3

Leucovorin—Administration of leucovorin decreases the antitumor activity of pemetrexed.

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### Drug Interaction 4

NSAIDs and aspirin—Concomitant administration of NSAIDs and aspirin may inhibit the renal excretion of pemetrexed, resulting in enhanced drug toxicity.

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### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose should be reduced in proportion to the creatinine clearance. Important to obtain baseline creatinine clearance and to monitor renal function before each cycle of therapy.
2. Dose reduction is not necessary in patients with mild to moderate liver impairment.
3. Monitor CBCs on a periodic basis.
4. Dietary folate status of patient may be an important factor in determining risk for clinical toxicity. Patients with insufficient folate intake may be at increased risk for host toxicity. Evaluation of serum homocysteine and folate levels at baseline and during therapy may be helpful. A baseline serum homocysteine level  $>10$  is a good predictor for the development of grade 3/4 toxicities.
5. All patients should receive vitamin supplementation with 350  $\mu\text{g}$ /day of folic acid PO and 1,000  $\mu\text{g}$  of vitamin B<sub>12</sub> SC every three cycles to reduce the risk and incidence of toxicity while on drug therapy. Folic acid supplementation should begin 7 days prior to initiation of pemetrexed treatment, and the first vitamin B<sub>12</sub> injection should be administered at least 1 week prior to the start of pemetrexed. No evidence that vitamin supplementation reduces clinical efficacy.
6. Prophylactic use of steroids may ameliorate and/or completely eliminate the development of skin rash. Dexamethasone can be given at a dose of 4 mg PO bid for 3 days beginning the day before therapy.

7. NSAIDs and aspirin should be discontinued for at least 2 days before therapy with pemetrexed and should not be restarted for at least 2 days after a drug dose. These agents may inhibit the renal clearance of pemetrexed, resulting in enhanced drug toxicity.
8. Pregnancy category D.

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**Toxicity 1**

Myelosuppression. Dose-limiting, dose-related toxicity with neutropenia and thrombocytopenia being most commonly observed.

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**Toxicity 2**

Skin rash, usually in the form of the hand-foot syndrome.

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**Toxicity 3**

Mucositis, diarrhea, and nausea and vomiting.

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**Toxicity 4**

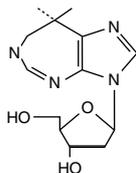
Transient elevation in serum transaminases and bilirubin. Occurs in 10%–15% of patients. Clinically asymptomatic in most cases.

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**Toxicity 5**

Fatigue.

# Pentostatin



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## Trade Names

2 -Deoxycoformycin, Nipent, dCF

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## Classification

Antimetabolite

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## Category

Chemotherapy drug

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## Drug Manufacturer

SuperGen

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## Mechanism of Action

- Fermentation product of *Streptomyces antibioticus*.
- Both cell cycle-specific and cell cycle-nonspecific effects.
- Inhibits the enzyme adenosine deaminase, which results in accumulation of deoxyadenosine and deoxyadenosine triphosphate (dATP). dATP is cytotoxic to lymphocytes.
- Feedback inhibition of ribonucleotide reductase by dATP resulting in inhibition of DNA synthesis and function.
- Inhibits S-adenosyl-L-homocysteine hydrolase resulting in inhibition of one-carbon dependent methylation reactions.

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## Mechanism of Resistance

- Decreased nucleoside transport resulting in decreased intracellular accumulation of drug.
- Increased expression of ribonucleotide reductase.

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## Absorption

Not orally bioavailable due to rapid degradation in acidic conditions. Given only by the IV route.

# P

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## Distribution

Widely distributed in total body water. Does not cross the blood-brain barrier. About 5%–15% of drug is bound to plasma proteins. After 1 hour of administration, plasma drug levels far exceed the inhibitory concentration for adenosine deaminase by approximately six orders of magnitude.

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## Metabolism

Metabolism occurs to only a very small degree. Greater than 90% of drug is eliminated in unchanged form and/or metabolites in urine. Elimination half-life is about 5–6 hours. Significant correlation between plasma levels and creatinine clearance.

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## Indications

1. Hairy cell leukemia.
2. Chronic lymphocytic leukemia.
3. Cutaneous T-cell lymphoma.
4. Acute lymphoblastic leukemia.

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## Dosage Range

Usual dose is 4 mg/m<sup>2</sup> IV every other week.

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## Drug Interaction 1

Vidarabine—Pentostatin enhances the activity and toxicity of vidarabine by preventing its inactivation.

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## Drug Interaction 2

Fludarabine—Combination of pentostatin and fludarabine has been associated with fatal pulmonary toxicity and is absolutely contraindicated.

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## Special Considerations

1. Use with caution in patients with abnormal renal function. Dose reduction is recommended in this setting and should be done in proportion to the creatinine clearance. Important to obtain baseline creatinine clearance and to monitor renal function before each cycle of therapy.
2. Fluid status of patient is important, and hydration with at least 2 liters of D<sub>5</sub>NS is required to ensure a sufficient urine output (2 liters) on the day of drug administration.
3. Use with caution in patients on sedative and hypnotic drugs as CNS toxicity may be enhanced.
4. Pregnancy category D.

---

**Toxicity 1**

Myelosuppression. Dose-limiting leukopenia observed more commonly than thrombocytopenia. Leukopenia nadir at days 10–14 with recovery by days 21–27.

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**Toxicity 2**

Immunosuppression. Both B and T lymphocytes are suppressed. Increased risk of viral, bacterial, fungal, and parasitic infections.

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**Toxicity 3**

Nausea and vomiting. Common but usually not severe.

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**Toxicity 4**

Mild elevations in serum bilirubin and transaminases. Usually reversible.

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**Toxicity 5**

Dose-related headache, lethargy, and fatigue.

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**Toxicity 6**

Allergic/hypersensitivity reaction in the form of fever, chills, myalgias, and arthralgias.

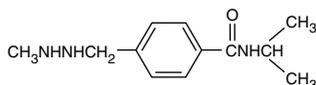
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**Toxicity 7**

Conjunctivitis, photophobia, and diplopia. Ototoxicity in the form of ear pain, labyrinthitis, and tinnitus is rare.

P

## Procarbazine



### Trade Names

Matulane, N-Methylhydrazine

### Classification

Nonclassic alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

Roche

### Mechanism of Action

- Hydrazine analog that acts as an alkylating agent. Weak monoamine oxidase (MAO) inhibitor and a relative of the MAO inhibitor 1-methyl-2-benzylhydrazine.
- Requires metabolic activation for cytotoxicity. Occurs spontaneously through a nonenzymatic process and/or by an enzymatic reaction mediated by the liver cytochrome P450 system.
- While the precise mechanism of cytotoxicity is unclear, this drug inhibits DNA, RNA, and protein synthesis.
- Cell cycle–nonspecific drug.

### Mechanism of Resistance

1. Enhanced DNA repair secondary to increased expression of O6-alkylguanine-DNA transferase (AGAT).
2. Enhanced DNA repair secondary to AGAT-independent mechanisms.

### Absorption

Rapid and complete absorption from the GI tract, reaching peak plasma levels within 1 hour.

### Distribution

Rapidly and extensively metabolized by the liver cytochrome P450 microsomal system. Procarbazine metabolites cross the blood-brain barrier, and peak CSF levels of drug occur within 30–90 min after drug administration.

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### Metabolism

Metabolized to active and inactive metabolites by two main pathways, chemical breakdown in aqueous solution and liver microsomal P450 system. Possible formation of free radical intermediates. About 70% of procarbazine is excreted in urine within 24 hours. Less than 5%–10% of the drug is eliminated in an unchanged form. The elimination half-life is short, being less than 1 hour after oral administration.

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### Indications

1. Hodgkin's disease.
2. Non-Hodgkin's lymphoma.
3. Brain tumors—adjuvant and/or advanced disease.
4. Cutaneous T-cell lymphoma.

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### Dosage Range

1. Hodgkin's disease: 100 mg/m<sup>2</sup> PO daily for 14 days, as part of MOPP regimen.
2. Brain tumors: 60 mg/m<sup>2</sup> PO daily for 14 days, as part of PCV regimen.

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### Drug Interaction 1

Alcohol- or tyramine-containing foods—Concurrent use with procarbazine can result in nausea, vomiting, increased CNS depression, hypertensive crisis, visual disturbances, and headache.

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### Drug Interaction 2

Antihistamines, CNS depressants—Concurrent use of procarbazine with antihistamines can result in CNS and/or respiratory depression.

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### Drug Interaction 3

Levodopa, meperidine—Concurrent use of procarbazine with levodopa or meperidine results in hypertension.

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### Drug Interaction 4

Tricyclic antidepressants—Concurrent use of procarbazine with sympathomimetics and tricyclic antidepressants may result in CNS excitation, hypertension, tremors, palpitations, and in severe cases, hypertensive crisis and/or angina.

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### Drug Interaction 5

Antidiabetic agents—Concurrent use of procarbazine with antidiabetic agents such as sulfonylurea compounds and insulin may potentiate hypoglycemic effect.

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### Special Considerations

1. Monitor CBC while on therapy.
2. Prophylactic use of antiemetics 30 minutes before drug administration to decrease risk of nausea and vomiting. Incidence and severity of nausea usually decrease with continued therapy.
3. Important to review patient's list of concurrent medications as procarbazine has several potential drug-drug interactions.
4. Instruct patients against ingestion of alcohol while on procarbazine. May result in Antabuse-like effect.
5. Instruct patients about specific types of food to avoid during drug therapy (e.g., dark beer, wine, cheese, bananas, yogurt, and pickled and smoked foods).
6. Pregnancy category D. Breast-feeding not recommended.

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### Toxicity 1

Myelosuppression. Dose-limiting toxicity. Thrombocytopenia is most pronounced effect with nadir in 4 weeks and return to normal in 4–6 weeks. Leukopenia usually occurs after thrombocytopenia. Patients with G6PD deficiency may present with hemolytic anemia while on procarbazine therapy.

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### Toxicity 2

Nausea and vomiting. Usually develop in the first days of therapy and improve with continued therapy. Diarrhea may also be observed.

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### Toxicity 3

Flulike syndrome in the form of fever, chills, sweating, myalgias, and arthralgias. Usually occurs with initial therapy.

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### Toxicity 4

Pain and/or burning at the site of injection.

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### Toxicity 5

CNS toxicity in the form of paresthesias, neuropathies, ataxia, lethargy, headache, confusion, and/or seizures.

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### Toxicity 6

Hypersensitivity reaction with pruritus, urticaria, maculopapular skin rash, flushing, eosinophilia, and pulmonary infiltrates. Skin rash responds to steroid therapy, and drug treatment may be continued. However, procarbazine-induced interstitial pneumonitis usually mandates discontinuation of therapy.

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**Toxicity 7**

Amenorrhea and azoospermia.

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**Toxicity 8**

Immunosuppressive activity with increased risk of infections.

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**Toxicity 9**

Increased risk of secondary malignancies in the form of acute leukemia. The drug is teratogenic, mutagenic, and carcinogenic.

# R

## Rituximab

### Trade Names

Rituxan

### Classification

Monoclonal antibody

### Category

Biologic response modifier agent

### Drug Manufacturer

Biogen-IDEC and Genentech

### Mechanism of Action

- Chimeric anti-CD20 antibody consisting of human IgG1-kappa constant regions and variable regions from the murine monoclonal anti-CD20 antibody.
- Targets the CD20 antigen, a 35 kDa cell surface non-glycosylated phosphoprotein expressed during early pre-B cell development until the plasma cell stage. Binding of antibodies to CD20 induces a transmembrane signal that blocks cell activation and cell cycle progression.
- CD20 is expressed on more than 90% of all B-cell non-Hodgkin's lymphomas and leukemias.
- CD20 is not expressed on early pre-B cells, plasma cells, normal bone marrow stem cells, antigen-presenting dendritic reticulum cells, or other normal tissues.
- Chimeric antibody mediates complement-dependent cell lysis (CDCC) in the presence of human complement and antibody-dependent cellular cytotoxicity (ADCC) with human effector cells.

### Absorption

Rituximab is given only by the IV route.

### Distribution

Peak and trough levels of rituximab correlate inversely with the number of circulating CD20-positive B cells.

### Metabolism

Plasma half-life of rituximab is dose-dependent. The median plasma half-life is 76 hours after the first infusion as compared to 206 hours after the fourth infusion. This change in half-life may reflect changes in either the tumor burden or the number of circulating CD20-positive cells.

Antibody can be detected in serum up to 3–6 months after completion of therapy. Elimination pathway has not been well characterized, although antibody-coated cells are reported to undergo elimination via Fc-receptor binding and phagocytosis by the reticuloendothelial system.

R

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### Indications

1. Relapsed and/or refractory low-grade or follicular, CD20+, B-cell non-Hodgkin's lymphoma.
2. Intermediate- and/or high-grade, CD20+, B-cell non-Hodgkin's lymphoma—Used as a single agent or in combination with chemotherapy regimens such as EPOCH or CHOP.
3. FDA-approved for first-line treatment of patients with low-grade or follicular CD20-positive, B-cell non-Hodgkin's lymphoma in combination with CVP chemotherapy or after CVP chemotherapy.

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### Dosage Range

Recommended dose is 375 mg/m<sup>2</sup> IV on a weekly schedule for 4 or 8 weeks.

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### Drug Interactions

None characterized to date.

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### Special Considerations

1. Contraindicated in patients with known type I hypersensitivity or anaphylactic reactions to murine proteins or product components.
2. Patients should be premedicated with acetaminophen and diphenhydramine to reduce the incidence of infusion-related reactions.
3. Infusion should be started at an initial rate of 50 mg/hour. If no toxicity is observed during the first hour, the infusion rate can be escalated by increments of 50 mg/hour every 30 minutes to a maximum of 400 mg/hour. If the first treatment is well tolerated, the starting infusion rate for the second and subsequent infusions can be administered at 100 mg/hour with 100 mg/hour increments at 30-minute intervals up to 400 mg/hour. Rituximab should **NOT** be given by IV push.
4. Monitor for infusion-related events, which usually occur 30–120 minutes after the start of the first infusion. Infusion should be immediately stopped if signs or symptoms of an allergic reaction are observed. Immediate institution of diphenhydramine, acetaminophen, corticosteroids, IV fluids, and/or vasopressors may be necessary. In most instances, the infusion can be restarted at a reduced rate (50%) once symptoms have completely resolved. Resuscitation equipment should be readily available at bedside.

5. Infusion-related deaths within 24 hours have been reported. Usually occur with the first infusion. Other risk factors include female gender, patients with pre-existing pulmonary disease, and patients with CLL or mantle cell lymphoma.
6. Monitor for tumor lysis syndrome, especially in patients with high numbers of circulating cells ( $>25,000/\text{mm}^3$ ) or high tumor burden. In this case, the first dose of rituximab can be split into two doses with 50% of the total dose to be given on days 1 and 2.
7. Use with caution in patients with pre-existing heart disease, including arrhythmias and angina, as there is an increased risk of cardiotoxicity. The development of cardiac arrhythmias requires cardiac monitoring with subsequent infusion of drug. Patients should be monitored during the infusion and in the immediate post-transfusion period.
8. Monitor for the development of skin reactions. Patients experiencing severe skin reactions should not receive further therapy, and skin biopsies may be required to guide future treatment.
9. Pregnancy category C. Breast-feeding should be avoided.

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#### Toxicity 1

Infusion-related symptoms, including fever, chills, urticaria, flushing, fatigue, headache, bronchospasm, rhinitis, dyspnea, angioedema, nausea, and/or hypotension. Usually occur within 30 minutes to 2 hours after the start of the first infusion. Usually resolves upon slowing or interrupting the infusion and with supportive care. Incidence decreases with subsequent infusion.

---

#### Toxicity 2

Tumor lysis syndrome. Characterized by hyperkalemia, hyperuricemia, hyperphosphatemia, hypocalcemia, and renal insufficiency. Usually occurs within the first 12–24 hours of treatment. Risk is increased in patients with high numbers of circulating malignant cells ( $>25,000/\text{mm}^3$ ) and/or high tumor burden.

---

#### Toxicity 3

Skin reactions, including pemphigus, Stevens-Johnson syndrome, lichenoid dermatitis, and toxic epidermal neurolysis. Usual onset ranges from 1 to 13 weeks following drug treatment.

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#### Toxicity 4

Arrhythmias and chest pain, usually occurring during drug infusion. Increased risk in patients with pre-existing cardiac disease.

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**Toxicity 5**

Myelosuppression is rarely observed. Lymphopenia more commonly seen in up to 50% of all patients. Median duration of neutropenia is 13 days, and median duration of lymphopenia is 14 days.

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**Toxicity 6**

Nausea and vomiting. Generally mild.

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**Toxicity 7**

Cough, rhinitis, dyspnea, and sinusitis are observed in up to 40% of patients.

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**Toxicity 8**

Development of HACA is rare.

R

# S

## Sargramostim

### Trade Names

Granulocyte-macrophage colony-stimulating factor, GM-CSF, Leukine

### Classification

Colony-stimulating growth factor

### Category

Biologic response modifier agent

### Drug Manufacturer

Immunex

### Mechanism of Action

- No known antitumor activity.
- Stimulates proliferation and differentiation of hematopoietic progenitor cells. Induces partially committed progenitor cells to differentiate along the granulocyte-macrophage pathways.
- Activates mature granulocytes and macrophages.
- Promotes the growth and differentiation of megakaryocytic and erythroid progenitor cells.

### Distribution

Distributed into various tissues of the body, including liver, spleen, and kidney. Peak plasma concentration occurs during or immediately after an IV infusion and 1–3 hours after SC administration. Appears to be highly protein-bound.

### Metabolism

Metabolism has not been completely characterized. Initial half-life 12–17 minutes with a terminal half-life of 1.6–2.6 hours.

### Indications

1. Use following induction chemotherapy in AML.
2. Mobilization of peripheral blood stem cells for either autologous or allogeneic stem cell transplant.
3. Use after bone marrow or stem cell transplant (autologous or allogeneic) to accelerate myeloid recovery.
4. Use in bone marrow transplantation failure or engraftment delay.
5. Use in chemotherapy-induced neutropenia for solid tumors.

### Dosage Range

1. Following induction chemotherapy for AML: 250  $\mu\text{g}/\text{m}^2/\text{day}$  IV over 4 hours starting 4 days after completion of induction chemotherapy.
2. Mobilization of peripheral blood stem cells: 250  $\mu\text{g}/\text{m}^2/\text{day}$  IV over 24 hours or SC once daily.
3. Use after peripheral blood stem cell transplant: 250  $\mu\text{g}/\text{m}^2/\text{day}$  IV over 24 hours or SC once daily starting immediately after infusion of progenitor stem cells.
4. Use after bone marrow transplant: 250  $\mu\text{g}/\text{m}^2/\text{day}$  IV over 2 hours beginning 2–4 hours after bone marrow infusion.
5. Use after bone marrow transplant failure or engraftment delay: 250  $\mu\text{g}/\text{m}^2/\text{day}$  IV over 2 hours for 14 days.
6. Use in chemotherapy-induced neutropenia for solid tumors: 250  $\mu\text{g}/\text{m}^2/\text{day}$  SC beginning no earlier than 24 hours after chemotherapy.

### Drug Interactions

Steroids, lithium—Concurrent use with steroids and/or lithium may potentiate the release of neutrophils in response to sargramostim.

### Special Considerations

1. Contraindicated in patients with excess number of leukemic blasts in peripheral blood ( $>10\%$ ) and/or bone marrow.
2. Contraindicated in patients with known hypersensitivity to GM-CSF or yeast-derived products.
3. Concurrent administration with chemotherapy or radiation therapy is contraindicated as an increased incidence of serious adverse events has been observed. Sargramostim must be given at least 24 hours after the last dose of chemotherapy and 12 hours after radiation therapy.
4. Premedication with acetaminophen helps to relieve the bone pain that arises due to bone marrow expansion in response to treatment.
5. Associated with higher incidence of fever and fluid retention than observed with G-CSF.
6. Monitor CBC at least twice per week during treatment. Therapy should be terminated once total WBC  $>10,000/\text{mm}^3$  or ANC  $>1,000/\text{mm}^3$  for 3 days.
7. Therapy should be discontinued immediately if leukemic growth or disease progression occurs.
8. Use with caution in the presence of steroids and lithium as they may potentiate the release of neutrophils following sargramostim therapy.

9. Use with caution in patients with pre-existing heart disease, congestive heart failure, and pulmonary infiltrates as sargramostim may aggravate fluid retention.
10. Pregnancy category C.

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**Toxicity 1**

Flulike syndrome characterized by fever, chills, lethargy, malaise, and headache.

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**Toxicity 2**

Transient bone pain. May be prevented by acetaminophen.

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**Toxicity 3**

Fluid retention syndrome. Presents as pleural and/or pericardial effusions and peripheral edema. Results from migration of neutrophils into the lung with release of various cytokines.

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**Toxicity 4**

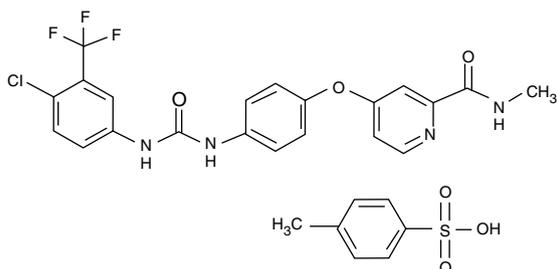
Injection reaction manifested by transient flushing, myalgias, dyspnea, nausea and vomiting, tachycardia, and rarely hypotension. Occurs usually with the first dose and tends not to recur with subsequent doses.

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**Toxicity 5**

Transient elevation in serum bilirubin and liver transaminases.

## Sorafenib



### Trade Name

Nexavar, BAY 43-9006

### Classification

Signal transduction inhibitor

### Category

Chemotherapy drug

### Drug Manufacturer

Bayer

### Mechanism of Action

- Inhibits multiple receptor tyrosine kinases (RTKs), some of which are involved in tumor growth, tumor angiogenesis, and metastasis.
- Potent inhibitor of intracellular kinases, including c-Raf and wild-type and mutant B-Raf.
- Targets vascular endothelial growth factor receptors, VEGFR<sub>2</sub> and VEGFR<sub>3</sub>, and platelet-derived growth factor receptor- $\beta$  (PDGFR- $\beta$ ), and in so doing, inhibits angiogenesis.

### Mechanism of Resistance

None well characterized to date.

### Absorption

Rapidly absorbed after an oral dose with peak plasma levels achieved within 2 to 7 hours. Oral administration should be without food at least 1 hour before or 2 hours after eating, as food with a high fat content reduces oral bioavailability by about 30%.

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### Distribution

Extensive binding (99%) to plasma proteins. Steady-state drug concentrations are reached in 7 days.

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### Metabolism

Metabolized in the liver primarily by the CYP<sub>3A4</sub> microsomal enzyme and by glucuronidation mediated by UGT<sub>1A9</sub>. Parent drug accounts for 70%–85% at steady-state, while the pyridine-N-oxide metabolite, which has similar biological activity to sorafenib, accounts for 10%–16%. Elimination is hepatic with excretion in the feces (~80%), with renal elimination of the glucuronidated metabolites accounting for 16% of the administered dose. The terminal half-life of sorafenib is approximately 25 to 48 hours.

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### Indications

1. FDA-approved for the treatment of advanced renal cell carcinoma.
2. Awaiting FDA approval for the treatment of advanced hepatocellular cancer (HCC).

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### Dosage Range

Recommended dose is 400 mg/day PO bid.

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### Drug Interactions

None well characterized to date.

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### Special Considerations

1. No dose adjustment is necessary in patients with Child-Pugh A and B liver dysfunction. However, sorafenib has not been studied in patients with Child-Pugh C liver disease, and caution should be used in this setting.
2. No dose adjustments are necessary in patients with mild to moderate renal dysfunction.
3. Use with caution when administering sorafenib with agents that are metabolized and/or eliminated by the UGT<sub>1A1</sub> pathway, such as irinotecan, as sorafenib is an inhibitor of UGT<sub>1A1</sub>.
4. Patients receiving sorafenib along with oral warfarin anticoagulant therapy should have their coagulation parameters (PT and INR) monitored frequently as elevations in INR and bleeding events have been observed.
5. Closely monitor blood pressure while on therapy, especially during the first 6 weeks of therapy, and treat as needed with standard oral anti-hypertensive medication.
6. Pregnancy category D. Breast-feeding should be avoided.

---

**Toxicity 1**

Hypertension occurs in nearly 30% of patients. Usually occurs within 6 weeks of starting therapy and well-controlled with oral anti-hypertensive medication.

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**Toxicity 2**

Skin rash occurs in 66% of patients. Hand-foot skin reaction also occurs in up to 30%.

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**Toxicity 3**

Bleeding complications with epistaxis most commonly observed.

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**Toxicity 4**

Constitutional side effects with fatigue and asthenia.

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**Toxicity 5**

Diarrhea and nausea are the most common GI side effects.

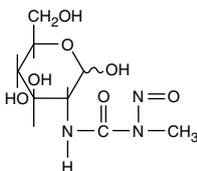
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**Toxicity 6**

Hypophosphatemia occurs in up to 45% of patients, but usually clinically asymptomatic.

# S

## Streptozocin



### Trade Names

Streptozotocin, Zanosar

### Classification

Alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

Teva Pharmaceuticals

### Mechanism of Action

- Cell cycle–nonspecific nitrosourea analog.
- Formation of intrastrand cross-links of DNA resulting in inhibition of DNA synthesis and function.
- Selectively targets pancreatic  $\beta$  cells, possibly due to the presence of a glucose moiety on the compound.
- In contrast with other nitrosourea analogs, no effect on RNA or protein synthesis.

### Mechanism of Resistance

- Decreased cellular uptake of drug.
- Increased intracellular thiol content due to glutathione and/or glutathione-related enzymes.
- Enhanced activity of DNA repair enzymes.

### Absorption

Not absorbed orally.

### Distribution

Rapidly cleared from plasma with an elimination half-life of 35 minutes. Drug concentrates in the liver and kidney, reaching concentrations equivalent

to those in plasma. Drug metabolites cross the blood-brain barrier and enter the CSF. Selectively concentrates in pancreatic  $\beta$  cells presumably due to the glucose moiety on the molecule.

---

### Metabolism

Metabolized primarily by the liver to active metabolites. The elimination half-life of the drug is short, being less than 1 hour. About 60%–70% of drug is excreted in urine, 20% in unchanged form. Less than 1% of drug is eliminated in stool.

---

### Indications

1. Pancreatic islet cell cancer.
2. Carcinoid tumors.

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### Dosage Range

1. Weekly schedule: 1,000–1,500 mg/m<sup>2</sup> IV weekly for 6 weeks followed by 4 weeks of observation.
2. Daily schedule: 500 mg/m<sup>2</sup> IV for 5 days every 6 weeks.

---

### Drug Interaction 1

Steroids—Concurrent use of steroids and streptozocin may result in severe hyperglycemia.

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### Drug Interaction 2

Phenytoin—Phenytoin antagonizes the antitumor effect of streptozocin.

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### Drug Interaction 3

Nephrotoxic drugs—Avoid concurrent use of streptozocin with nephrotoxic agents as renal toxicity may be enhanced.

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### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose reduction is recommended in this setting as nephrotoxicity is dose-limiting and can be severe and/or fatal. Baseline creatinine clearance is required, as is monitoring of renal function before each cycle of therapy. Hydration with 1–2 liters of fluid is recommended to prevent nephrotoxicity.
2. Monitor CBC while on therapy.
3. Avoid the use of other nephrotoxic agents in combination with streptozocin.
4. Carefully administer drug to minimize and/or avoid burning, pain, and extravasation.
5. Pregnancy category D. Breast-feeding should be avoided.

# S

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## Toxicity 1

Renal toxicity is dose-limiting. Seen in 40%–60% of patients and manifested initially by proteinuria and azotemia. Can also present as glucosuria, hypophosphatemia, and nephrogenic diabetes insipidus. Permanent renal damage can occur in rare instances.

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## Toxicity 2

Nausea and vomiting occur in 90% of patients. More frequently observed with the daily dosage schedule and can be severe.

---

## Toxicity 3

Myelosuppression. Usually mild with nadir occurring at 3–4 weeks.

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## Toxicity 4

Pain and/or burning at the injection site.

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## Toxicity 5

Altered glucose metabolism resulting in either hypoglycemia or hyperglycemia.

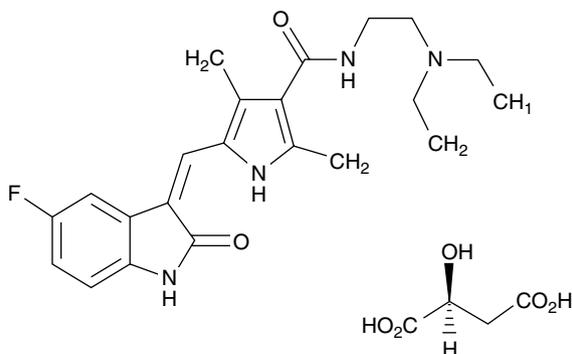
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## Toxicity 6

Mild and transient increases in SGOT, alkaline phosphatase, and bilirubin. Usual onset is within 2–3 weeks of starting therapy.

# Sunitinib

S



## Trade Name

Sutent, SU11248

## Classification

Signal transduction inhibitor

## Category

Chemotherapy drug

## Drug Manufacturer

Pfizer

## Mechanism of Action

- Inhibits multiple RTKs, some of which are involved in tumor growth, tumor angiogenesis, and metastasis.
- Potent inhibitor of platelet-derived growth factor receptors (PDGFR- $\alpha$  and PDGFR- $\beta$ ), vascular endothelial growth factor receptors (VEGFR<sub>1</sub>, VEGFR<sub>2</sub> and VEGFR<sub>3</sub>), stem cell factor receptor (KIT), Fms-like tyrosine kinase-3 (FLT3), colony stimulating factor receptor type I (CSF-1R), and the glial cell-line derived neurotrophic factor receptor (RET).

## Mechanism of Resistance

- Increased expression of PDGFR- $\alpha$ , PDGFR- $\beta$ , VEGFR<sub>1</sub>, VEGFR<sub>2</sub>, VEGFR<sub>3</sub>, KIT, CSF-1R, and RET.
- Alterations in binding affinity of the drug to the RTK resulting from mutations in the RTKs.

- Increased degradation and/or metabolism of the drug through as yet ill-defined mechanisms.

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### Absorption

Oral bioavailability is nearly 100%. Sunitinib may be taken with or without food, as food does not affect oral bioavailability.

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### Distribution

Extensive binding (90%–95%) of sunitinib and its primary metabolite to plasma proteins. Peak plasma levels are achieved 6 to 12 hours after ingestion. Steady-state drug concentrations of sunitinib and its primary active metabolite are reached in 10 to 14 days.

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### Metabolism

Metabolized in the liver primarily by the CYP<sub>3A4</sub> microsomal enzyme to produce its primary active metabolite, which is further metabolized by CYP<sub>3A4</sub>. The primary active metabolite comprises 23% to 37% of the total exposure. Elimination is hepatic with excretion in the feces (~60%), with renal elimination accounting for 16% of the administered dose. The terminal half-lives of sunitinib and its primary active metabolite are approximately 40 to 60 hours and 80 to 110 hours, respectively. With repeated daily administration, sunitinib accumulates 3- to 4-fold, while the primary metabolite accumulates 7- to 10-fold.

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### Indications

1. FDA-approved for the treatment of GIST after disease progression on or intolerance to imatinib.
2. FDA-approved for the treatment of advanced renal cell carcinoma.

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### Dosage Range

Recommended dose is 50 mg/day PO for 4 weeks followed by 2 weeks off.

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### Drug Interaction 1

Drugs such as ketoconazole, itraconazole, erythromycin, clarithromycin, atazanavir, indinavir, nefazodone, nelfinavir, ritonavir, saquinavir, telithromycin, and voriconazole decrease the rate of metabolism of sunitinib, resulting in increased drug levels and potentially increased toxicity.

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### Drug Interaction 2

Drugs such as rifampicin, dilantin, phenobarbital, carbamazepine, and St. John's Wort, increase the rate of metabolism of sunitinib, resulting in its inactivation.

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### Special Considerations

1. Baseline and periodic evaluations of LVEF should be performed while on sunitinib therapy.
2. Use with caution in patients with underlying cardiac disease, especially those who presented with cardiac events within 12 months prior to initiation of sunitinib, such as myocardial infarction (including severe/unstable angina), coronary/peripheral artery bypass graft, and CHF.
3. In the presence of clinical manifestations of CHF, discontinuation of sunitinib is recommended. The dose of sunitinib should be interrupted and/or reduced in patients without clinical evidence of CHF but with an ejection fraction  $<50\%$  and  $>20\%$  below baseline.
4. Closely monitor blood pressure while on therapy and treat as needed with standard oral anti-hypertensive medication. In cases of severe hypertension, temporary suspension of sunitinib is recommended until hypertension is controlled.
5. Monitor for adrenal insufficiency in patients who experience increased stress such as surgery, trauma, or severe infection.
6. Closely monitor thyroid function tests and TSH at 2 to 3-month intervals, as sunitinib treatment results in hypothyroidism. The incidence of hypothyroidism is increased with prolonged duration of therapy.
7. Avoid grapefruit and grapefruit juice for the duration of sunitinib therapy.
8. Pregnancy category D. Breast-feeding should be avoided.

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### Toxicity 1

Hypertension occurs in up to nearly 30% of patients. Usually occurs within 3–4 weeks of starting therapy and well-controlled with oral anti-hypertensive medication.

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### Toxicity 2

Yellowish discoloration of the skin occurs in approximately 30% of patients. Skin rash, dryness, thickness, and/or cracking of skin. Depigmentation of hair and/or skin may also occur.

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### Toxicity 3

Bleeding complications with epistaxis most commonly observed.

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### Toxicity 4

Constitutional side effects with fatigue and asthenia, which may be significant in some patients.

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## Toxicity 5

Diarrhea, stomatitis, altered taste, and abdominal pain are the most common GI side effects. Pancreatitis has been reported rarely with elevations in serum lipase and amylase.

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## Toxicity 6

Myelosuppression with neutropenia and thrombocytopenia.

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## Toxicity 7

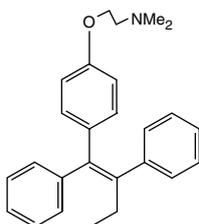
Increased risk of left ventricular dysfunction, which in some cases, results in CHF.

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## Toxicity 8

Adrenal insufficiency and hypothyroidism.

# Tamoxifen



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## Trade Names

Nolvadex

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## Classification

Anti-estrogen

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## Category

Hormonal agent

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## Drug Manufacturer

AstraZeneca

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## Mechanism of Action

- Nonsteroidal anti-estrogen with weak estrogen agonist effects.
- Competes with estrogen for binding to ERs. Binding of tamoxifen to ER leads to ER dimerization. The tamoxifen-bound ER dimer is transported to the nucleus, where it binds to DNA sequences referred to as ER elements. This interaction results in inhibition of critical transcriptional processes and signal transduction pathways that are required for cellular growth and proliferation.
- Cell cycle-specific agent that blocks cells in the mid-G<sub>1</sub> phase of the cell cycle. Effect may be mediated by cyclin D.
- Stimulates the secretion of transforming growth factor-beta (TGF- $\beta$ ) which then acts to inhibit the expression and/or activity of TGF- $\alpha$  and IGF-1, two genes that are involved in cell growth and proliferation.

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### Mechanism of Resistance

- Decreased expression of ER.
- Mutations in the ER leading to decreased binding affinity to tamoxifen.
- Overexpression of growth factor receptors such as TGF- $\alpha$  or IGF-1 that counteract the inhibitory effects of tamoxifen.

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### Absorption

Rapidly and completely absorbed in the GI tract. Peak plasma levels are achieved within 4–6 hours after oral administration.

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### Distribution

Distributes to most body tissues, especially in those expressing estrogen receptors. Present in very low concentrations in CSF. Nearly all of drug is bound to plasma proteins.

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### Metabolism

Extensively metabolized by liver cytochrome P450 enzymes after oral administration. The main metabolite, N-desmethyl tamoxifen, has biologic activity similar to that of the parent drug. Both tamoxifen and its metabolites are excreted primarily (75%) in feces with minimal clearance in urine. The terminal half-lives of tamoxifen and its metabolites are relatively long, approaching 7–14 days.

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### Indications

1. Adjuvant therapy in axillary node—negative breast cancer following surgical resection.
2. Adjuvant therapy in axillary node—positive breast cancer in postmenopausal women following surgical resection.
3. Adjuvant therapy in women with ductal carcinoma in situ (DCIS) after surgical resection and radiation therapy.
4. Metastatic breast cancer in women and men.
5. Approved as a chemopreventive agent for women at high risk for breast cancer. “High-risk” women are defined as women >35 years and with a 5-year predicted risk of breast cancer  $\geq 1.67\%$ , according to the Gail model.
6. Endometrial cancer.

---

### Dosage Range

Recommended dose for treatment of breast cancer patients is 20 mg PO every day.

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### Drug Interaction 1

Warfarin—Tamoxifen can inhibit metabolism of warfarin by the liver P<sub>450</sub> system leading to increased anticoagulant effect. Coagulation parameters, including PT and INR, must be closely monitored, and dose adjustments may be required.

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### Drug Interaction 2

Drugs activated by liver P<sub>450</sub> system—Tamoxifen and its metabolites are potent inhibitors of hepatic P<sub>450</sub> enzymes and may inhibit the metabolic activation of drugs utilizing this pathway, including cyclophosphamide.

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### Drug Interaction 3

Drugs metabolized by liver P<sub>450</sub> system—Tamoxifen and its metabolites are potent inhibitors of hepatic P<sub>450</sub> enzymes and may inhibit the metabolism of various drugs, including erythromycin, calcium channel blockers, and cyclosporine.

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### Special Considerations

1. Instruct patients to notify physician about menstrual irregularities, abnormal vaginal bleeding, and pelvic pain and/or discomfort while on therapy.
2. Patients should have routine follow-up with a gynecologist as tamoxifen therapy is associated with an increased risk of endometrial hyperplasia, polyps, and endometrial cancer.
3. Use with caution in patients with abnormal liver function as there may be an increased risk of drug accumulation resulting in toxicity.
4. Use with caution in patients with either personal history or family history of thromboembolic disease or hypercoagulable states as tamoxifen is associated with an increased risk of thromboembolic events. Tamoxifen therapy is associated with antithrombin III deficiency.
5. Initiation of treatment with tamoxifen may induce a transient tumor flare. Tamoxifen should not be given in patients with impending ureteral obstruction, spinal cord compression, or in those with extensive painful bone metastases.
6. Premenopausal patients should be warned about the possibility of developing menopausal symptoms with tamoxifen therapy.
7. Monitor CBC during therapy with tamoxifen as myelosuppression can occur, albeit rarely.
8. Pregnancy category D.

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**Toxicity 1**

Menopausal symptoms, including hot flashes, nausea, vomiting, vaginal bleeding, and menstrual irregularities. Vaginal discharge and vaginal dryness also observed.

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**Toxicity 2**

Fluid retention and peripheral edema observed in about 30% of patients.

---

**Toxicity 3**

Tumor flare usually occurs within the first 2 weeks of starting therapy. May observe increased bone pain, urinary retention, back pain with spinal cord compression, and/or hypercalcemia.

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**Toxicity 4**

Headache, lethargy, dizziness occur rarely. Visual disturbances, including cataracts, retinopathy, and decreased visual acuity, have been described.

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**Toxicity 5**

Skin rash, pruritus, hair thinning, and/or partial hair loss.

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**Toxicity 6**

Myelosuppression is rare, with transient thrombocytopenia and leukopenia. Usually resolves after the first week of treatment.

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**Toxicity 7**

Thromboembolic complications, including deep vein thrombosis, pulmonary embolism, and superficial phlebitis. Incidence of thromboembolic events may be increased when tamoxifen is given concomitantly with chemotherapy.

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**Toxicity 8**

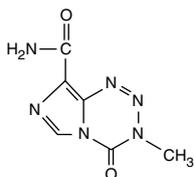
Elevations in serum triglycerides.

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**Toxicity 9**

Increased incidence of endometrial hyperplasia, polyps, and endometrial cancer.

# Temozolomide



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## Trade Names

Temodar

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## Classification

Nonclassic alkylating agent

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## Category

Chemotherapy drug

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## Drug Manufacturer

Schering

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## Mechanism of Action

- Imidazotetrazine analog that is structurally and functionally similar to dacarbazine.
- Cell cycle–nonspecific agent.
- Metabolic activation to the reactive compound MTIC is required for antitumor activity.
- Although the precise mechanism of cytotoxicity is unclear, this drug methylates guanine residues in DNA and inhibits DNA, RNA, and protein synthesis. Does not cross-link DNA strands.

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## Mechanism of Resistance

Increased activity of DNA repair enzymes such as O6-alkylguanine DNA alkyltransferase.

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## Absorption

Widely distributed in body tissues. Rapidly and completely absorbed with an oral bioavailability approaching 100%. Maximum plasma concentrations are reached within 1 hour after administration. Food reduces the rate and extent of drug absorption.

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### Distribution

Because temozolomide is lipophilic, it crosses the blood-brain barrier. Levels in brain and CSF are 30%–40% of those achieved in plasma.

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### Metabolism

Metabolized primarily by nonenzymatic hydrolysis at physiologic pH. Undergoes conversion to the metabolite MTIC, which is further hydrolyzed to AIC, a known intermediate in purine de novo synthesis, and methylhydrazine, the presumed active alkylating species. The elimination half-life of the drug is 2 hours. About 40%–50% of the parent drug is excreted in urine within 6 hours of administration, and tubular secretion is the predominant mechanism of renal excretion. No specific guidelines for drug dosing in the setting of hepatic and/or renal dysfunction. However, dose modification should be considered in patients with moderately severe hepatic and/or renal dysfunction.

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### Indications

1. Brain tumors. FDA-approved for refractory anaplastic astrocytomas at first relapse following treatment with a nitrosourea and procarbazine-containing regimen.
2. Metastatic melanoma.

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### Dosage Range

- Usual dose is 150 mg/m<sup>2</sup> PO daily for five days every 28 days.
- Dose is adjusted to nadir neutrophil and platelet counts. If nadir of ANC is acceptable, the dose may be increased to 200 mg/m<sup>2</sup> PO daily for five days. If ANC falls below acceptable levels during any cycle, the next dose should be reduced by 50 mg/m<sup>2</sup> PO daily.

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### Drug Interactions

None known.

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### Special Considerations

1. Temozolomide is a moderately emetogenic agent. Aggressive use of antiemetics prior to drug administration is required to decrease the risk of nausea and vomiting.
2. Patients should be warned to avoid sun exposure for several days after drug treatment.
3. Use with caution in elderly patients (age >65) as they are at increased risk for myelosuppression.
4. Pregnancy category D. Breast-feeding should be discontinued.

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**Toxicity 1**

Myelosuppression. Dose-limiting toxicity. Leukopenia and thrombocytopenia are commonly observed.

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**Toxicity 2**

Nausea and vomiting. Mild to moderate, usually occurring within 1–3 hours and lasting for up to 12 hours. Aggressive antiemetic therapy strongly recommended.

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**Toxicity 3**

Headache and fatigue.

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**Toxicity 4**

Mild elevation in hepatic transaminases.

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**Toxicity 5**

Photosensitivity.

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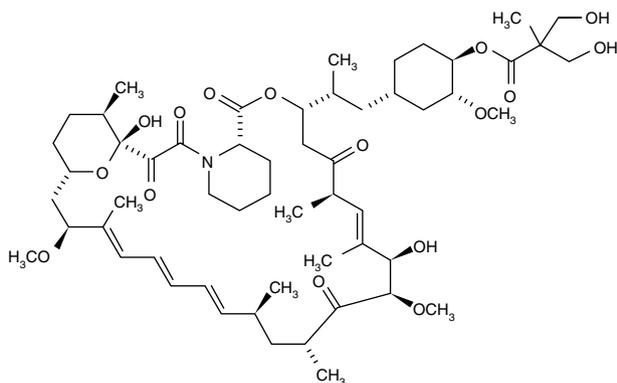
**Toxicity 6**

Teratogenic, mutagenic, and carcinogenic.

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## Temsirolimus



### Trade Names

Torisel, CCI-779

### Classification

Signal transduction inhibitor

### Category

Chemotherapy drug

### Drug Manufacturer

Wyeth

### Mechanism of Action

- Potent inhibitor of the mammalian target of rapamycin (mTOR) kinase, which is a key component of cellular signaling pathways involved in the growth and proliferation of tumor cells.
- Inhibition of mTOR signaling results in cell cycle arrest, induction of apoptosis, and inhibition of angiogenesis.

### Mechanism of Resistance

None well characterized to date.

### Absorption

Not available for oral use and is administered only by the IV route.

### Distribution

Widely distributed in tissues. Steady-state drug concentrations are reached in 7 to 8 days.

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## Metabolism

Metabolism in the liver primarily by the CYP3A4 microsomal enzyme. The main metabolite is sirolimus, which is a potent inhibitor of mTOR signaling, with the other metabolites accounting for <10% of all of the metabolites measured. Elimination is mainly hepatic with excretion in the feces, and renal elimination of parent drug and its metabolites accounts for only 5% of an administered dose. The terminal half-life of the parent drug is 17 hours, whereas that of sirolimus is 55 hours.

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## Indications

FDA-approved for the treatment of advanced renal cell cancer.

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## Dosage Range

Recommended dose is 25 mg IV administered on a weekly schedule.

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## Drug Interaction 1

Dilantin and other drugs that stimulate the liver microsomal CYP3A4 enzyme, including carbamazepine, rifampin, phenobarbital, and St. John's Wort—These drugs may increase the rate of metabolism of temsirolimus, resulting in its inactivation.

---

## Drug Interaction 2

Drugs that inhibit the liver microsomal CYP3A4 enzyme, including ketoconazole, itraconazole, erythromycin, and clarithromycin—These drugs may decrease the rate of metabolism of temsirolimus, resulting in increased drug levels and potentially increased toxicity.

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## Special Considerations

1. Use with caution in patients with hepatic impairment, and dose reduction and/or interruption should be considered.
2. Patients should be premedicated with an H<sub>1</sub> antihistamine (diphenhydramine 25 to 50 mg IV) 30 minutes before the start of therapy to reduce the incidence of hypersensitivity reactions.
3. Closely monitor serum glucose levels in all patients, especially those with diabetes mellitus.
4. Closely monitor patients for new or progressive pulmonary symptoms, including cough, dyspnea, and fever. Temsirolimus therapy should be interrupted pending further diagnostic evaluation.
5. Patients are at increased risk for developing opportunistic infections while on temsirolimus.
6. Closely monitor serum triglyceride and cholesterol levels while on therapy.

- 
7. Patients should be advised to report the development of fever, abdominal pain, and/or bloody stools, as temsirolimus may cause bowel perforation.
  8. Closely monitor renal dysfunction during therapy, as temsirolimus can cause progressive and severe renal failure, especially in patients with pre-existing renal impairment.
  9. Use with caution after surgical procedures, as temsirolimus can impair the process of wound healing.
  10. Pregnancy category D.

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**Toxicity 1**

Asthenia and fatigue.

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**Toxicity 2**

Pruritus, dry skin with mainly a pustular, acneiform skin rash.

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**Toxicity 3**

Nausea/vomiting, mucositis, and anorexia.

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**Toxicity 4**

Hyperlipidemia with increased serum triglycerides and/or cholesterol in up to 90% of patients.

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**Toxicity 5**

Hyperglycemia in up to 80% to 90% of patients.

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**Toxicity 6**

Allergic, hypersensitivity reactions occur in 10% of patients.

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**Toxicity 7**

Pulmonary toxicity in the form of ILD manifested by increased cough, dyspnea, fever, and pulmonary infiltrates. Observed in less than 1% of patients and more frequent in patients with underlying pulmonary disease.

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**Toxicity 8**

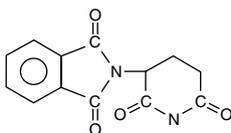
Renal toxicity with elevation in serum creatinine.

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**Toxicity 9**

Peripheral edema.

# Thalidomide



## Trade Names

Thalomid

## Classification

Immunomodulatory agent, anti-angiogenic agent

## Category

Unclassified therapeutic agent, biologic response modifier agent

## Drug Manufacturer

Celgene

## Mechanism of Action

- Mechanism of action is not fully characterized.
- Inhibition of TNF- $\alpha$  synthesis and down-modulation of selected cell surface adhesion molecules.
- May exert an anti-angiogenic effect through inhibition of bFGF and VEGF as well as through as yet undefined mechanisms.

## Mechanism of Resistance

None known.

## Absorption

Oral bioavailability of thalidomide is not known due to poor aqueous solubility. Slowly absorbed from the GI tract with peak plasma levels reached 3–6 hours after oral administration.

## Distribution

The apparent volume of distribution varies by dose level: 67 L and 166 L at doses of 200 and 1,200 mg/day. Remains unclear whether thalidomide is present in the ejaculate of males. The extent of binding to plasma proteins is not known.

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## Metabolism

Nonenzymatic hydrolysis appears to be the principal mechanism of thalidomide breakdown. However, the exact metabolic pathway(s) has not been fully characterized. The precise route of drug excretion is not well defined.

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## Indications

1. FDA-approved in combination with dexamethasone for the treatment of newly diagnosed multiple myeloma.
2. FDA-approved for the treatment of the cutaneous manifestations of erythema nodosum leprosum (ENL).
3. Thalidomide has activity in MDS and in a broad range of solid tumors.

---

## Dosage Range

No standard dose recommendations for use in cancer patients have been established. When used in combination with chemotherapy, doses are typically titrated up to 400 mg PO daily given as a single bedtime dose. As a single agent, doses have been in the range of 100 mg to 1,200 mg daily.

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## Drug Interaction 1

Barbiturates, chlorpromazine, and reserpine—Sedative effect of thalidomide is enhanced with concurrent use of these medications.

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## Drug Interaction 2

Alcohol—Sedative effect of thalidomide is enhanced with concurrent use of alcohol.

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## Special Considerations

1. Pregnancy category X. Severe fetal malformations can occur if even one capsule is taken by a pregnant woman. All women should have a baseline  $\beta$ -human chorionic gonadotropin before starting therapy with thalidomide. All women of childbearing potential should practice two forms of birth control throughout treatment with thalidomide: one highly effective (intrauterine device, hormonal contraception, partner's vasectomy) and one additional barrier method (latex condom, diaphragm, cervical cap). It is strongly recommended that these precautionary measures begin 4 weeks before initiation of therapy, that they continue while on therapy, and continue for at least 4 weeks after therapy is discontinued.
2. Breast-feeding while on therapy should be avoided given the potential for serious adverse reactions from thalidomide in nursing infants. It remains unknown whether thalidomide is excreted in human milk.

3. Men taking thalidomide must use latex condoms for every sexual encounter with a woman of childbearing potential since thalidomide may be present in semen.
4. Patients with AIDS should have their HIV mRNA levels monitored after the first and third months after treatment initiation with thalidomide, then every 3 months thereafter, as HIV mRNA levels may be increased while on thalidomide.
5. Instruct patients to avoid operating heavy machinery or driving a car while on thalidomide as the drug can cause drowsiness.
6. Patients who develop a skin rash during therapy with thalidomide should have prompt medical evaluation. Serious skin reactions, including Stevens-Johnson syndrome, which may be fatal, have been reported.
7. There is an increased risk of thromboembolic complications, including DVT and PE, and prophylaxis with coumadin or aspirin can help to prevent and/or reduce the incidence.

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#### Toxicity 1

Teratogenic effect is most serious toxicity. Severe birth defects or death to an unborn fetus. Manifested as absent or defective limbs, hypoplasia or absence of bones, facial palsy, absent or small ears, absent or shrunken eyes, congenital heart defects, and GI and renal abnormalities.

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#### Toxicity 2

General neurologic-related events that occur frequently include fatigue, orthostatic hypotension, and dizziness. Specific peripheral neuropathy in the form of numbness, tingling, and pain in the feet or hands does not appear to be dose- or duration-related. Prior exposure to neurotoxic agents increases the risk of occurrence.

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#### Toxicity 3

Constipation is most common GI toxicity.

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#### Toxicity 4

No known direct myelosuppressive effects. Effects on blood cell counts may occur indirectly through its effect on TNF- $\alpha$  or other cytokines that influence blood cell regulation, recruitment, and activation. Certain treatment populations (ENL and HIV) have reported a higher incidence of abnormalities in blood counts.

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#### Toxicity 5

Maculopapular skin rash, urticaria, and dry skin. Serious dermatologic reactions, including Stevens-Johnson syndrome, have been reported. Patients who develop a skin rash during therapy with thalidomide should discontinue

# T

therapy. Therapy can be restarted with caution if the rash was not exfoliative, purpuric, or bullous or otherwise suggestive of a serious skin condition.

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## Toxicity 6

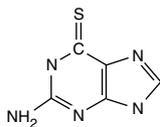
Daytime sedation or fatigue following an evening dose often associated with larger initial doses. Doses can be reduced until the patient accommodates to the effect.

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## Toxicity 7

Increased risk of thromboembolic complications, including DVT and PE.

# Thioguanine



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## Trade Names

6-Thioguanine, 6-TG

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## Classification

Antimetabolite

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## Category

Chemotherapy drug

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## Drug Manufacturer

GlaxoSmithKline

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## Mechanism of Action

- Cell cycle–specific purine analog with activity in the S-phase.
- Parent drug is inactive. Requires intracellular phosphorylation by the enzyme HGPRT to the cytotoxic monophosphate form, which is then eventually metabolized to the triphosphate metabolite form.
- Inhibits *de novo* purine synthesis by inhibiting PRPP amidotransferase.
- Incorporation of thiopurine triphosphate nucleotides into DNA resulting in inhibition of DNA synthesis and function.
- Incorporation of thiopurine triphosphate nucleotides into RNA resulting in alterations in RNA processing and/or translation.

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## Mechanism of Resistance

- Decreased expression of the activating enzyme HGPRT.
- Increased expression of the catabolic enzyme alkaline phosphatase or the conjugating enzyme TPMT.
- Decreased cellular transport of drug.
- Decreased expression of MMR enzymes (e.g., hMLH1, hMSH2).
- Cross-resistance between thioguanine and mercaptopurine.

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## Absorption

Oral absorption of drug is incomplete and variable. Only 30% of an oral dose is absorbed. Peak plasma levels are reached in 2–4 hours after ingestion.

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## Distribution

Distributes widely into the RNA and DNA of peripheral blood and bone marrow cells. Crosses the placenta but does not appear to cross the blood-brain barrier.

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## Metabolism

Metabolized in the liver by the processes of deamination and methylation. Main pathway of inactivation is catalyzed by guanine deaminase (guanase). In contrast with mercaptopurine, metabolism of thioguanine does not involve xanthine oxidase. Metabolites are eliminated in both feces and urine. Plasma half-life is on the order of 80–90 minutes.

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## Indications

1. Acute myelogenous leukemia.
2. Acute lymphoblastic leukemia.
3. Chronic myelogenous leukemia.

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## Dosage Range

1. Induction: 100 mg/m<sup>2</sup> PO every 12 hours on days 1–5, usually in combination with cytarabine.
2. Maintenance: 100 mg/m<sup>2</sup> PO every 12 hours on days 1–5, every 4 weeks, usually in combination with other agents.
3. Single-agent: 1–3 mg/kg PO daily.

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## Drug Interactions

None known.

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## Special Considerations

1. Dose of drug does not need to be reduced in patients with abnormal liver and/or renal function.
2. In contrast with 6-mercaptopurine, dose of drug does not need to be reduced in the presence of concomitant allopurinol therapy.
3. Administer on an empty stomach to facilitate absorption.
4. Use with caution in the presence of other hepatotoxic drugs as the risk of thioguanine-associated hepatotoxicity is increased.
5. Pregnancy category D.

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**Toxicity 1**

Myelosuppression. Dose-limiting toxicity. Leukopenia tends to precede thrombocytopenia with nadir at 10–14 days and recovery by day 21.

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**Toxicity 2**

Nausea and vomiting. Dose-related, usually mild.

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**Toxicity 3**

Mucositis and diarrhea. May be severe, requiring dose reduction.

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**Toxicity 4**

Hepatotoxicity in the form of elevated serum bilirubin and transaminases. Veno-occlusive disease has been reported rarely.

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**Toxicity 5**

Immunosuppression. Increased risk of bacterial, fungal, and parasitic infections.

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**Toxicity 6**

Transient renal toxicity.

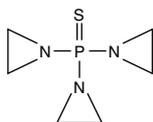
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**Toxicity 7**

Mutagenic, teratogenic, and carcinogenic.

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## Thiotepa



### Trade Names

Triethylenethiophosphoramidate, Thioplex

### Classification

Alkylating agent

### Category

Chemotherapy drug

### Drug Manufacturer

Immunex

### Mechanism of Action

- Ethylenimine analog chemically related to nitrogen mustard.
- Functions as an alkylating agent by alkylating the N-7 position of guanine.
- Cell cycle–nonspecific agent.
- Inhibits DNA, RNA, and protein synthesis.

### Mechanism of Resistance

- Decreased uptake of drug into cell.
- Increased activity of DNA repair enzymes.
- Increased expression of sulfhydryl proteins, including glutathione and glutathione-related proteins.

### Absorption

Incomplete and erratic absorption via the oral route. Thiotepa is primarily administered by the IV route. Also given by intravesical route where the absorption from the bladder is variable, ranging from 10%–100% of an administered dose.

### Distribution

Widely distributed throughout the body. About 40% of drug is bound to plasma proteins.

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### Metabolism

Extensively metabolized by the liver microsomal P<sub>450</sub> system to both active and inactive metabolites. About 60% of a dose is eliminated in urine within 24–72 hours with only a small amount excreted as parent drug. Elimination half-life is on the order of 2–3 hours.

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### Indications

1. Breast cancer.
2. Ovarian cancer.
3. Superficial transitional cell cancer of the bladder.
4. Hodgkin's and non-Hodgkin's lymphoma.
5. High-dose transplant setting for breast and ovarian cancer.

---

### Dosage Range

1. Usual dose is 10–20 mg/m<sup>2</sup> IV given every 3–4 weeks.
2. High-dose transplant setting: Doses range from 180 to 1,100 mg/m<sup>2</sup> IV.
3. Intravesical instillation: Dose for bladder instillation is 60 mg administered in 60 mL sterile water weekly for up to 4 weeks.

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### Drug Interaction 1

Myelosuppressive agents—Bone marrow toxicity of thiotepa is enhanced when combined with other myelosuppressive anticancer agents.

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### Special Considerations

1. Monitor CBC while on therapy as thiotepa is highly toxic to the bone marrow.
2. Use with caution in regimens including other myelosuppressive agents as the risk of bone marrow toxicity is significantly increased.
3. Resuscitation equipment and medications should be available during administration of drug as there is a risk of hypersensitivity reaction.
4. Monitor CBC after intravesical administration of drug into the bladder as severe bone marrow depression can arise from systemically absorbed drug.
5. Caution patients about the risk of skin changes such as rash, urticaria, bronzing, flaking, and desquamation that can occur following high-dose therapy. Topical skin care should be initiated promptly.
6. Pregnancy category D.

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### Toxicity 1

Myelosuppression. Dose-limiting toxicity. Leukopenia nadir 7–10 days with recovery by day 21. Platelet count nadir occurs at day 21 with usual recovery by day 28–35.

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## Toxicity 2

Nausea and vomiting. Dose-dependent. Usual onset is 6–12 hours after treatment.

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## Toxicity 3

Mucositis. May be dose-limiting with high-dose therapy.

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## Toxicity 4

Allergic reaction in the form of skin rash, hives, and rarely bronchospasm.

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## Toxicity 5

Chemical and/or hemorrhagic cystitis. Occurs rarely following intravesical treatment.

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## Toxicity 6

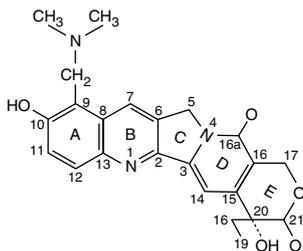
Skin changes with rash and bronzing of skin, erythema, flaking, and desquamation developing after high-dose therapy.

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## Toxicity 7

Increased risk of secondary malignancies, usually in the form of acute myelogenous leukemia. Breast cancer and non-small cell lung cancer have also been reported. Thiotepa is teratogenic, mutagenic, and carcinogenic.

# Topotecan



## Trade Names

Hycamtin

## Classification

Topoisomerase I inhibitor

## Category

Chemotherapy drug

## Drug Manufacturer

GlaxoSmithKline

## Mechanism of Action

- Semisynthetic derivative of camptothecin, an alkaloid extract from the *Camptotheca acuminata* tree.
- Inhibits topoisomerase I function. Binds to and stabilizes the topoisomerase I-DNA complex and prevents the relegation of DNA after it has been cleaved by topoisomerase I. The collision between this stable complex (“cleavable complex”) and the advancing replication fork results in double-strand DNA breaks and cellular death.
- Antitumor activity of drug requires the presence of topoisomerase I and ongoing DNA synthesis.

## Mechanism of Resistance

- Decreased expression of topoisomerase I.
- Mutations in topoisomerase I enzyme with decreased binding affinity to drug.

- Increased expression of the multidrug-resistant phenotype with overexpression of P170 glycoprotein. Results in enhanced efflux of drug and decreased intracellular accumulation of drug.
- Decreased accumulation of drug into cells through non-multidrug-resistant-related mechanisms.

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### Absorption

Administered only by the IV route.

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### Distribution

Widely distributed in body tissues. Binding to plasma proteins is on the order of 10%–35%. Levels of drug in the CSF are only 30% of those in plasma. Peak drug levels are achieved within 1 hour after drug administration.

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### Metabolism

Rapid conversion of topotecan in plasma and in aqueous solution from the lactone ring form to the carboxylate acid form. At pH4, topotecan is mainly in the lactone ring, while at physiologic pH, the carboxylate form predominates. Only about 20% to 30% of a given dose is present as the active lactone metabolite at 1 hour after drug administration. The major route of elimination of topotecan is renal excretion accounting for 40%–68% of drug clearance. Metabolism in the liver appears to be minimal and is mediated by the liver microsomal P450 system. The elimination half-life is approximately 3 hours.

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### Indications

1. Ovarian cancer—FDA-approved in patients with advanced ovarian cancer who failed platinum-based chemotherapy.
2. Small cell lung cancer—FDA-approved in patients with sensitive disease who failed first-line chemotherapy.
3. Acute myelogenous leukemia.

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### Dosage Range

Usual dose is 1.5 mg/m<sup>2</sup> IV for 5 consecutive days given every 21 days.

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### Drug Interactions

None known.

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### Special Considerations

1. Use with caution in patients with abnormal renal function. Dose reduction is necessary in this setting. Baseline creatinine clearance is critical, as is periodic monitoring of renal function.
2. Monitor CBC on a weekly basis.

3. Carefully monitor administration of drug as it is a mild vesicant. The infusion site should be carefully monitored for extravasation, in which case flushing with sterile water, elevation of the extremity, and local application of ice are recommended. In severe cases, a plastic surgeon should be consulted.
4. If granulocyte nadir count is low, begin G-CSF or GM-CSF 24 hours after the completion of topotecan therapy.
5. Pregnancy category D. Breast-feeding should be avoided.

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#### Toxicity 1

Myelosuppression. Dose-limiting with neutropenia being most commonly observed. Typical nadir occurs at days 7–10 with full recovery by days 21–28.

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#### Toxicity 2

Nausea and vomiting. Mild to moderate and dose-related. Occur in 60%–80% of patients. Diarrhea with abdominal pain also observed.

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#### Toxicity 3

Headache, fever, malaise, arthralgias, and myalgias.

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#### Toxicity 4

Microscopic hematuria. Seen in 10% of patients.

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#### Toxicity 5

Alopecia.

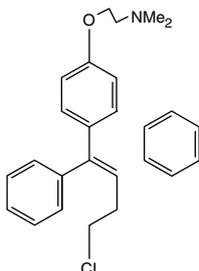
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#### Toxicity 6

Transient elevation in serum transaminases, alkaline phosphatase, and bilirubin.

# T

## Toremifene



### Trade Names

Fareston

### Classification

Anti-estrogen

### Category

Hormonal agent

### Drug Manufacturer

Orion and Schering

### Mechanism of Action

- Synthetic analog of tamoxifen.
- Nonsteroidal anti-estrogen that directly binds to estrogen receptors on breast cancer cells. Affinity for estrogen receptor is 4-fold to 5-fold higher than tamoxifen. Blocks downstream intracellular signal transduction pathways, leading to inhibition of cell growth and induction of apoptosis.

### Mechanism of Resistance

None known.

### Absorption

Well absorbed after oral administration. Food does not interfere with oral absorption.

### Distribution

Widely distributed to body tissues. Extensive (>99%) binding to plasma proteins, mainly albumin. Steady-state plasma concentrations are reached in 4–6 weeks.

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## Metabolism

Extensive metabolism in the liver by the cytochrome P<sub>450</sub> system. Major metabolites, N-demethyltoremifene and 4-hydroxytoremifene, have long terminal half-lives of 4–6 days secondary to enterohepatic recirculation. Parent drug and metabolites are excreted mainly in bile and feces. Minimal excretion in urine.

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## Indications

Metastatic breast cancer in postmenopausal women with ER+ tumors or in cases where ER– status is not known. Not recommended in ER– tumors.

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## Dosage Range

Recommended dose is 60 mg PO daily until disease progression.

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## Drug Interaction 1

Thiazide diuretics—Decreases renal clearance of calcium and increases the risk of hypercalcemia associated with toremifene.

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## Drug Interaction 2

Warfarin—Toremifene inhibits liver P<sub>450</sub> metabolism of warfarin resulting in an increased anticoagulant effect. Coagulation parameters, PT and INR, should be closely monitored, and dose adjustments made accordingly.

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## Drug Interaction 3

Phenobarbital, carbamazepine, phenytoin—Liver P<sub>450</sub> metabolism of toremifene may be enhanced by phenobarbital, carbamazepine, and phenytoin resulting in reduced blood levels and reduced clinical efficacy.

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## Drug Interaction 4

Ketoconazole and erythromycin—Liver P<sub>450</sub> metabolism of toremifene may be inhibited by ketoconazole and erythromycin, resulting in elevated blood levels and enhanced clinical efficacy.

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## Drug Interaction 5

Tamoxifen—Cross-resistance between toremifene, tamoxifen, and other antiestrogen agents.

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## Special Considerations

1. Patients with a prior history of thromboembolic events must be carefully monitored while on therapy as toremifene is thrombogenic.
2. Use with caution in the setting of brain and/or vertebral body metastases as tumor flare with bone and/or muscular pain, erythema, and transient increase in tumor volume can occur upon initiation of therapy.



3. Monitor CBC, LFTs, and serum calcium on a regular basis.
4. Contraindicated in patients with a prior history of endometrial hyperplasia. Increased risk of endometrial cancer associated with therapy. Onset of vaginal bleeding during therapy requires immediate gynecologic evaluation.
5. Baseline and biannual eye exams are recommended as toremifene can lead to cataract formation.
6. Pregnancy category D. Not known whether toremifene is excreted in breast milk.

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**Toxicity 1**

Hot flashes, sweating, menstrual irregularity, milk production in breast, and vaginal discharge and bleeding are commonly observed.

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**Toxicity 2**

Transient tumor flare manifested by bone and/or tumor pain.

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**Toxicity 3**

Ocular toxicity with cataract formation and xerophthalmia.

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**Toxicity 4**

Nausea, vomiting, and anorexia.

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**Toxicity 5**

Myelosuppression is usually mild.

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**Toxicity 6**

Rare skin toxicity in the form of rash, alopecia, and peripheral edema.

# Tositumomab



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## Trade Names

Bexxar

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## Classification

Monoclonal antibody

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Corixa and GlaxoSmithKline

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## Mechanism of Action

- Radioimmunotherapeutic monoclonal antibody-based regimen composed of the tositumomab monoclonal antibody and the radiolabeled monoclonal antibody I-131 tositumomab, a radio-iodinated derivative of tositumomab that has been covalently linked to I-131.
- The antibody moiety is tositumomab, which targets the CD20 antigen, a 35 kDa cell surface non-glycosylated phosphoprotein expressed during early pre-B cell development until the plasma cell stage. Binding of the antibody to CD20 induces a transmembrane signal that blocks cell activation and cell cycle progression.
- CD20 is expressed on more than 90% of all B-cell non-Hodgkin's lymphomas and leukemias. CD20 is not expressed on early pre-B cells, plasma cells, normal bone marrow stem cells, antigen-presenting dendritic reticulum cells, or other normal tissues.
- Ionizing radiation from the I-131 radioisotope results in cell death.

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## Absorption

Tositumomab is given only by the IV route.

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## Distribution

Higher clearance, shorter terminal half-life, and larger volumes of distribution observed in patients with higher tumor burden, splenomegaly, and/or bone marrow involvement.

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## Metabolism

Elimination of I-131 occurs by decay and excretion in the urine. The total body clearance is 67% of an administered dose, and nearly 100% of the clearance is accounted for in the urine.

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### Indications

Relapsed and/or refractory CD20-positive, follicular non-Hodgkin's lymphoma with and without transformation-disease is refractory to rituximab therapy and has relapsed following chemotherapy.

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### Dosage Range

The treatment schema is as follows: Day 0: Begin Lugol's solution or oral potassium iodide solution; Day 1, Dosimetric dose: 450 mg unlabeled tositumomab, followed by 5 mCi of <sup>131</sup>I-tositumomab (35 mg). Measurement of whole body counts and calculation of therapeutic dose; Day 7 up to Day 14, Therapeutic dose: 450 mg unlabeled tositumomab, followed by calculated therapeutic dose of <sup>131</sup>I-tositumomab to deliver 75 cGy; Days 8–21: Continue Lugol's solution or oral potassium iodide solution.

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### Drug Interactions

None characterized to date.

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### Special Considerations

1. Contraindicated in patients with known type I hypersensitivity or known hypersensitivity to any component of the BEXXAR therapeutic regimen.
2. TSH levels should be monitored before treatment and on an annual basis thereafter.
3. Before receiving the dosimetric dose of I-<sup>131</sup>I, patients must receive at least three doses of SSKI, three doses of Lugol's solution, or one dose of 130 mg potassium iodide (at least 24 hours prior to the dosimetric dose).
4. This therapy should be used only by physicians and health care professionals who are qualified and experienced in the safe use and handling of radioisotopes.
5. Patients should be premedicated with acetaminophen and diphenhydramine before each administration of tositumomab in the dosimetric and therapeutic steps to reduce the incidence of infusion-related reactions.
6. The same IV tubing set and filter must be used throughout the dosimetric and therapeutic step as a change in filter can result in loss of effective drug delivery.
7. Monitor for infusion-related events resulting from tositumomab infusion, which usually occur during or within 48 hours of infusion. Infusion rate should be reduced by 50% for mild to moderate allergic reaction and immediately stopped for a severe reaction. Immediate institution of diphenhydramine, acetaminophen, corticosteroids, IV fluids, and/or vasopressors may be necessary. In the setting of a

severe reaction, the infusion can be restarted at a reduced rate (50%) once symptoms have completely resolved. Resuscitation equipment should be readily available at bedside.

8. Tositumomab therapy should not be given to patients with >25% involvement of the bone marrow by lymphoma and/or impaired bone marrow reserve or to patients with platelet count <100,000/mm<sup>3</sup> or neutrophil count <15,000/mm<sup>3</sup>.
9. Complete blood counts and platelet counts should be monitored weekly following tositumomab therapy for up to 10–12 weeks after therapy.
10. The tositumomab regimen should be given only as a single-course treatment.
11. The tositumomab regimen may have direct toxic effects on the male and female reproductive organs, and effective contraception should be used during therapy and for up to 12 months following the completion of therapy.
12. Pregnancy category X. Contraindicated in women who are pregnant.
13. Breast-feeding should be discontinued immediately prior to starting therapy.

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#### Toxicity 1

Infusion-related symptoms, including fever, chills, urticaria, flushing, fatigue, headache, bronchospasm, rhinitis, dyspnea, angioedema, nausea, and/or hypotension. Usually resolve upon slowing and/or interrupting the infusion and with supportive care.

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#### Toxicity 2

Myelosuppression is most common side effect with all elements affected. The time to nadir is typically 4–7 weeks, and the duration of cytopenias is 30 days. In 5%–7% of patients, severe cytopenias persist beyond 12 weeks after therapy.

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#### Toxicity 3

Mild asthenia and fatigue occur in up to 40% of patients.

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#### Toxicity 4

Infections develop in up to 45% of patients. Majority of infection events are viral and relatively minor, but up to 10% of patients experience infections that require hospitalization.

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#### Toxicity 5

Mild nausea and vomiting.

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**Toxicity 6**

Hypothyroidism.

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**Toxicity 7**

Secondary malignancies occur in about 2%–3% of patients. Acute myelogenous leukemia and myelodysplastic syndrome have been reported with a cumulative incidence of 1.4% at 2 years and 4.8% at 4 years following therapy.

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**Toxicity 8**

Development of HAMAs. Rare event in less than 1%–2% of patients.

# Trastuzumab



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## Trade Names

Herceptin, Anti-HER-2-antibody

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## Classification

Monoclonal antibody

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## Category

Biologic response modifier agent

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## Drug Manufacturer

Genentech

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## Mechanism of Action

- Recombinant humanized monoclonal antibody directed against the extracellular domain of the HER-2/neu human epidermal growth factor receptor. This receptor is overexpressed in several human cancers, including 25%–30% of breast cancers.
- Precise mechanism(s) of action remains unknown.
- Downregulates expression of HER-2/neu receptors.
- Inhibits HER-2/neu intracellular signaling pathways.
- Induction of apoptosis through as yet undetermined mechanisms.
- Immunologic mechanisms may also be involved in antitumor activity, and they include recruitment of antibody-dependent cellular cytotoxicity (ADCC) and/or complement-mediated cell lysis.

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## Mechanism of Resistance

- Mutation in the HER-2/neu growth factor receptor leading to decreased binding affinity to trastuzumab.
- Decreased expression of HER-2/neu receptors.
- Activation/induction of alternative cellular signaling pathways, such as IGF-1R.

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## Distribution

Distribution in body is not well characterized.

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## Metabolism

Metabolism of trastuzumab has not been extensively characterized. Half-life is on the order of 5–6 days with minimal clearance by the liver or kidneys, as has been observed for other monoclonal antibodies and peptides used in the clinic.

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## Indications

1. Metastatic breast cancer—First-line therapy in combination with paclitaxel. Patient's tumor must express HER-2/neu protein to be treated with this monoclonal antibody.
2. Metastatic breast cancer—Second- and third-line therapy as a single agent in patients whose tumors overexpress the HER-2/neu protein.
3. FDA-approved for the adjuvant therapy of node-positive, HER2-overexpressing breast cancer as part of a treatment regimen containing doxorubicin, cyclophosphamide, and paclitaxel.

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## Dosage Range

1. Recommended loading dose of 4 mg/kg IV administered over 90 minutes, followed by maintenance dose of 2 mg/kg IV on a weekly basis.
2. Alternative schedule is to give a loading dose of 8 mg/kg IV administered over 90 minutes, followed by maintenance dose of 6 mg/kg IV every 3 weeks.

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## Drug Interactions

Anthracyclines, taxanes—Increased risk of cardiotoxicity when trastuzumab is used in combination with anthracyclines and/or taxanes.

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## Special Considerations

1. Caution should be exercised in treating patients with pre-existing cardiac dysfunction. Careful baseline assessment of cardiac function before treatment and frequent monitoring of cardiac while on therapy. Trastuzumab should be stopped immediately in patients who develop clinically significant congestive heart failure.
2. Administer initial loading dose over 90 minutes and then observe patient for 1 hour following completion of the loading dose. Carefully monitor for infusion-related symptoms. May need to treat with Benadryl and acetaminophen. Rarely, in severe cases, may need to treat with IV fluids and/or pressors.
3. Maintenance doses are administered over 30 minutes if loading dose was well tolerated without fever and chills. However, if fever and chills were experienced with loading dose, need to administer over 90 minutes.
4. Pregnancy category B.

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**Toxicity 1**

Infusion-related symptoms with fever, chills, urticaria, flushing, fatigue, headache, bronchospasm, dyspnea, angioedema, and hypotension. Occurs in 40%–50% of patients. Usually mild to moderate in severity and observed most commonly with administration of the first infusion.

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**Toxicity 2**

Nausea and vomiting, diarrhea. Generally mild.

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**Toxicity 3**

Cardiotoxicity in the form of dyspnea, peripheral edema, and reduced left ventricular function. Occurs in 5%–7% of patients treated with trastuzumab alone, in 25%–30% of patients treated with trastuzumab plus anthracycline, and in 12% of patients treated with trastuzumab plus paclitaxel. Significantly increased risk when used in combination with an anthracycline/cyclophosphamide regimen. In most instances, cardiac dysfunction is readily reversible.

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**Toxicity 4**

Myelosuppression. Increased risk and severity when trastuzumab is administered with chemotherapy.

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**Toxicity 5**

Generalized pain, asthenia, and headache.

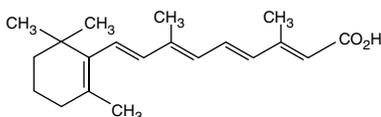
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**Toxicity 6**

Pulmonary toxicity in the form of increased cough, dyspnea, rhinitis, sinusitis, pulmonary infiltrates, and/or pleural effusions.

# T

## Tretinoin



### Trade Names

All-Trans-Retinoic Acid, ATRA, Vesanoïd

### Classification

Retinoid

### Category

Differentiating agent

### Drug Manufacturer

Roche

### Mechanism of Action

- Precise mechanism of action has not been fully elucidated.
- Induces differentiation of acute promyelocytic cells to normal myelocyte cells, thereby decreasing cellular proliferation.
- Upon entry into cells, tretinoin binds to the cytoplasmic protein, cellular retinoic acid binding protein (CRABP). The retinoid CRABP complex is transported to the nucleus where it binds to retinoid-dependent receptors known as RAR and/or RXR. This process affects the transcription and subsequent expression of various target cellular genes involved in growth, proliferation, and differentiation.
- Effects on the immune system may also contribute to antitumor activity.
- Induces apoptosis through as yet undetermined mechanisms.

### Mechanism of Resistance

- Alteration in drug metabolism by the liver P450 system. Tretinoin induces the activity of cytochrome P450 enzymes, which are responsible for its oxidative metabolism. Plasma concentrations decrease to about one-third of their day one values after 1 week of continuous therapy.
- Increased expression of CRABP, which acts to sequester tretinoin within the cell, preventing its subsequent delivery to the nucleus.

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### Absorption

Well-absorbed by the GI tract, reaching peak plasma concentration between 1 and 2 hours after oral administration.

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### Distribution

Binds extensively (>95%) to plasma proteins, mainly to albumin. The apparent volume of distribution has not been determined.

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### Metabolism

Undergoes oxidative metabolism by the liver cytochrome P<sub>450</sub> system. Several metabolites have been identified, including 13-cis retinoic acid, 4-oxo trans retinoic acid, 4-oxo cis retinoic acid, and 4-oxo trans retinoic acid glucuronide. Excreted in urine (63%) and in feces (31%). The terminal elimination half-life is approximately 40 to 120 minutes.

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### Indications

Acute promyelocytic leukemia (APL)—induction of remission in patients with APL characterized by the t(15;17) translocation and/or the presence of the PML/RAR- $\alpha$  gene following progression and/or relapse with anthracycline-based chemotherapy or for whom anthracycline-based chemotherapy is contraindicated.

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### Dosage Range

Recommended dose is 45 mg/m<sup>2</sup>/day PO divided in two daily doses for a minimum of 45 days and a maximum of 90 days.

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### Drug Interaction 1

Drugs metabolized by liver P<sub>450</sub> system—Tretinoin is metabolized by hepatic cytochrome P<sub>450</sub> enzymes. Caution should be exercised when using drugs that induce this enzyme system, such as rifampin and phenobarbital, and drugs that inhibit this system, including ketoconazole, cimetidine, erythromycin, verapamil, diltiazem, and cyclosporine.

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### Drug Interaction 2

Vitamin A supplements—Use of vitamin A supplements may increase toxicity of tretinoin.

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### Special Considerations

1. Contraindicated in patients with a known hypersensitivity to retinoids.
2. Monitor for new-onset fever, respiratory symptoms, and leukocytosis as 25% of patients develop the retinoic acid syndrome. Tretinoin should be stopped immediately, and high-dose dexamethasone, 10 mg IV q 12 hours should be given for 3 days or until resolution of symptoms. In most cases, therapy can be resumed once the

syndrome has completely resolved. Usually occurs during the first month of treatment.

3. Use with caution in patients with pre-existing hypertriglyceridemia and in those with diabetes mellitus, obesity, and/or predisposition to excessive alcohol intake. Serum triglyceride and cholesterol levels should be closely monitored.
4. Monitor CBC, coagulation profile, and LFTs on a frequent basis during therapy.
5. Oral absorption of tretinoin may be increased when taken with food.
6. Pregnancy category D.

---

#### Toxicity 1

Vitamin A toxicity. Nearly universal. Most common side effects are headache, usually occurring in the first week of therapy with improvement thereafter, fever, dryness of the skin and mucous membranes, skin rash, peripheral edema, mucositis, pruritus, and conjunctivitis.

---

#### Toxicity 2

Tretinoic acid syndrome. Can be dose-limiting; occurs in 25% of patients. Varies in severity but has resulted in death. Characterized by fever, leukocytosis, dyspnea, weight gain, diffuse pulmonary infiltrates on chest x-ray, and pleural and/or pericardial effusions. More commonly observed with WBC  $>10,000/\text{mm}^3$ . Usually observed during the first month of therapy but may follow the initial drug dose.

---

#### Toxicity 3

Flushing, hypotension, hypertension, phlebitis, and congestive heart failure. Cardiac ischemia, myocardial infarction, stroke, myocarditis, pericarditis, and pulmonary hypertension are rarer events, each being reported in less than 3% of patients.

---

#### Toxicity 4

Increased serum cholesterol and triglyceride levels. Occur in up to 60% of patients. Usually reversible upon completion of treatment.

---

#### Toxicity 5

CNS toxicity in the form of dizziness, anxiety, paresthesias, depression, confusion, and agitation. Hallucinations, agnosia, aphasia, slow speech, asterixis, cerebellar disorders, convulsion, coma, dysarthria, encephalopathy, facial paralysis, hemiplegia, and hyporeflexia are less often seen.

---

**Toxicity 6**

GI toxicity. Relatively common and manifested by abdominal pain, constipation, diarrhea, and GI bleeding. Elevations in serum transaminases and alkaline phosphatase occur in 50%–60% of patients and usually resolve after completion of therapy.

---

**Toxicity 7**

Alterations in hearing sensation with hearing loss. About 25% of patients describe earache or a fullness in the ears.

---

**Toxicity 8**

Renal dysfunction and dysuria. Uncommon.

---

**Toxicity 9**

Pseudotumor cerebri. Benign intracranial hypertension with papilledema, headache, nausea and vomiting, and visual disturbances.

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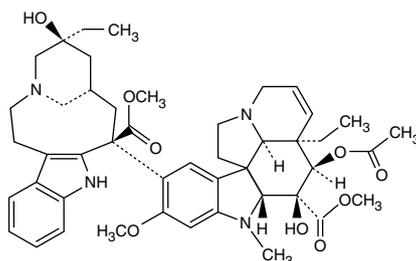
**Toxicity 10**

Teratogenic.

T

# V

## Vinblastine



### Trade Names

Velban

### Classification

Vinca alkaloid, anti-microtubule agent

### Category

Chemotherapy drug

### Drug Manufacturer

Eli Lilly

### Mechanism of Action

- Plant alkaloid extracted from the periwinkle plant *Catharanthus roseus*.
- Cell cycle-specific with activity in the mitosis (M) phase.
- Inhibits tubulin polymerization, disrupting formation of microtubule assembly during mitosis. This results in an arrest in cell division, ultimately leading to cell death.
- May also inhibit DNA, RNA, and protein synthesis.

### Mechanism of Resistance

- Overexpression of the P170 glycoprotein encoded by the multidrug-resistant gene, resulting in enhanced efflux of drug and decreased intracellular drug accumulation. Cross-resistance may be observed with other natural products, such as taxanes, epipodophyllotoxins, anthracyclines, and actinomycin-D.
- Mutations in  $\alpha$ - and  $\beta$ -tubulin proteins with decreased binding affinity to vinblastine.

---

### Absorption

Poorly and erratically absorbed by the oral route.

---

### Distribution

Widely and rapidly distributed into most body tissues. Binds extensively to platelets, RBCs, and WBCs within 30 minutes of administration. Poor penetration into the CSF.

---

### Metabolism

Metabolized in the liver by the cytochrome P<sub>450</sub> microsomal system. Small quantities of at least one metabolite, desacetyl vinblastine, may be as active as the parent drug. Majority of vinblastine is excreted in metabolite form via the enterohepatic biliary system. Only about 10% of the parent drug is excreted in feces. Approximately 14% of the drug is eliminated by the kidneys. Plasma terminal half-life of about 25 hours.

---

### Indications

1. Hodgkin's and non-Hodgkin's lymphoma.
  2. Testicular cancer.
  3. Breast cancer.
  4. Kaposi's sarcoma.
  5. Renal cell carcinoma.
- 

### Dosage Range

1. Hodgkin's disease: 6 mg/m<sup>2</sup> IV on days 1 and 15, as part of the ABVD regimen.
  2. Testicular cancer: 0.15 mg/kg IV on days 1 and 2, as part of the PVB regimen.
- 

### Drug Interaction 1

Drugs metabolized by liver P<sub>450</sub> system—Vinblastine should be used cautiously in patients receiving medications that inhibit drug metabolism via the hepatic cytochrome P<sub>450</sub> system, including calcium channel blockers, cimetidine, cyclosporine, erythromycin, metoclopramide, and ketoconazole.

---

### Drug Interaction 2

Phenytoin—Vinblastine reduces blood levels of phenytoin through either reduced absorption of phenytoin or an increase in the rate of its metabolism and elimination.

---

### Drug Interaction 3

Bleomycin—Risk of Raynaud's syndrome may be increased with the combination of vinblastine and bleomycin.

---

# V

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## Special Considerations

1. Use with caution in patients with abnormal liver function as toxicity of vinblastine may be significantly enhanced. Dose reduction is recommended in this setting.
2. Vinblastine should be infused as a rapid push in a free-flowing IV line to avoid extravasation. If extravasation occurs, the infusion should be discontinued immediately. Flushing with sterile water, elevation of the involved extremity, and local application of ice are recommended. In severe cases, a plastic surgeon should be consulted.
3. Patients should be warned about the risk of constipation upon starting therapy, and a bowel regimen including a high-fiber diet and a stool softener should be initiated.
4. Observe for hypersensitivity reactions, especially when the drug is administered in association with mitomycin-C.
5. Contamination of the eye may lead to severe irritation and even corneal ulceration. If accidental contamination occurs, the eyes should be immediately and thoroughly washed.
6. Pregnancy category D. Not known if excreted in milk.

---

## Toxicity 1

Myelosuppression. Dose-limiting toxicity with neutropenia being most commonly observed with nadir at days 4–6. Thrombocytopenia and anemia are less common.

---

## Toxicity 2

Mucositis and stomatitis. More frequently observed with vinblastine than with vincristine. Nausea, vomiting, anorexia, and diarrhea may also occur.

---

## Toxicity 3

Alopecia is common. Usually mild and reversible.

---

## Toxicity 4

Hypertension. Most common cardiovascular side effect and occurs as a consequence of autonomic dysfunction.

---

## Toxicity 5

Neurotoxicity. Occurs much less frequently than with vincristine. Presents with the same manifestations as seen with vincristine: peripheral neuropathy (paresthesias, paralysis, loss of deep tendon reflexes, and constipation) and autonomic nervous system dysfunction (orthostatic hypotension, paralytic ileus, and urinary retention). Less commonly, cranial nerve paralysis, ataxia, cortical blindness, seizures, and coma may occur.

---

**Toxicity 6**

Vesicant. Extravasation may cause local skin damage.

---

**Toxicity 7**

SIADH.

---

**Toxicity 8**

Headache and depression.

---

**Toxicity 9**

Vascular events, such as stroke, myocardial infarction, and Raynaud's syndrome.

---

**Toxicity 10**

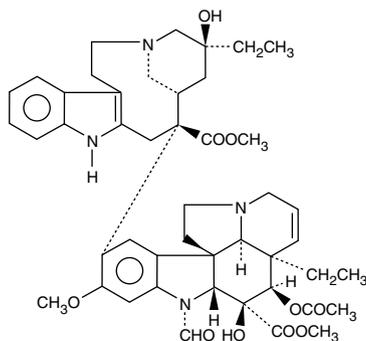
Acute pulmonary edema, bronchospasm, acute respiratory distress, interstitial pulmonary infiltrates, and dyspnea have been reported on rare occasion.



V

# V

## Vincristine



### Trade Names

Oncovin, VCR

### Classification

Vinca alkaloid, anti-microtubule agent

### Category

Chemotherapy drug

### Drug Manufacturer

Eli Lilly

### Mechanism of Action

- Plant alkaloid derived from the periwinkle plant *Catharanthus roseus*.
- Cell cycle-specific with activity in the mitosis (M) phase.
- Inhibits tubulin polymerization, disrupting formation of microtubule assembly during mitosis. This results in an arrest in cell division, ultimately leading to cell death.
- May also inhibit DNA, RNA, and protein synthesis.

### Mechanism of Resistance

- Overexpression of the P170 glycoprotein encoded by the multidrug-resistant gene, resulting in enhanced efflux of drug and decreased intracellular drug accumulation. Cross-resistance may be observed with other natural products, such as taxanes, epipodophyllotoxins, anthracyclines, and actinomycin-D.
- Mutations in  $\alpha$ - and  $\beta$ -tubulin proteins with decreased affinity to vincristine.

---

### Absorption

Not available for oral use and administered only by the IV route.

---

### Distribution

Widely and rapidly distributed into body tissues within 30 minutes of administration. Poor penetration across the blood-brain barrier and into the CSF.

---

### Metabolism

Metabolized in the liver by the cytochrome P<sub>450</sub> microsomal system. The majority of vincristine (80%) is excreted in bile and feces. Only 15%–20% of the drug is recovered in urine. Terminal half-life is long, on the order of 85 hours.

---

### Indications

1. Acute lymphoblastic leukemia.
2. Hodgkin's and non-Hodgkin's lymphoma.
3. Multiple myeloma.
4. Rhabdomyosarcoma.
5. Neuroblastoma.
6. Ewing's sarcoma.
7. Wilms' tumor.
8. Chronic leukemias.
9. Thyroid cancer.
10. Brain tumors.
11. Trophoblastic neoplasms.

---

### Dosage Range

1. Doses usually vary between 0.5 and 1.4 mg/m<sup>2</sup>. The total individual dose should be limited to 2 mg to prevent the development of neurotoxicity.
2. Continuous infusion: 0.4 mg/day IV continuous infusion for 4 days, as part of the VAD regimen for multiple myeloma.

---

### Drug Interaction 1

Drugs metabolized by liver P<sub>450</sub> system—Vincristine should be used with caution in patients receiving medications that inhibit drug metabolism via the hepatic cytochrome P<sub>450</sub> system.

---

### Drug Interaction 2

Phenytoin—Vincristine reduces the blood levels of phenytoin and its subsequent efficacy through either reduced absorption of phenytoin or an increase in the rate of its metabolism and/or elimination.

# V

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### Drug Interaction 3

Digoxin—Vincristine reduces the blood levels of digoxin resulting in decreased efficacy.

---

### Drug Interaction 4

Cisplatin and paclitaxel—Concurrent administration of vincristine with other neurotoxic agents such as cisplatin and paclitaxel may increase the risk and severity of neurotoxicity.

---

### Drug Interaction 5

L-Asparaginase—When used in combination with L-Asparaginase, vincristine should be administered 12–24 hours before as L-Asparaginase inhibits vincristine clearance.

---

### Drug Interaction 6

Methotrexate—Vincristine increases the cellular uptake of methotrexate resulting in enhanced antitumor activity and host toxicity.

---

### Drug Interaction 7

Filgrastim—Concurrent use of vincristine with filgrastim may result in severe atypical neuropathy.

---

### Special Considerations

1. Use with caution in patients with abnormal liver function as increased toxicity may be observed. Dose reduction is necessary in this setting.
2. Vincristine should be infused as a rapid push over 1 minute in a side port of a free-flowing IV line to avoid extravasation. If extravasation occurs, the infusion should be discontinued immediately. Application of ice to the area of leakage along with elevation of involved extremity may minimize discomfort and the possibility of cellulitis. In severe cases, a plastic surgeon should be consulted.
3. Contamination of the eye may lead to severe irritation and even corneal ulceration. If accidental contamination occurs, the eyes should be washed immediately and thoroughly.
4. Patients should be warned about the risk of constipation upon starting therapy, and a bowel regimen including stool softeners and high-fiber diet should be initiated. Patients should be advised to seek medical attention if persistent nausea, vomiting, and abdominal pain develop after beginning therapy.
5. Careful baseline neurologic evaluation should be performed before starting therapy and at the start of each cycle. The onset of severe signs and/or symptoms of neurotoxicity warrants immediate

discontinuation of the drug. Avoid the simultaneous use of drugs associated with neurologic toxicity. Risk factors for neurotoxicity include elderly patients and those with pre-existing neuropathies and/or neuromuscular disorders.

6. Overdose of vincristine may be treated with leucovorin 100 mg IV every 3 hours for the first 24 hours and then every 6 hours for 48 hours. Other supportive measures should be considered, including prevention of SIADH; use of anticonvulsants, enemas, or cathartics to prevent ileus; monitoring of the cardiovascular system; and monitoring of CBC.
7. Pregnancy category D. Not known if excreted in milk.

---

#### Toxicity 1

Neurotoxicity. Most commonly observed dose-limiting toxicity. Clinical manifestations are variable, and include peripheral neuropathy (paresthesias, paralysis, and loss of deep tendon reflexes), autonomic nervous system dysfunction (orthostasis, sphincter problems, and paralytic ileus), cranial nerve palsies, ataxia, cortical blindness, seizures, and coma. Bone, back, limb, jaw, and parotid gland pain may also occur.

---

#### Toxicity 2

Constipation, abdominal pain, and paralytic ileus are common. A prophylactic bowel regimen for constipation is recommended. Nausea, vomiting, and diarrhea can also occur, but are rare.

---

#### Toxicity 3

Alopecia, skin rash, and fever.

---

#### Toxicity 4

Vesicant. Extravasation may cause local tissue injury, inflammation, and necrosis.

---

#### Toxicity 5

Myelosuppression. Generally mild and much less significant than with vinblastine.

---

#### Toxicity 6

SIADH.

---

#### Toxicity 7

Hypersensitivity reactions.

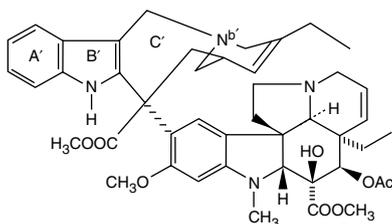
---

#### Toxicity 8

Azoospermia and amenorrhea may be permanent.

# V

## Vinorelbine



### Trade Names

Navelbine

### Classification

Vinca alkaloid, anti-microtubule agent

### Category

Chemotherapy drug

### Drug Manufacturer

GlaxoSmithKline

### Mechanism of Action

- Semisynthetic alkaloid derived from vinblastine.
- Cell cycle-specific with activity in mitosis (M) phase.
- Inhibits tubulin polymerization, disrupting formation of microtubule assembly during mitosis. This results in an arrest in cell division, ultimately leading to cell death.
- Relatively high specificity for mitotic microtubules with lower affinity for axonal microtubules.
- May also inhibit DNA, RNA, and protein synthesis.

### Mechanism of Resistance

- Overexpression of the P170 glycoprotein encoded by the multidrug-resistant gene, resulting in enhanced efflux of drug and decreased intracellular drug accumulation. Cross-resistance may be observed with other natural products, such as taxanes, epipodophyllotoxins, anthracyclines, and actinomycin-D.
- Mutations in  $\alpha$ - and  $\beta$ -tubulin proteins with decreased binding affinity to vinorelbine.

---

### Absorption

Administered only by the IV route.

---

### Distribution

Widely and rapidly distributed into most body tissues with a large apparent volume of distribution ( $>30$  L/kg). Extensive binding to plasma proteins (about 80%).

---

### Metabolism

Metabolized in the liver by the cytochrome P<sub>450</sub> microsomal system. Small quantities of at least one metabolite, desacetyl vinorelbine, have antitumor activity similar to that of parent drug. Majority of vinorelbine excreted in feces via the enterohepatic biliary system (50%). About 15%–20% of the drug is eliminated by the kidneys. Prolonged terminal half-life of 27–43 hours secondary to relatively slow efflux of drug from peripheral tissues.

---

### Indications

1. Non–small cell lung cancer.
  2. Breast cancer.
  3. Ovarian cancer.
- 

### Dosage Range

Usual dose is 30 mg/m<sup>2</sup> IV on a weekly schedule either as a single agent or in combination with cisplatin. Dose adjustment on day of treatment according to ANC.

---

### Drug Interaction 1

Drugs metabolized by the liver P<sub>450</sub> system—Vinorelbine should be used cautiously in patients receiving medications that inhibit drug metabolism via the hepatic cytochrome P<sub>450</sub> system.

---

### Drug Interaction 2

Phenytoin—Vinorelbine reduces blood levels of phenytoin through either reduced absorption of phenytoin or an increase in the rate of its metabolism and elimination.

---

### Drug Interaction 3

Cisplatin—Risk of myelosuppression increases when vinorelbine is used in combination with cisplatin.

---

### Drug Interaction 4

Mitomycin-C—Increased risk of acute allergic reactions when vinorelbine is used in combination with mitomycin-C.

---

# V

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## Special Considerations

1. Use with caution in patients with abnormal liver function as toxicity of vinorelbine may be significantly enhanced. Dose reduction is recommended in this setting.
2. Use with caution in patients previously treated with chemotherapy and/or radiation therapy as their bone marrow reserve may be compromised.
3. Vinorelbine should be infused as a rapid push in a free-flowing IV line to avoid extravasation. If extravasation occurs, the infusion should be discontinued immediately. Flushing with sterile water, elevation of the extremity, and local application of ice are recommended. In severe cases, a plastic surgeon should be consulted.
4. Contamination of the eye may lead to severe irritation and even corneal ulceration. If accidental contamination occurs, the eyes should be immediately and thoroughly washed.
5. Pregnancy category D. Breast-feeding should be avoided.

---

## Toxicity 1

Myelosuppression. Dose-limiting toxicity. Readily reversible once treatment is stopped. Neutropenia is most commonly observed. Nadirs occur by day 7, with recovery by day 14. Thrombocytopenia and anemia are less common.

---

## Toxicity 2

Nausea and vomiting. Usually moderate and occur within first 24 hours after treatment.

---

## Toxicity 3

GI toxicities in the form of constipation (35%), diarrhea (17%), stomatitis (<20%), and anorexia (<20%).

---

## Toxicity 4

Transient elevation in LFTs, including SGOT and bilirubin. Usually clinically asymptomatic.

---

## Toxicity 5

Vesicant. Extravasation may cause local tissue injury and inflammation.

---

## Toxicity 6

Neurotoxicity. Usually mild in severity and occurs much less frequently than with other vinca alkaloids. Vinorelbine has lower affinity for axonal microtubules than observed with vincristine or vinblastine. Increased risk in patients with pre-existing neuromuscular disease.

---

**Toxicity 7**

Alopecia. Observed in 10%–15% of patients.

---

**Toxicity 8**

SIADH.

---

**Toxicity 9**

Hypersensitivity and/or allergic reactions presenting as dyspnea and bronchospasm. Incidence is increased when used in combination with mitomycin-C.

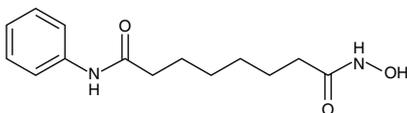
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**Toxicity 10**

Generalized fatigue. Occurs in 35% of patients and incidence increases with cumulative doses.

# V

## Vorinostat



### Trade Names

Zolinza

### Classification

Histone deacetylase (HDAC) inhibitor

### Category

Chemotherapy drug

### Drug Manufacturer

Merck

### Mechanism of Action

- Potent inhibitor of histone deacetylases HDAC<sub>1</sub>, HDAC<sub>2</sub>, and HDAC<sub>3</sub> (Class I) and HDAC<sub>6</sub> (Class II).
- Inhibition of HDAC activity leads to accumulation of acetyl groups on the histone lysine residues, resulting in open chromatin structure and transcriptional activation. Induction of cell cycle arrest and/or apoptosis may then occur.
- The precise mechanisms by which vorinostat exerts its antitumor activity has not been fully characterized.

### Mechanism of Resistance

None well characterized to date.

### Absorption

Oral absorption is not significantly affected when administered with food.

### Distribution

Significant binding (75%) to plasma proteins and extensive tissue distribution. Peak plasma levels are achieved 4 hours after ingestion.

---

## Metabolism

Metabolism involves glucuronidation and hydrolysis followed by  $\beta$ -oxidation. In vitro studies suggest minimal biotransformation by the cytochrome P450 system. Elimination is mainly via metabolism, and renal elimination of parent drug accounts for <1% of an administered dose. The terminal half-life of the parent drug is 2 hours.

---

## Indications

FDA-approved for the treatment of patients with CTCL who have progressive, persistent, or recurrent disease on or after two systemic therapies.

---

## Dosage Range

Recommended dose is 400 mg PO daily.

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## Drug Interaction 1

Warfarin—Patients receiving coumarin-derived anticoagulants should be closely monitored for alterations in their clotting parameters (PT and INR) and/or bleeding, as prolongation of PT and INR has been observed with concomitant use of vorinostat. The dose of warfarin may require careful adjustment in the presence of vorinostat therapy.

---

## Drug Interaction 2

HDAC inhibitors—Severe thrombocytopenia and GI bleeding have been reported when vorinostat and other HDAC inhibitors, such as valproic acid, are used together. CBC and platelet counts should be monitored every 2 weeks for the first 2 months of therapy.

---

## Special Considerations

1. Use with caution in patients with hepatic impairment, although no specific dose recommendations have been provided.
2. Patients should be instructed to drink at least 2 L/day of fluids to maintain hydration.
3. Closely monitor CBC and platelet count every 2 weeks during the first 2 months of therapy and subsequently, at monthly intervals.
4. Monitor EKG with QT measurement at baseline and periodically during therapy, as QTc prolongation has been observed. Use with caution in patients at risk of developing QT prolongation, including hypokalemia, hypomagnesemia, congenital long QT syndrome, patients taking antiarrhythmic medications or any other products that may cause QT prolongation, and cumulative high-dose anthracycline therapy.
5. Closely monitor serum glucose levels, especially in diabetic patients, as hyperglycemia may develop while on therapy. Alterations in diet and/or therapy for increased glucose may be necessary.

# V

## 6. Pregnancy category D.

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### Toxicity 1

Nausea/vomiting and diarrhea are the most common GI toxicities.

---

### Toxicity 2

Myelosuppression with thrombocytopenia and anemia more common than neutropenia.

---

### Toxicity 3

Fatigue and anorexia.

---

### Toxicity 4

Cardiac toxicity with QTc prolongation.

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### Toxicity 5

Hyperglycemia.

---

### Toxicity 6

Increased risk of thromboembolic complications, including DVT and PE.

# 3

## *Guidelines for Chemotherapy and Dosing Modifications*

M. Sitki Copur, Dawn Tiedemann,  
and Edward Chu

Successful administration of chemotherapy relies on several critical factors: the patient's age; performance status; co-morbid illnesses; and baseline hematologic, hepatic, and renal status. The dose of a given chemotherapeutic agent must be adjusted accordingly to reflect these parameters, as well as any specific drug-induced toxicities that may have been experienced with prior treatment. This chapter outlines performance scales that have been established to determine a patient's functional status; reviews methods to determine creatinine clearance, body surface area, and drug dose; and provides recommendations for dosing in the setting of myelosuppression, hepatic dysfunction, and renal dysfunction. General guidelines for dialyzing chemotherapeutic agents in the setting of drug overdose or renal failure are provided, and the extravasation potential of various agents is reviewed. A more detailed review for each individual drug is provided in Chapter 2, and the reader is advised to refer to the published literature for further details regarding specific guidelines for drug precautions and dose modifications.

## Table 1. Performance Scales

### *Karnofsky*

(%)	<i>Performance</i>
100	Normal, no evidence of disease
90	Able to carry on normal activity, minor signs or symptoms of disease
80	Normal activity with effort, some signs or symptoms of disease
70	Unable to perform normal activity, cares for self
60	Requires occasional assistance
50	Requires considerable assistance and frequent medical care
40	Disabled, requires special care and assistance
30	Severely disabled, hospitalization may be required
20	Hospitalization necessary for support, very sick
10	Moribund, rapid progression of disease
0	Dead

### *ECOG*

(%)	<i>Performance</i>
0	Asymptomatic, normal activity
1	Fully ambulatory, symptomatic, able to perform activities of daily living
2	Symptomatic, up and about, in bed less than 50% of time
3	Symptomatic, capable of only limited self-care, in bed more than 50% of time
4	Completely disabled, cannot perform any self-care, bedridden 100% of time
5	Dead

## Table 2. Determination of Creatinine Clearance

- The creatinine clearance is determined by the Cockcroft-Gault formula (Cockcroft, DW, Gault, MH. *Nephron* 1976; 16:31-34), which takes into account age, weight, and serum creatinine.

$$\text{Males: Creatinine Clearance (mL/min)} = \frac{\text{weight (kg)} \times (140 - \text{age})}{72 \times \text{serum creatinine (mg/dL)}}$$

**Table 2 (cont.)**

$$\text{Females: Creatinine Clearance (mL/min)} = \frac{\text{weight (kg)} \times (140 - \text{age}) \times 0.85}{72 \times \text{serum creatinine (mg/dL)}}$$

- The creatinine clearance can also be determined from a timed urine collection.

$$\text{Creatinine Clearance} = \frac{\text{urine creatinine}}{\text{serum creatinine}} \times \frac{\text{urine volume}}{\text{time}}$$

## **Table 3. Determination of Target Area Under the Curve (AUC)**

The area under AUC refers to the area under the drug concentration  $\times$  time curve, and it provides a measure of total drug exposure. It is expressed in concentration  $\times$  units (mg/mL  $\times$  min).

A formula for quantifying exposure to carboplatin based on dose and renal function was developed by Calvert et al. (Calvert, H, et al. *J Clin Oncol* 1989; 7:1748–1756) and is as follows:

$$\text{Carboplatin Dose (mg)} = \text{target AUC (mg/mL} \times \text{min)} \times [\text{GFR (mL/min)} + 25].$$

It is important to note that the total dose is in mg and NOT mg/m<sup>2</sup>. Target AUC is usually between 5 and 7 mg/mL/min for previously untreated patients. In previously treated patients, lower AUCs (between 4 and 6 mg/mL/min) are recommended. AUCs >7 are generally not associated with improved response rates.

## **Table 4. Determination of Drug Dose**

- Drug doses are calculated according to body surface area (BSA, mg/m<sup>2</sup>).
- BSA is typically determined by using a nomogram scale or by using a BSA calculator.
- Once the BSA is determined, multiply the BSA by the amount of drug specified in the regimen to give the total dose of drug to be administered.
- For obese patients, ideal body weight (IBW), as opposed to the actual body weight, may be used to calculate BSA. It is important to refer to an IBW table to determine the IBW based on the individual's actual height. Once the IBW is determined, add one-third of the IBW to the IBW, which is then used to determine the BSA.
- IBW can be calculated from the following formulas: IBW for men (kg): 50.0 kg + 2.3 kg per inch over = feet; IBW for women (kg): 45.5 kg + 2.3 kg per inch over = feet

Taken from: Olin B (Ed): "Drug Facts and Comparisons" St. Louis, Missouri, 1996.

## Table 5. Calculation of Body Surface Area in Adult Amputees

<b>Body Part</b>	<b>% Surface Area of Amputated Part</b>
Hand and five fingers	3.0
Lower part of arm	4.0
Upper part of arm	6.0
Foot	3.0
Lower part of leg	6.0
Thigh	12.0

$BSA (m^2) = BSA - [(BSA) \times (\%BSA_{part})]$ , where  $BSA$  = body surface area,  $BSA_{part}$  = body surface area of amputated part.

Taken from: Colangelo, PM, et al. *Am J Hosp Pharm* 1984; 41:2650–2655.

## Table 6. General Guidelines for Chemotherapy Dosage Based on Hepatic Function

<b>Drug</b>	<b>Recommended Dose Reduction for Hepatic Dysfunction</b>
Alemtuzumab	N/A
Altretamine	No dose reduction is necessary.
Amifostine	No dose reduction is necessary.
Aminoglutethimide	No dose reduction is necessary.
Amsacrine	Reduce dose by 25% if bilirubin > 2.0 mg/dL.
Anastrozole	No formal recommendation for dose reduction. Dose reduction may be necessary in patients with hepatic dysfunction.
Arsenic trioxide	No dose reduction is necessary.
Asparaginase	No dose reduction is necessary.
Azacitidine	No dose reduction is necessary.
Bicalutamide	No formal recommendation for dose reduction. Dose reduction may be necessary if bilirubin >3.0 mg/dL.

**Table 6 (cont.)**

<b>Drug</b>	<b>Recommended Dose Reduction for Hepatic Dysfunction</b>
Bleomycin	No dose reduction is necessary.
Buserelin	No dose reduction is necessary.
Busulfan	No dose reduction is necessary.
Capecitabine	No dose reduction is necessary.
Carboplatin	No dose reduction is necessary.
Carmustine	No dose reduction is necessary.
Chlorambucil	No dose reduction is necessary.
Cisplatin	No dose reduction is necessary.
Cladribine	No dose reduction is necessary.
Cyclophosphamide	Reduce by 25% if bilirubin 3.0–5.0 mg/dL or SGOT >180 mg/dL. Omit if bilirubin >5.0 mg/dL.
Cytarabine	No formal recommendation for dose reduction. Dose reduction may be necessary in patients with hepatic dysfunction.
Dacarbazine	No dose reduction is necessary.
Dactinomycin	Reduce dose by 50% if bilirubin >3.0 mg/dL.
Daunorubicin	Reduce dose by 25% if bilirubin 1.5–3.0 mg/dL. Reduce dose by 50% if bilirubin >3.0 mg/dL. Omit if bilirubin >5.0 mg/dL.
Decitabine	N/A
Docetaxel	Omit if bilirubin >1.5 mg/dL, SGOT >60 mg/dL, or alkaline phosphatase > 2.5 × upper limit of normal.
Doxorubicin	Reduce dose by 50% if bilirubin 1.5–3.0 mg/dL. Reduce dose by 75% if bilirubin 3.1–5.0 mg/dL. Omit if bilirubin >5.0 mg/dL.
Doxorubicin liposome	Reduce dose by 50% if bilirubin 1.5–3.0 mg/dL. Reduce dose by 75% if bilirubin 3.1–5.0 mg/dL. Omit if bilirubin >5.0 mg/dL.
Estramustine	No dose reduction is necessary.
Etoposide	Reduce dose by 50% if bilirubin 1.5–3.0 mg/dL or SGOT 60–180 mg/dL.

**Table 6 (cont.)**

<b>Drug</b>	<b>Recommended Dose Reduction for Hepatic Dysfunction</b>
Etoposide phosphate	Omit if bilirubin >3 mg/dL or SGOT > 180 mg/dL. Reduce dose by 50% if bilirubin 1.5–3.0 mg/dL or SGOT 60–180 mg/dL. Omit if bilirubin >3 mg/dL or SGOT >180 mg/dL.
Floxuridine	No dose reduction is necessary.
Fludarabine	No dose reduction is necessary. 5-Fluorouracil Omit if bilirubin >5.0 mg/dL.
Flutamide	No formal recommendation for dose reduction. Dose reduction may be necessary if bilirubin >3.0 mg/dL.
Gemcitabine	No dose reduction is necessary.
Goserelin	No dose reduction is necessary.
Hydroxyurea	No dose reduction is necessary.
Idarubicin	Reduce dose by 25% if bilirubin 1.5–3.0 mg/dL or SGOT 60–180 mg/dL. Reduce dose by 50% if bilirubin 3.0–5.0 or SGOT >180 mg/dL. Omit if bilirubin >5.0 mg/dL.
Ifosfamide	No dose reduction is necessary.
Imatinib	Omit if bilirubin >3 mg/dL or SGOT >5 × ULN. Once bilirubin <1.5 or SGOT <2.5 × ULN, reduce dose from 400 mg to 300 mg or from 600 mg to 400 mg.
Interferon-alpha	No dose reduction is necessary.
Interleukin-2	Omit if signs of hepatic failure (ascites, encephalopathy, jaundice) are observed. Do NOT restart sooner than seven weeks after recovery from severe hepatic dysfunction.
Irinotecan	No formal recommendation for dose reduction in the presence of hepatic dysfunction. Dose reduction may be necessary.
Isotretinoin	No formal recommendation for dose reduction in the presence of hepatic dysfunction. Dose reduction may be necessary.

**Table 6 (cont.)**

<b>Drug</b>	<b>Recommended Dose Reduction for Hepatic Dysfunction</b>
Lapatinib	No formal recommendation for dose reduction in the presence of hepatic dysfunction. Dose reduction may be necessary.
Leuprolide	No dose reduction is necessary.
Lomustine	No dose reduction is necessary.
Mechlorethamine	No dose reduction is necessary.
Megestrol acetate	No dose reduction is necessary.
Melphalan	No dose reduction is necessary.
6-Mercaptopurine	No dose reduction is necessary.
Methotrexate	Reduce dose by 25% if bilirubin 3.1–5.0 mg/dL or SGOT >180 mg/dL. Omit if bilirubin >5.0 mg/dL.
Mitomycin-C	No dose reduction is necessary.
Mitotane	No formal recommendation for dose reduction in the presence of hepatic dysfunction. Dose reduction may be necessary.
Mitoxantrone	Reduce dose by 25% if bilirubin >3.0 mg/dL.
Nilutamide	No formal recommendation for dose reduction. Dose reduction may be necessary if bilirubin > 3.0 mg/dL.
Oxaliplatin	N/A
Paclitaxel	No formal recommendation for dose reduction if bilirubin 1.5–3.0 mg/dL or SGOT 60–180 mg/dL. Omit if bilirubin >5.0 mg/dL or SGOT >180 mg/dL.
Pegasparginase	No dose reduction is necessary.
Pemetrexed	No dose reduction is necessary.
Pentostatin	No dose reduction is necessary.
Procarbazine	No formal recommendation for dose reduction in the presence of hepatic dysfunction. Dose reduction may be necessary.
Rituximab	No dose reduction is necessary.
Sorafenib	No formal recommendation for dose reduction in the presence of hepatic dysfunction. Dose reduction may be necessary.

**Table 6 (cont.)**

<b>Drug</b>	<b>Recommended Dose Reduction for Hepatic Dysfunction</b>
Streptozocin	No dose reduction is necessary.
Sunitinib	N/A
Tamoxifen	No dose reduction is necessary.
Temozolomide	No dose reduction is necessary.
Thalidomide	N/A
Thioguanine	Omit if bilirubin >5.0 mg/dL.
Thiotepa	No formal recommendation for dose reduction in the presence of hepatic dysfunction. Dose reduction may be necessary.
Topotecan	No dose reduction is necessary.
Trastuzumab	N/A
Tretinoin	Reduce dose to a maximum of 25 mg/m <sup>2</sup> if bilirubin 3.1–5.0 mg/dL or SGOT >180 mg/dL. Omit if bilirubin >5.0 mg/dL.
Vinblastine	No dose reduction if bilirubin <1.5 mg/dL and SGOT <60 mg/dL. Reduce by 50% if bilirubin 1.5–3.0 mg/dL and SGOT 60–180 mg/dL. Omit if bilirubin >3.0 mg/dL or SGOT >180 mg/dL.
Vincristine	No dose reduction if bilirubin <1.5 mg/dL and SGOT <60 mg/dL. Reduce by 50% if bilirubin 1.5–3.0 mg/dL and SGOT 60–180 mg/dL. Omit if bilirubin >3.0 mg/dL or SGOT >180 mg/dL.
Vinorelbine	No dose reduction if bilirubin <2.0 mg/dL. Reduce dose by 50% if bilirubin 2.0–3.0 mg/dL. Reduce dose by 75% if bilirubin 3.1–5.0 mg/dL. Omit if bilirubin >5.0 mg/dL.
Vorinostat	N/A
N/A—	not available
ULN—	upper limit of normal

## Table 7. General Guidelines for Chemotherapy Dosage Based on Renal Function

<i>Drug</i>	<i>Recommended Dose Reduction for Renal Dysfunction</i>
Alemtuzumab	N/A
Altretamine	N/A
Aminoglutethimide	N/A
Anastrozole	No dose reduction is necessary.
Arsenic trioxide	No formal recommendation for dose reduction in the presence of renal dysfunction. Dose reduction may be necessary.
L-Asparaginase	Omit if CrCl <60 mL/min.
Bicalutamide	No dose reduction is necessary.
Bleomycin	No dose reduction if CrCl >60 mL/min. Reduce dose by 25% if CrCl 10–60 mL/min. Reduce dose by 50% if CrCl <10 mL/min.
Buserelin	N/A
Busulfan	No dose reduction is necessary.
Capecitabine	Reduce dose by 25% if CrCl 30–50 mL/min. Omit if CrCl <30 mL/min.
Carboplatin	No dose reduction if CrCl <60 mL/min. AUC dose is modified according to CrCl.
Carmustine	Omit if CrCl <60 mL/min.
Chlorambucil	No dose reduction is necessary.
Cisplatin	No dose reduction if CrCl >60 mL/min. Reduce dose by 50% if CrCl 30–60 mL/min. Omit if CrCl <30 mL/min.
Cladribine	N/A
Cyclophosphamide	No dose reduction if CrCl >50 mL/min. Reduce dose by 25% if CrCl 10–50 mL/min. Reduce dose by 50% if CrCl <10 mL/min.
Cytarabine	No formal recommendation for dose reduction in the presence of renal dysfunction. Dose reduction may be necessary.

**Table 7 (cont.)**

<b>Drug</b>	<b>Recommended Dose Reduction for Renal Dysfunction</b>
Dacarbazine	No formal recommendation for dose reduction in the presence of renal dysfunction. Dose reduction may be necessary.
Dactinomycin	N/A
Dasatinib	No dose reduction is necessary.
Daunorubicin	Reduce dose by 50% if serum creatinine >3.0 mg/dL.
Decitabine	N/A
Docetaxel	No dose reduction is necessary.
Doxorubicin	No dose reduction is necessary.
Doxorubicin liposome	No dose reduction is necessary.
Erlotinib	No dose reduction is necessary.
Estramustine	N/A
Etoposide	No dose reduction if CrCl >50 mL/min. Reduce dose by 25% if CrCl 10–50 mL/min. Reduce dose by 50% if CrCl <10 mL/min.
Etoposide phosphate	No dose reduction if CrCl >50 mL/min. Reduce dose by 25% if CrCl 10–50 mL/min. Reduce dose by 50% if CrCl <10 mL/min.
Floxuridine	N/A
Fludarabine	No formal recommendation for dose reduction in the presence of renal dysfunction. Dose reduction may be necessary.
5-Fluorouracil	No dose reduction is necessary.
Flutamide	N/A
Gefitinib	No dose reduction is necessary.
Gemcitabine	No dose reduction is necessary.
Goserelin	No dose reduction is necessary.
Hydroxyurea	Reduce dose by 80% if CrCl <10 mL/min.
Idarubicin	No dose reduction is necessary.
Ifosfamide	N/A
Imatinib	No dose reduction is necessary.
Interferon-alpha	No dose reduction is necessary.

**Table 7 (cont.)**

<b>Drug</b>	<b>Recommended Dose Reduction for Renal Dysfunction</b>
Interleukin-2	Omit or discontinue if serum creatinine >4.5 mg/dL or serum creatinine >4.0 mg/dL in the presence of fluid overload.
Irinotecan	No dose reduction is necessary.
Isotretinoin	N/A
Lapatinib	No dose reduction is necessary.
Leuprolide	N/A
Lomustine	Omit if CrCl <60 mL/min.
Mechlorethamine	N/A
Megestrol acetate	N/A
Melphalan	No dose reduction is necessary. However, use with caution in the presence of renal dysfunction.
6-Mercaptopurine	No formal recommendation for dose reduction in the presence of renal dysfunction. Adjust for renal dysfunction by either increasing the interval or decreasing the dose.
Methotrexate	No dose reduction is necessary if CrCl >60 mL/min. Reduce by 50% if CrCl 30–60 mL/min. Omit if CrCl <30 mL/min.
Mitomycin-C	No dose reduction is necessary if CrCl >60 mL/min. Reduce dose by 25% if CrCl 10–60 mL/min. Reduce dose by 50% if CrCl <10 mL/min.
Mitotane	N/A
Mitoxantrone	No dose reduction is necessary.
Nilutamide	No dose reduction is necessary.
Oxaliplatin	N/A
Paclitaxel	No dose reduction is necessary.
Pegasparaginase	N/A
Pemetrexed	Dose reduction is necessary when CrCl <60 mL/min. and in proportion to the reduction in CrCl.

**Table 7 (cont.)**

<b>Drug</b>	<b>Recommended Dose Reduction for Renal Dysfunction</b>
Pentostatin	No formal recommendation for dose reduction in the presence of renal dysfunction. Dose reduction may be necessary if CrCl 30–60 mL/min.
Procarbazine	Omit if CrCl <30 mL/min.
Rituximab	N/A
Sorafenib	No dose reduction is necessary.
Streptozocin	Omit if CrCl <60 mL/min.
Sunitinib	N/A
Tamoxifen	No dose reduction is necessary.
Temozolomide	N/A
Temsirolimus	No dose reduction is necessary.
Thalidomide	N/A
Thioguanine	N/A
Thiotepa	No formal recommendation for dose reduction in the presence of renal dysfunction. Dose reduction may be necessary.
Topotecan	No dose reduction is necessary if CrCl >60 mL/min. Reduce dose by 50% if CrCl 10–60 mL/min. Omit if CrCl <10 mL/min.
Trastuzumab	N/A
Tretinoin	Give a maximum of 25 mg/m <sup>2</sup> in the presence of renal dysfunction. No dose reduction is necessary.
Vinblastine	No dose reduction is necessary.
Vincristine	No dose reduction is necessary.
Vinorelbine	No dose reduction is necessary.
Vorinostat	No dose reduction is necessary.
CrCl–creatinine clearance	
N/A–not available	

## Table 8. Guidelines for Dialysis of Chemotherapy Drugs

<i>Drug</i>	<i>Hemodialysis</i>			<i>Peritoneal Dialysis</i>		
	<i>YES</i>	<i>NO</i>	<i>UNKNOWN</i>	<i>YES</i>	<i>NO</i>	<i>UNKNOWN</i>
Alemtuzumab			X			X
Altretamine			X			X
Aminoglutethimide	X					X
Amsacrine			X			X
Anastrozole			X			X
Arsenic trioxide			X			X
Azacitidine			X			X
Bevacizumab			X			X
Bicalutamide			X			X
Bleomycin		X				X
Bortezomib			X			X
Buserelin			X			X
Busulfan			X			X
Capecitabine			X			X
Carboplatin	X				X	
Carmustine		X				X
Cetuximab			X			X
Chlorambucil			X			X
Cisplatin	X					X
Cladribine			X			X
Cyclophosphamide	X					X
Cytarabine			X		X	
Dacarbazine			X			X
Dactinomycin			X			X
Daunorubicin			X			X
Docetaxel			X			X
Doxorubicin		X				X
Doxorubicin liposome			X			X
Estramustine			X			X

**Table 8 (cont.)**

<b>Drug</b>	<b>Hemodialysis</b>			<b>Peritoneal Dialysis</b>		
	<b>YES</b>	<b>NO</b>	<b>UNKNOWN</b>	<b>YES</b>	<b>NO</b>	<b>UNKNOWN</b>
Etoposide	X					X
Etoposide phosphate		X				X
Floxuridine		X				X
Fludarabine		X				X
5-Fluorouracil		X				X
Flutamide		X				X
Gemcitabine		X				X
Goserelin		X				X
Hydroxyurea		X				X
Idarubicin		X				X
Ifosfamide		X				X
Imatinib		X				X
Irinotecan		X				X
Isotretinoin		X				X
Lapatinib			X			X
Lenalidomide			X			X
Leuprolide		X				X
Lomustine	X					X
Mechlorethamine			X			X
Megestrol acetate			X			X
Melphalan			X			X
6-Mercaptopurine			X			X
Methotrexate		X			X	
Mitomycin-C			X			X
Mitotane			X			X
Mitoxantrone			X			X
Nilutamide			X			X
Oxaliplatin			X			X
Paclitaxel			X			X
Pemetrexed		X				X

**Table 8 (cont.)**

<b>Drug</b>	<b>Hemodialysis</b>			<b>Peritoneal Dialysis</b>		
	<b>YES</b>	<b>NO</b>	<b>UNKNOWN</b>	<b>YES</b>	<b>NO</b>	<b>UNKNOWN</b>
Pentostatin			X			X
Procarbazine			X			X
Rituximab			X			X
Sorafenib			X			X
Streptozocin			X			X
Sunitinib			X			X
Tamoxifen			X			X
Temozolomide			X			X
Temsirolimus			X			X
Thalidomide			X			X
Thioguanine			X			X
Thiotepa			X			X
Topotecan			X			X
Trastuzumab			X			X
Vinblastine			X			X
Vincristine			X			X
Vinorelbine			X			X

**Table 9. Local Skin Toxicity Associated with Administration of Chemotherapy Drugs**

<b>Drug</b>	<b>VESICANT</b>	<b>IRRITANT</b>
Aldesleukin	No	No
Amifostine	No	No
Amsacrine	Yes	No
L-Asparaginase	No	No
Bleomycin	No	Yes
Busulfan	No	No

**Table 9 (cont.)**

<b>Drug</b>	<b>VESICANT</b>	<b>IRRITANT</b>
Carboplatin	No	Yes
Carmustine	No	Yes
Cisplatin	No <sup>1</sup>	Yes
Cladribine	No	No
Cyclophosphamide	No	No
Cytarabine	No	No
Dacarbazine	No	Yes
Dactinomycin	Yes	No
Daunorubicin	Yes	No
Daunorubicin liposome	No	No
Denileukin difitox	No	Yes
Dexrazoxane	No	Yes
Docetaxel	No	No
Doxorubicin	Yes	Yes
Doxorubicin liposome	No	Yes
Epirubicin	Yes	No
Etoposide	No <sup>2</sup>	Yes
Floxuridine	No	No
Fludarabine	No	No
5-Fluorouracil	No	No
Gemcitabine	No	No
Idarubicin	Yes	No
Ifosfamide	No	Yes
Irinotecan	No	No
Mechlorethamine	Yes	No
Methotrexate	No	No
Mitomycin-C	Yes	No
Mitoxantrone	Yes <sup>3</sup>	No
Oxaliplatin	No	No
Paclitaxel	Yes <sup>4</sup>	No
Pentostatin	No	No

**Table 9 (cont.)**

<b>Drug</b>	<b>VESICANT</b>	<b>IRRITANT</b>
Rituximab	No	No
Streptozocin	Yes	Yes
Thiotepa	No	Yes
Topotecan	No	No
Trastuzumab	No	No
Vinblastine	Yes	No
Vincristine	Yes	No
Vindesine	Yes	No
Vinorelbine	Yes	Yes

<sup>1</sup>Cisplatin is vesicant if > 20 mL of 0.5 mg/mL solution extravasates.

<sup>2</sup>Treatment is necessary only if a large volume of concentrated solution extravasates.

<sup>3</sup>Ulceration rarely occurs unless concentrated doses infiltrate.

<sup>4</sup>Weak vesicant.

### **Irritant**

- Capable of inducing a local inflammatory reaction.
- Tenderness along the vein with burning and erythema.
- Intact blood return.
- Short-term injury that does not lead to tissue injury or necrosis.

### **Vesicant**

- Infiltration of drug into surrounding tissue causes erythema and blistering.
- Symptoms may be delayed for up to 6–12 hours after drug extravasation. Complaints of pruritus are common in the absence of pain.
- Severe necrosis with involvement of tendons and joints may occur.
- Absent blood return.
- Level of tissue damage depends on the vesicant potential of the drug, the volume and concentration of drug infiltrated, the site of infiltration, the length of drug exposure, and the immediate measures taken once drug extravasation occurs.

## **Table 10. Classification of Teratogenic Potential and Use-in-Pregnancy for Chemotherapy Agents**

### ***Pregnancy Category A. Controlled studies show no risk in pregnancy.***

Controlled studies in pregnant women have not shown an increased risk of fetal abnormalities when the drug is administered during pregnancy. The possibility of fetal harm appears remote when the drug is used during pregnancy.

### ***Pregnancy Category B. No evidence of risk in pregnancy.***

(a) Controlled studies in animals have shown that the drug poses a risk to the fetus. However, studies in pregnant women have failed to show such a risk.

(b) Controlled studies in animals do not show evidence of impaired fertility or harm to the fetus. However, similar studies have not been performed in humans. Because animal studies are not entirely predictive of human response, the drug should be used during pregnancy only if clearly needed.

### ***Pregnancy Category C. Risk in pregnancy cannot be ruled out.***

Controlled studies either have not been conducted in animals or show that the drug is teratogenic or has an embryocidal effect and/or other adverse effect in animals. However, there are no adequate and well-controlled studies in pregnant women. The drug should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

### ***Pregnancy Category D. Clear evidence of risk in pregnancy.***

The drug can cause fetal harm when administered to a pregnant woman. If the drug is used during pregnancy, or if a patient becomes pregnant while taking this drug, the patient should be informed of the potential hazard to the fetus. However, the potential benefits of treatment may outweigh any potential risk.

### ***Pregnancy Category X. Absolutely contraindicated in pregnancy.***

The drug has been shown to cause fetal harm when administered to a pregnant woman. The drug is absolutely contraindicated in women who are or may become pregnant. If this drug is used during pregnancy, or if a patient becomes pregnant while taking this drug, the patient should be informed of the potential hazard to the fetus. The potential risk, in this case, outweighs any potential benefit from treatment.

# 4

## **Common Chemotherapy Regimens in Clinical Practice**

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This chapter provides some of the common combination regimens as well as selected single-agent regimens for solid tumors and hematologic malignancies. They are organized alphabetically by the specific cancer type. In each case, the regimens selected are based on the published literature and are used in clinical practice in the medical oncology community. It should be emphasized that not all of the drugs and dosages in the regimens have been officially approved by the Food and Drug Administration (FDA) for the treatment of a particular tumor. This chapter should serve as a quick reference for physicians and health care providers actively engaged in the practice of cancer treatment and provides several options for treating an individual tumor type. It is not intended to be an all-inclusive review of current treatments nor is it intended to endorse and/or prioritize any particular combination or single-agent regimen.

It is important to emphasize that the reader should carefully review the original reference for each of the regimens cited to confirm the specific doses and schedules and to check the complete prescribing information contained within the package insert for each agent.

While considerable efforts have been made to ensure the accuracy of the regimens presented, printing and/or typographical errors may have been made in the preparation of this book. As a result, no liability can be assumed for their use. Moreover, the reader should be reminded that several variations

in combination and single-agent regimens exist based on institutional and/or individual experience. Additionally, modifications in dose and schedule may be required according to individual performance status, co-morbid illnesses, baseline blood counts, baseline hepatic and/or renal function, and development of toxicity.

## ANAL CANCER

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### **5-Fluorouracil + Mitomycin-C + Radiation Therapy (Wayne State regimen)**

5-Fluorouracil:	1,000 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4 and 29–32
Mitomycin-C:	15 mg/m <sup>2</sup> IV on day 1
Radiation therapy:	200 cGy/day on days 1–5, 8–12, and 5–19 (total dose, 3,000 cGy)

Chemotherapy is given concurrently with radiation therapy (1).

### **5-Fluorouracil + Mitomycin-C + Radiation Therapy (EORTC regimen)**

5-Fluorouracil:	750 mg/m <sup>2</sup> /day IV continuous infusion on days 1–5 and 29–33
Mitomycin-C:	15 mg/m <sup>2</sup> IV on day 1
Radiation therapy:	180 cGy/day over 5-week period (total dose, 4,500 cGy)

Chemotherapy is given concurrently with radiation therapy. If partial or complete response, a boost of 1,500–2,000 cGy is given (2).

### **5-Fluorouracil + Cisplatin + Radiation Therapy (MD Anderson regimen)**

5-Fluorouracil:	250 mg/m <sup>2</sup> /day IV continuous infusion on days 1–5 of each week of radiation therapy
Cisplatin:	4 mg/m <sup>2</sup> /day IV continuous infusion on days 1–5 of each week of radiation therapy
Radiation therapy:	Total dose, 5,500 cGy over 6 weeks

Chemotherapy is given concurrently with radiation therapy (3).

## Metastatic Disease and/or Salvage Chemotherapy

### **5-Fluorouracil + Cisplatin**

5-Fluorouracil:	1,000 mg/m <sup>2</sup> /day IV continuous infusion on days 1–5
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Cisplatin: 100 mg/m<sup>2</sup> IV on day 2  
Repeat cycle every 21–28 days (4).

## BILIARY TRACT CANCER

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### Combination Regimens

#### **Gemcitabine + Cisplatin**

Gemcitabine: 1,250 mg/m<sup>2</sup> IV on days 1 and 8  
Cisplatin: 75 mg/m<sup>2</sup> on day 1  
Repeat cycle every 21 days (5).

#### **Gemcitabine + Capecitabine**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8  
Capecitabine: 650 mg/m<sup>2</sup> PO bid on days 1–14  
Repeat cycle every 21 days (6).

#### **Gemcitabine + Oxaliplatin**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on day 1  
Oxaliplatin: 100 mg/m<sup>2</sup> on day 2  
Repeat cycle every 14 days (7).

#### **5-Fluorouracil + Cisplatin**

5-Fluorouracil: 400 mg/m<sup>2</sup> IV on day 1, followed by 600 mg/m<sup>2</sup> IV infusion over 22 hours on days 1 and 2  
Cisplatin: 50 mg/m<sup>2</sup> IV on day 2  
Repeat cycle every 21 days (8).

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### Single-Agent Regimens

#### **Capecitabine**

Capecitabine: 1,000 mg/m<sup>2</sup> PO bid on days 1–14  
Repeat cycle every 21 days (9). Dose may be reduced to 825–900 mg/m<sup>2</sup> PO bid on days 1–14.

#### **Docetaxel**

Docetaxel: 100 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (10).

### ***Gemcitabine***

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 21 days (11).

## **BLADDER CANCER**

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### Combination Regimens

#### ***ITP***

Ifosfamide: 1,500 mg/m<sup>2</sup> IV on days 1–3  
Paclitaxel: 200 mg/m<sup>2</sup> IV over 3 hours on day 1  
Cisplatin: 70 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (12). G-CSF support is recommended.  
Regimen can also be administered every 28 days.

#### ***Gemcitabine + Cisplatin***

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Cisplatin: 75 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 28 days (13).

#### ***Gemcitabine + Paclitaxel***

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Paclitaxel: 200 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (14).

#### ***MVAC***

Methotrexate: 30 mg/m<sup>2</sup> IV on days 1, 15, and 22  
Vinblastine: 3 mg/m<sup>2</sup> IV on days 2, 15, and 22  
Doxorubicin: 30 mg/m<sup>2</sup> IV on day 2  
Cisplatin: 70 mg/m<sup>2</sup> IV on day 2  
Repeat cycle every 28 days (15).

#### ***CMV***

Cisplatin: 100 mg/m<sup>2</sup> IV on day 2 (give 12 hours after methotrexate)  
Methotrexate: 30 mg/m<sup>2</sup> IV on days 1 and 8

Vinblastine: 4 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 21 days (16).

**CISCA**

Cyclophosphamide: 650 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1  
Cisplatin: 100 mg/m<sup>2</sup> IV on day 2  
Repeat cycle every 21–28 days (17).

**Paclitaxel + Carboplatin**

Paclitaxel: 225 mg/m<sup>2</sup> IV over 3 hours on day 1  
Carboplatin: AUC of 6, IV on day 1, given 15 minutes after paclitaxel  
Repeat cycle every 21 days (18).

**CAP**

Cyclophosphamide: 400 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 40 mg/m<sup>2</sup> IV on day 1  
Cisplatin: 75 mg/m<sup>2</sup> IV on day 2  
Repeat cycle every 21 days (19).

**CMV + Radiation Therapy**

Cisplatin: 70 mg/m<sup>2</sup> IV on day 2  
Methotrexate: 30 mg/m<sup>2</sup> IV on days 1, 15, and 22  
Vinblastine: 3 mg/m<sup>2</sup> IV on days 2, 15, and 22  
Repeat cycle every 28 days for 2 cycles (20). Radiation therapy to be given after 2 cycles of induction chemotherapy at a total dose of 45 cGy in 180 cGy fractions combined with cisplatin 70 mg/m<sup>2</sup> IV on days 1 and 2 of radiation therapy.

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Single-Agent Regimens

**Gemcitabine**

Gemcitabine: 1,200 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Repeat cycle every 28 days (21).

**Paclitaxel**

Paclitaxel: 250 mg/m<sup>2</sup> IV over 24 hours on day 1  
Repeat cycle every 21 days (22)

or

Paclitaxel: 80 mg/m<sup>2</sup> IV weekly for 3 weeks

Repeat cycle every 4 weeks (23).

## BRAIN CANCER

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### Adjuvant Therapy

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#### Combination Regimens

##### **Temozolomide + Radiation Therapy**

Radiation therapy: 200 cGy/day for 5 days per week for total of 6 weeks

Temozolomide: 75 mg/m<sup>2</sup> PO for 6 weeks with radiation therapy, followed by 150 mg/m<sup>2</sup> PO on days 1–5

Repeat cycle every 28 days (24). If well tolerated, can increase dose to 200 mg/m<sup>2</sup>.

##### **PCV**

Procarbazine: 60 mg/m<sup>2</sup> PO on days 8–21

Lomustine: 130 mg/m<sup>2</sup> PO on day 1

Vincristine: 1.4 mg/m<sup>2</sup> IV on days 8 and 29

Repeat cycle every 8 weeks for 6 cycles (25).

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#### Single-Agent Regimens

##### **BCNU**

BCNU: 220 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 6–8 weeks for 1 year (26).

or

BCNU: 75–100 mg/m<sup>2</sup> IV on days 1 and 2

Repeat cycle every 6–8 weeks (26).

### Advanced Disease

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#### Combination Regimens

##### **PCV**

Procarbazine: 75 mg/m<sup>2</sup> PO on days 8–21

Lomustine: 130 mg/m<sup>2</sup> PO on day 1

Vincristine: 1.4 mg/m<sup>2</sup> IV on days 8 and 29  
Repeat cycle every 8 weeks (27).

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Single-Agent Regimens

**BCNU**

BCNU: 200 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 6–8 weeks (28).

**Procarbazine**

Procarbazine: 150 mg/m<sup>2</sup> PO daily divided into 3 doses  
Repeat daily (28).

**Temozolomide**

Temozolomide: 150 mg/m<sup>2</sup> PO on days 1–5  
Repeat cycle every 28 days (29). If well tolerated, can increase dose to 200 mg/m<sup>2</sup>.

**Irinotecan**

Irinotecan: 350 mg/m<sup>2</sup> IV over 90 min on day 1  
Repeat cycle every 3 weeks (30).

or

Irinotecan: 125 mg/m<sup>2</sup> IV weekly for 4 weeks  
Repeat cycle every 6 weeks (31).

## BREAST CANCER

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### Neoadjuvant Therapy

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Combination Regimens

**ACT**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Docetaxel: 100 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles, followed by surgery (32).

## Adjuvant Therapy

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Combination Regimens: HER2-negative disease

### **AC**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles (33).

### **AC→T**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles, followed by  
Paclitaxel: 175 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles (34).

### **A→T→C (dose-dense therapy)**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 2 weeks for 4 cycles, followed by  
Paclitaxel: 175 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 2 weeks for 4 cycles, followed by  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 2 weeks for 4 cycles.  
Administer filgrastim 5 µg/kg SC on days 3–10 of each weekly cycle (35).

### **AC→Docetaxel**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles, followed by  
Docetaxel: 100 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles (36).

### **AC→Docetaxel (weekly)**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles, followed by  
Docetaxel: 35 mg/m<sup>2</sup> IV on day 1  
Repeat weekly for a total of 12 weeks (37).

**TC**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles (38).

**TAC**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 500 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 6 cycles (39).

**CAF**

Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 28 days for a total of 4 cycles (40).

**Epirubicin + CMF**

Epirubicin: 100 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for 4 cycles, followed by  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Methotrexate: 40 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles (41).

**FEC**

5-Fluorouracil: 500 mg/m<sup>2</sup> IV on day 1  
Epirubicin: 100 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 500 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 6 cycles (42).

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Combination Regimens: HER2-positive disease

**AC→T + Trastuzumab**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for a total of 4 cycles, followed by

Paclitaxel: 80 mg/m<sup>2</sup> IV over 1 hour on day 1  
Trastuzumab: 4 mg/kg IV loading dose, then 2 mg/kg IV weekly  
Repeat weekly for 12 weeks, followed by  
Trastuzumab: 2 mg/kg IV weekly  
Repeat weekly for 40 weeks (43).

**AC→T + Trastuzumab (dose dense)**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 14 days for a total of 4 cycles, followed by  
Paclitaxel: 175 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 14 days for a total of 4 cycles.  
Trastuzumab: 4 mg/kg IV loading dose along with paclitaxel and then 2 mg/kg IV weekly  
Trastuzumab is administered for a total of 1 year (44).

**TCH**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Carboplatin: AUC of 6, IV on day 1  
Trastuzumab: 4 mg/kg IV loading dose and then 2 mg/kg IV weekly  
Repeat chemotherapy every 21 days for a total of 6 cycles. At the completion of chemotherapy, trastuzumab is administered at 6 mg/kg IV every 3 weeks for a total of 1 year (45).

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Single-Agent Regimens

**Tamoxifen**

Tamoxifen: 20 mg PO daily  
Repeat daily for 5 years in patients with ER+ tumors or ER status unknown (46).

**Anastrozole**

Anastrozole: 1 mg PO daily  
Repeat daily for 5 years in patients with ER+ tumors or ER status unknown (47).

**Tamoxifen + Letrozole (48)**

Tamoxifen: 20 mg PO daily for 5 years, followed by  
Letrozole: 2.5 mg PO daily for 5 years

**Tamoxifen + Exemestane (49)**

Tamoxifen: 20 mg PO daily for 2–3 years, followed by  
Exemestane: 25 mg PO daily for the remainder of 5 years

**Metastatic Disease**

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Combination Regimens: HER2-negative disease

**AC**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (33).

**AT**

Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1  
Paclitaxel: 150 mg/m<sup>2</sup> IV over 24 hours on day 1  
Repeat cycle every 21 days (50)

or

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days up to a maximum of 8 cycles, followed by  
Paclitaxel: 175 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days until disease progression (50).

or

Paclitaxel: 175 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days until disease progression, followed by  
Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days up to a maximum of 8 cycles (50).

**CAF**

Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (40).

**CEF**

Cyclophosphamide: 75 mg/m<sup>2</sup> PO on days 1–14  
Epirubicin: 60 mg/m<sup>2</sup> IV on days 1 and 8

5-Fluorouracil: 500 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 28 days (51).

**CMF**

Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Methotrexate: 40 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (41).

**Capecitabine + Docetaxel (XT)**

Capecitabine: 1,250 mg/m<sup>2</sup> PO bid on days 1–14  
Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (52). May decrease dose of capecitabine to 825–1,000 mg/m<sup>2</sup> PO bid on days 1–14 to reduce the risk of toxicity without compromising clinical efficacy.

**Capecitabine + Paclitaxel (XP)**

Capecitabine: 825 mg/m<sup>2</sup> PO bid on days 1–14  
Paclitaxel: 175 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (53).

**Capecitabine + Navelbine (XN)**

Capecitabine: 1,000 mg/m<sup>2</sup> PO bid on days 1–14  
Navelbine: 25 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 21 days (53).

**Capecitabine + Lapatinib**

Capecitabine: 1,000 mg/m<sup>2</sup> PO bid on days 1–14  
Lapatinib: 1,250 mg PO qd  
Repeat cycle every 21 days (54).

**Docetaxel + Doxorubicin**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (55).

**FEC-100**

5-Fluorouracil: 500 mg/m<sup>2</sup> IV on day 1  
Epirubicin: 100 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 500 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (56).

**Gemcitabine + Paclitaxel**

Gemcitabine: 1,250 mg/m<sup>2</sup> IV on days 1 and 8  
Paclitaxel: 175 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (57).

**Carboplatin + Paclitaxel**

Carboplatin: AUC of 6, IV on day 1  
Paclitaxel: 200 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (58).

**Carboplatin + Docetaxel**

Carboplatin: AUC of 6, IV on day 1  
Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (59).

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Combination Regimens: HER2-positive disease

**Trastuzumab-Paclitaxel**

Trastuzumab: 4 mg/kg IV loading dose and then 2 mg/kg weekly  
Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (60)

or

Trastuzumab: 4 mg/kg IV loading dose and then 2 mg/kg weekly  
Paclitaxel: 80 mg/m<sup>2</sup> IV weekly  
Repeat cycle every 4 weeks (61).

**Trastuzumab-Docetaxel**

Trastuzumab: 4 mg/kg IV loading dose and then 2 mg/kg IV on days 8 and 15  
Docetaxel: 35 mg/m<sup>2</sup> IV on days 1, 8, and 15

The first cycle is administered weekly for 3 weeks, with 1 week rest.

For subsequent cycles,

Trastuzumab: 2 mg/kg IV weekly  
Docetaxel: 35 mg/m<sup>2</sup> IV weekly  
Repeat cycle every 4 weeks (62).

### **TCH**

Carboplatin: AUC of 6, IV on day 1  
Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Trastuzumab: 4 mg/kg IV loading dose on day 1 and then  
2 mg/kg IV on days 8 and 15  
2 mg/kg IV weekly thereafter

Repeat cycle every 21 days (63).

### **Trastuzumab-Navelbine**

Trastuzumab: 4 mg/kg IV loading dose and then 2 mg/kg  
IV weekly  
Navelbine: 25 mg/m<sup>2</sup> IV weekly  
Repeat on a weekly basis until disease progression (64).

### **Trastuzumab-Gemcitabine**

Trastuzumab: 4 mg/kg IV loading dose and then 2 mg/kg  
IV weekly  
Gemcitabine: 1,200 mg/m<sup>2</sup> IV weekly for 2 weeks  
Repeat cycle every 21 days (64a).

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### Single-Agent Regimens

#### **Tamoxifen**

Tamoxifen: 20 mg PO daily (65)

#### **Toremifene citrate**

Toremifene: 60 mg PO daily (66)

#### **Exemestane**

Exemestane: 25 mg PO daily (67)

#### **Anastrozole**

Anastrozole: 1 mg PO daily (68)

**Letrozole**

Letrozole: 2.5 mg PO daily (69)

**Fulvestrant**

Fulvestrant: 250 mg IM on day 1

Repeat injection every month (70).

**Megestrol**

Megestrol: 40 mg PO qid (71)

**Trastuzumab**

Trastuzumab: 4 mg/kg IV loading dose and then 2 mg/kg IV weekly

Repeat cycle weekly for a total of 10 weeks. In the absence of disease progression, continue weekly maintenance dose of 2 mg/kg (72)

or

Trastuzumab: 8 mg/kg IV loading dose, then 6 mg/kg IV every 3 weeks

Continue 6 mg/kg every 3 weeks until disease progression (73).

**Capecitabine**

Capecitabine: 1,250 mg/m<sup>2</sup> PO bid for 2 weeks followed by 1-week rest period

Repeat cycle every 21 days (74). May decrease dose to 850–1,000 mg/m<sup>2</sup> PO bid on days 1–14 to reduce the risk of toxicity without compromising clinical efficacy.

**Docetaxel**

Docetaxel: 100 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (75).

or

Docetaxel: 35–40 mg/m<sup>2</sup> IV weekly for 6 weeks

Repeat cycle every 8 weeks (76).

**Paclitaxel**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1

Repeat cycle every 21 days (77)

or

Paclitaxel: 80–100 mg/m<sup>2</sup> IV weekly for 3 weeks

Repeat cycle every 4 weeks (78).

### ***Vinorelbine***

Vinorelbine: 30 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 7 days (79).

### ***Doxorubicin***

Doxorubicin: 20 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 7 days (80).

### ***Gemcitabine***

Gemcitabine: 725 mg/m<sup>2</sup> IV weekly for 3 weeks

Repeat cycle every 28 days (81).

### ***Liposomal Doxorubicin***

Liposomal

Doxorubicin: 45–60 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21–28 days (82).

### ***Abraxane***

Abraxane: 260 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (83).

or

Abraxane: 125 mg/m<sup>2</sup> IV on days 1, 8, and 15

Repeat cycle every 28 days (84).

## **CANCER OF UNKNOWN PRIMARY**

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### ***PCE***

Paclitaxel: 200 mg/m<sup>2</sup> IV over 1 hour on day 1

Carboplatin: AUC of 6, IV on day 1

Etoposide: 50 mg alternating with 100 mg PO on days  
1–10

Repeat cycle every 21 days (85).

**EP**

Etoposide: 100 mg/m<sup>2</sup> IV on days 1–5  
Cisplatin: 100 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (86).

**PEB**

Cisplatin: 20 mg/m<sup>2</sup> IV on days 1–5  
Etoposide: 100 mg/m<sup>2</sup> IV on days 1–5  
Bleomycin: 30 units IV on days 1, 8, and 15  
Repeat cycle every 21 days (87).

**GCP**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1 and 8  
Carboplatin: AUC of 5, IV on day 1  
Paclitaxel: 200 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for 4 cycles (88). This is to be followed by paclitaxel at 70 mg/m<sup>2</sup> IV every week for 6 weeks with a 2-week rest. Repeat for a total of 3 cycles.

## CARCINOID TUMORS

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Combination Regimens

**5-Fluorouracil + Streptozocin**

5-Fluorouracil: 400 mg/m<sup>2</sup>/day IV on days 1–5  
Streptozocin: 500 mg/m<sup>2</sup>/day IV on days 1–5  
Repeat cycle every 6 weeks (89).

**Doxorubicin + Streptozocin**

Doxorubicin: 50 mg/m<sup>2</sup> IV on days 1 and 22  
Streptozocin: 500 mg/m<sup>2</sup>/day IV on days 1–5  
Repeat cycle every 6 weeks (89).

**Cisplatin + Etoposide**

Cisplatin: 45 mg/m<sup>2</sup>/day IV continuous infusion on days 2 and 3  
Etoposide: 130 mg/m<sup>2</sup>/day IV continuous infusion on days 1–3

Repeat cycle every 21 days (90).

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Single-Agent Regimens

**Octreotide**

Octreotide: 150–250 µg SC tid

Continue until disease progression (91).

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## CERVICAL CANCER

Combination Regimens

**Cisplatin + Radiation Therapy**

Radiation therapy: 1.8 to 2 Gy per fraction (total dose, 45 Gy)

Cisplatin: 40 mg/m<sup>2</sup> IV weekly (maximal dose, 70 mg per week)

Cisplatin is given 4 hours before radiation therapy on weeks 1–6 (92).

**Paclitaxel + Cisplatin**

Paclitaxel: 135 mg/m<sup>2</sup> IV over 24 hours on day 1

Cisplatin: 75 mg/m<sup>2</sup> IV on day 2

Repeat cycle every 21 days (93).

**Cisplatin + Topotecan**

Cisplatin: 50 mg/m<sup>2</sup> IV on day 1

Topotecan: 0.75 mg/m<sup>2</sup>/day IV on days 1–3

Repeat cycle every 21 days (94).

**BIP**

Bleomycin: 30 U IV over 24 hours on day 1

Ifosfamide: 5,000 mg/m<sup>2</sup> IV over 24 hours on day 2

Mesna: 6,000 mg/m<sup>2</sup> IV over 36 hours on day 2

Cisplatin: 50 mg/m<sup>2</sup> IV on day 2

Repeat cycle every 21 days (95).

**BIC**

Bleomycin: 30 U IV on day 1

Ifosfamide: 2,000 mg/m<sup>2</sup> IV on days 1–3

Mesna: 400 mg/m<sup>2</sup> IV, 15 minutes before ifosfamide dose, then 400 mg/m<sup>2</sup> IV at 4 and 8 hours following ifosfamide

Carboplatin: 200 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (96).

**Cisplatin + 5-Fluorouracil**

Cisplatin: 75 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 1,000 mg/m<sup>2</sup> IV continuous infusion on days 2–5

Repeat cycle every 21 days (97).

**Cisplatin + Vinorelbine**

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1

Vinorelbine: 25 mg/m<sup>2</sup> IV on days 1 and 8

Repeat cycle every 21 days (98).

**Cisplatin + Irinotecan**

Cisplatin: 60 mg/m<sup>2</sup> IV on day 1

Irinotecan: 60 mg/m<sup>2</sup> IV on days 1, 8, and 15

Repeat cycle every 28 days (99).

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Single-Agent Regimens

**Docetaxel**

Docetaxel: 100 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (100).

**Paclitaxel**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1

Repeat cycle every 21 days (101).

**Irinotecan**

Irinotecan: 125 mg/m<sup>2</sup> IV weekly for 4 weeks

Repeat cycle every 6 weeks (102).

**Topotecan**

Topotecan: 1.5 mg/m<sup>2</sup>/day on days 1–5

Repeat cycle every 21 days (103).

# COLORECTAL CANCER

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## Neoadjuvant Combined Modality Therapy for Rectal Cancer

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### Combination Regimens

#### **5-Fluorouracil + Radiation Therapy (German AIO regimen)**

5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on days 1–5

Repeat infusional 5-FU on weeks 1 and 5.

Radiation therapy: 180 cGy/day for 5 days per week (total dose, 5,040 cGy)

Followed by surgical resection and then adjuvant chemotherapy with 5-FU at 500 mg/m<sup>2</sup> IV for 5 days every 28 days for a total of 4 cycles (104).

#### **Infusion 5-FU + Radiation Therapy**

5-Fluorouracil: 225 mg/m<sup>2</sup>/day IV continuous infusion throughout entire course of radiation therapy

Radiation therapy: 180 cGy/day for 5 days per week (total dose, 5,040 cGy)

Followed by surgical resection and then adjuvant chemotherapy with capecitabine, 5-FU/LV, or FOLFOX<sub>4</sub> for a total of 4 months (105).

#### **Capecitabine + Radiation Therapy**

Capecitabine: 825 mg/m<sup>2</sup> PO bid throughout the entire course of radiation therapy or 900–1,000 mg/m<sup>2</sup> PO bid on days 1–5 of each week of radiation therapy

Radiation therapy: 180 cGy/day for 5 days per week (total dose, 5,040 cGy)

Followed by surgical resection and then adjuvant chemotherapy with capecitabine, 5-FU, or 5-FU/LV for a total of 4 cycles (106).

### Adjuvant Therapy

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#### **5-Fluorouracil + Leucovorin (Mayo Clinic schedule)**

5-Fluorouracil: 425 mg/m<sup>2</sup> IV on days 1–5

Leucovorin: 20 mg/m<sup>2</sup> IV on days 1–5, administered before 5-fluorouracil

Repeat cycle every 4–5 weeks for a total of 6 cycles (107).

**5-Fluorouracil + Leucovorin (weekly schedule, high dose)**

5-Fluorouracil: 500 mg/m<sup>2</sup> IV weekly for 6 weeks  
Leucovorin: 500 mg/m<sup>2</sup> IV over 2 hours weekly for 6 weeks, administered before 5-fluorouracil

Repeat cycle every 8 weeks for a total of 4 cycles (32 weeks total) (108).

**5-Fluorouracil + Leucovorin (weekly schedule, low dose)**

5-Fluorouracil: 500 mg/m<sup>2</sup> IV weekly for 6 weeks  
Leucovorin: 20 mg/m<sup>2</sup> IV weekly for 6 weeks, administered before 5-fluorouracil

Repeat cycle every 8 weeks for a total of 4 or 6 cycles (32 or 48 weeks total) (109).

**Oxaliplatin + 5-Fluorouracil + Leucovorin (FOLFOX4)**

Oxaliplatin: 85 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus, followed by 600 mg/m<sup>2</sup> IV continuous infusion for 22 hours on days 1 and 2

Leucovorin: 200 mg/m<sup>2</sup> IV on days 1 and 2 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks for a total of 12 cycles (110).

**Oxaliplatin + 5-Fluorouracil + Leucovorin (mFOLFOX7)**

Oxaliplatin: 100 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 3,000 mg/m<sup>2</sup> IV continuous infusion on days 1 and 2 for 46 hours  
Leucovorin: 200 mg/m<sup>2</sup> IV on day 1 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks (111).

**LV5FU2 (deGramont regimen)**

5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus, followed by 600 mg/m<sup>2</sup> IV continuous infusion for 22 hours on days 1 and 2

Leucovorin: 200 mg/m<sup>2</sup> IV on days 1 and 2 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks for a total of 12 cycles (110).

### **Capecitabine**

Capecitabine: 1,250 mg/m<sup>2</sup> PO bid on days 1–14

Repeat cycle every 21 days for a total of 8 cycles (112). Dose may be decreased to 850–1,000 mg/m<sup>2</sup> PO bid on days 1–14 to reduce the risk of toxicity without compromising clinical efficacy.

### **Metastatic Disease**

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#### Combination Regimens

#### ***Irinotecan + 5-Fluorouracil + Leucovorin (IFL Saltz regimen)***

Irinotecan: 125 mg/m<sup>2</sup> IV over 90 minutes weekly for 4 weeks

5-Fluorouracil: 500 mg/m<sup>2</sup> IV weekly for 4 weeks

Leucovorin: 20 mg/m<sup>2</sup> IV weekly for 4 weeks

Repeat cycle every 6 weeks (113).

#### ***Irinotecan + 5-Fluorouracil + Leucovorin (IFL Saltz regimen) + Bevacizumab (BV)***

Irinotecan: 125 mg/m<sup>2</sup> IV over 90 minutes weekly for 4 weeks

5-Fluorouracil: 500 mg/m<sup>2</sup> IV weekly for 4 weeks

Leucovorin: 20 mg/m<sup>2</sup> IV weekly for 4 weeks

Bevacizumab: 5 mg/kg IV every 2 weeks

Repeat cycle every 6 weeks (114).

#### ***Irinotecan + 5-Fluorouracil + Leucovorin (Modified IFL Saltz regimen)***

Irinotecan: 125 mg/m<sup>2</sup> IV over 90 minutes weekly for 2 weeks

5-Fluorouracil: 500 mg/m<sup>2</sup> IV weekly for 2 weeks

Leucovorin: 20 mg/m<sup>2</sup> IV weekly for 2 weeks

Repeat cycle every 3 weeks (115).

#### ***Irinotecan + 5-Fluorouracil + Leucovorin (Douillard regimen)***

Irinotecan: 180 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus, followed by 600 mg/m<sup>2</sup> IV continuous infusion for 22 hours on days 1 and 2

Leucovorin: 200 mg/m<sup>2</sup> IV on days 1 and 2 as a 2-hour infusion prior to 5-fluorouracil

Repeat cycle every 2 weeks (116).

***Irinotecan + 5-Fluorouracil + Leucovorin (FOLFIRI Regimen)***

Irinotecan: 180 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus on day 1, followed by 2,400 mg/m<sup>2</sup> IV continuous infusion for 46 hours

Leucovorin: 200 mg/m<sup>2</sup> IV on day 1 as a 2-hour infusion prior to 5-fluorouracil

Repeat cycle every 2 weeks (117).

***Oxaliplatin + 5-Fluorouracil + Leucovorin (FOLFOX4)***

Oxaliplatin: 85 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus, followed by 600 mg/m<sup>2</sup> IV continuous infusion for 22 hours on days 1 and 2

Leucovorin: 200 mg/m<sup>2</sup> IV on days 1 and 2 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks (118).

***Oxaliplatin + 5-Fluorouracil + Leucovorin (FOLFOX6)***

Oxaliplatin: 100 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus on day 1, followed by 2,400 mg/m<sup>2</sup> IV continuous infusion for 46 hours

Leucovorin: 400 mg/m<sup>2</sup> IV on day 1 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks (119).

***Oxaliplatin + 5-Fluorouracil + Leucovorin (FOLFOX7)***

Oxaliplatin: 130 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 2,400 mg/m<sup>2</sup> IV continuous infusion on days 1 and 2 for 46 hours

Leucovorin: 400 mg/m<sup>2</sup> IV on day 1 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks (120).

**Oxaliplatin + 5-Fluorouracil + Leucovorin (mFOLFOX7)**

Oxaliplatin:	100 mg/m <sup>2</sup> IV on day 1
5-Fluorouracil:	3,000 mg/m <sup>2</sup> IV continuous infusion on days 1 and 2 for 46 hours
Leucovorin:	400 mg/m <sup>2</sup> IV on day 1 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks (121).

**FOLFOXIRI Regimen**

Irinotecan:	165 mg/m <sup>2</sup> IV on day 1
Oxaliplatin:	85 mg/m <sup>2</sup> IV on day 1
5-Fluorouracil:	3,200 mg/m <sup>2</sup> IV continuous infusion for 46 hours
Leucovorin:	200 mg/m <sup>2</sup> IV on day 1 as a 2-hour infusion prior to 5-fluorouracil

Repeat cycle every 2 weeks for a total of 12 cycles (122).

**Cetuximab + Irinotecan**

Cetuximab:	400 mg/m <sup>2</sup> IV loading dose, then 250 mg/m <sup>2</sup> IV weekly
Irinotecan:	350 mg/m <sup>2</sup> IV on day 1

Repeat cycle every 21 days (123).

**Capecitabine + Oxaliplatin (XELOX)**

Capecitabine:	1,000 mg/m <sup>2</sup> PO bid on days 1–14
Oxaliplatin:	130 mg/m <sup>2</sup> IV on day 1

Repeat cycle every 21 days (124). May decrease dose of capecitabine to 850 mg/m<sup>2</sup> PO bid and dose of oxaliplatin to 100 mg/m<sup>2</sup> IV to reduce the risk of toxicity without compromising clinical efficacy.

or

Capecitabine:	1,750 mg/m <sup>2</sup> PO bid on days 1–7
Oxaliplatin:	85 mg/m <sup>2</sup> IV on day 1

Repeat cycle every 14 days (124).

**Capecitabine + Irinotecan (XELIRI)**

Capecitabine:	1,000 mg/m <sup>2</sup> PO bid on days 1–14
Irinotecan:	250 mg/m <sup>2</sup> IV on day 1

Repeat cycle every 21 days (125). May decrease dose of capecitabine to 850 mg/m<sup>2</sup> PO bid and dose of irinotecan to 200 mg/m<sup>2</sup> IV to reduce the risk of toxicity without compromising clinical efficacy.

or

Capecitabine: 1,500 mg/m<sup>2</sup> PO bid on days 2–8

Irinotecan: 150 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 14 days (126).

***Oxaliplatin + Irinotecan (IROX regimen)***

Oxaliplatin: 85 mg/m<sup>2</sup> IV on day 1

Irinotecan: 200 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 3 weeks (127).

***5-Fluorouracil + Leucovorin (Mayo Clinic schedule)***

5-Fluorouracil: 425 mg/m<sup>2</sup> IV on days 1–5

Leucovorin: 20 mg/m<sup>2</sup> IV on days 1–5, administered before 5-fluorouracil

Repeat cycle every 4–5 weeks (128).

***5-Fluorouracil + Leucovorin (Roswell Park schedule, high dose)***

5-Fluorouracil: 500 mg/m<sup>2</sup> IV weekly for 6 weeks

Leucovorin: 500 mg/m<sup>2</sup> IV weekly for 6 weeks, administered before 5-fluorouracil

Repeat cycle every 8 weeks (129).

***5-Fluorouracil + Leucovorin + Bevacizumab***

5-Fluorouracil: 500 mg/m<sup>2</sup> IV weekly for 6 weeks

Leucovorin: 500 mg/m<sup>2</sup> IV weekly for 6 weeks, administered before 5-fluorouracil

Bevacizumab: 5 mg/kg IV every 2 weeks

Repeat cycle every 8 weeks (130).

***5-Fluorouracil + Leucovorin (German schedule, low dose)***

5-Fluorouracil: 600 mg/m<sup>2</sup> IV weekly for 6 weeks

Leucovorin: 20 mg/m<sup>2</sup> IV weekly for 6 weeks, administered before 5-fluorouracil

Repeat cycle every 8 weeks following a 2-week rest period (131).

**5-Fluorouracil + Leucovorin (de Gramont regimen)**

5-Fluorouracil: 400 mg/m<sup>2</sup> IV and then 600 mg/m<sup>2</sup> IV for 22 hours on days 1 and 2

Leucovorin: 200 mg/m<sup>2</sup> IV on days 1 and 2 as a 2-hour infusion before 5-fluorouracil

Repeat cycle every 2 weeks (132).

**FOLFOX<sub>4</sub> + Bevacizumab**

Oxaliplatin: 85 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus, followed by 600 mg/m<sup>2</sup> IV continuous infusion on days 1 and 2

Leucovorin: 200 mg/m<sup>2</sup> IV on days 1 and 2 as a 2-hour infusion before 5-fluorouracil

Bevacizumab: 10 mg/kg IV every 2 weeks

Repeat cycle every 2 weeks (133).

**Capecitabine + Oxaliplatin (XELOX) + Bevacizumab**

Capecitabine: 850 mg/m<sup>2</sup> PO bid on days 1–14

Oxaliplatin: 130 mg/m<sup>2</sup> IV on day 1

Bevacizumab: 7.5 mg/kg every 3 weeks

Repeat cycle every 21 days (134).

**Cetuximab + Bevacizumab + Irinotecan**

Cetuximab: 400 mg/m<sup>2</sup> IV loading dose, then 250 mg/m<sup>2</sup> IV weekly

Bevacizumab: 5 mg/kg IV every 2 weeks

Irinotecan: 180 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 2 weeks (135).

**Cetuximab + Bevacizumab**

Cetuximab: 400 mg/m<sup>2</sup> IV loading dose, then 250 mg/m<sup>2</sup> IV weekly

Bevacizumab: 5 mg/kg IV every 2 weeks

Repeat cycle every 2 weeks (135).

**FOLFIRI + Cetuximab**

Irinotecan: 180 mg/m<sup>2</sup> IV on day 1

- 5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus on day 1, followed by 2,400 mg/m<sup>2</sup> IV continuous infusion for 46 hours
- Leucovorin: 400 mg/m<sup>2</sup> IV on day 1 as a 2-hour infusion prior to 5-fluorouracil
- Cetuximab: 400 mg/m<sup>2</sup> IV loading dose, then 250 mg/m<sup>2</sup> IV weekly
- Repeat cycle every 2 weeks (136).

**FOLFOX<sub>4</sub> + Cetuximab**

- Oxaliplatin: 85 mg/m<sup>2</sup> IV on day 1
- 5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus on day 1, followed by 600 mg/m<sup>2</sup> IV continuous infusion for 22 hours on days 1 and 2
- Leucovorin: 400 mg/m<sup>2</sup> IV on days 1 and 2 as a 2-hour infusion prior to 5-fluorouracil
- Cetuximab: 400 mg/m<sup>2</sup> IV loading dose, then 250 mg/m<sup>2</sup> IV weekly
- Repeat cycle every 2 weeks (137).

**FOLFOX6 + Cetuximab**

- Oxaliplatin: 85 mg/m<sup>2</sup> IV on day 1
- 5-Fluorouracil: 2,400 mg/m<sup>2</sup> IV continuous infusion over 46 hours on days 1 and 2
- Leucovorin: 200 mg/m<sup>2</sup> IV on day 1 as a 2-hour infusion prior to 5-fluorouracil
- Cetuximab: 400 mg/m<sup>2</sup> IV loading dose and then 250 mg/m<sup>2</sup> IV weekly
- Repeat cycle every 2 weeks (138).

**FOLFIRI + Bevacizumab**

- Irinotecan: 180 mg/m<sup>2</sup> IV on day 1
- 5-Fluorouracil: 400 mg/m<sup>2</sup> IV bolus on day 1, followed by 2,400 mg/m<sup>2</sup> IV continuous infusion for 46 hours
- Leucovorin: 400 mg/m<sup>2</sup> IV on day 1 as a 2-hour infusion prior to 5-fluorouracil
- Bevacizumab: 5 mg/kg IV every 2 weeks
- Repeat cycle every 2 weeks (139).

## Hepatic Artery Infusion

### **Floxuridine**

Floxuridine (FUDR): 0.3 mg/kg/day HAI on days 1–14  
Dexamethasone: 20 mg HAI on days 1–14  
Heparin: 50,000 U HAI on days 1–14  
Repeat cycle every 14 days (140).

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### Single-Agent Regimens

### **Capecitabine**

Capecitabine: 1,250 mg/m<sup>2</sup> PO bid on days 1–14  
Repeat cycle every 21 days (141). Dose may be decreased to 850–1,000 mg/m<sup>2</sup> PO bid on days 1–14. This dose reduction may reduce the risk of toxicity without compromising clinical efficacy.

### **CPT-11 (weekly schedule)**

CPT-11: 125 mg/m<sup>2</sup> IV over 90 minutes weekly for  
4 weeks

Repeat cycle every 6 weeks (142).

or

CPT-11: 125 mg/m<sup>2</sup> IV over 90 minutes weekly for  
2 weeks

Repeat cycle every 3 weeks.

or

CPT-11: 175 mg/m<sup>2</sup> IV on days 1 and 10

Repeat cycle every 3 weeks (143).

### **CPT-11 (monthly schedule)**

CPT-11: 350 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 3 weeks (144).

### **Cetuximab**

Cetuximab: 400 mg/m<sup>2</sup> IV loading dose, then 250 mg/m<sup>2</sup>  
IV weekly

Repeat cycle on a weekly basis (145).

or

Cetuximab: 500 mg/m<sup>2</sup> IV every 2 weeks

Repeat cycle every 2 weeks (146).

**Panitumumab**

Panitumumab: 6 mg/kg every 2 weeks

Repeat cycle every 2 weeks (147).

**5-Fluorouracil (continuous infusion)**

5-Fluorouracil: 2,600 mg/m<sup>2</sup> IV over 24 hours weekly

Repeat cycle weekly for 4 weeks (148).

or

5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on days 1–4

Repeat cycle every 21–28 days (149).

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## ENDOMETRIAL CANCER

Combination Regimens

**Paclitaxel and Carboplatin**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1

Carboplatin: AUC of 5–7, IV on day 1

Repeat cycle every 28 days (150).

**AC**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1

Cyclophosphamide: 500 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (151).

**AP**

Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1

Cisplatin: 50 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (152).

**Doxorubicin + Paclitaxel**

Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1

Paclitaxel: 150 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (153).

***Cisplatin + Doxorubicin + Paclitaxel***

Cisplatin: 50 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 45 mg/m<sup>2</sup> IV on day 1  
Paclitaxel: 160 mg/m<sup>2</sup> IV over 3 hours on day 2  
Filgrastim: 5 µg/kg SC on days 3–12  
Repeat cycle every 21 days (154).

***CAP***

Cyclophosphamide: 500 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1  
Cisplatin: 50 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (155).

***Carboplatin + Liposomal Doxorubicin***

Carboplatin: AUC of 5, IV on day 1  
Liposomal: 40 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 28 days (156).

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Single-Agent Regimens

***Doxorubicin***

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (157).

***Megestrol***

Megestrol: 160 mg PO daily  
Repeat on a daily basis (158).

***Paclitaxel***

Paclitaxel: 200 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (159). Reduce dose to 175 mg/m<sup>2</sup> IV for patients with prior pelvic radiation therapy.

***Topotecan***

Topotecan: 1.0 mg/m<sup>2</sup>/day IV on days 1–5  
Repeat cycle every 21 days (160). Reduce dose to 0.8 mg/m<sup>2</sup>/day IV on days 1–3 in patients with prior radiation therapy.

# ESOPHAGEAL CANCER

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## Combined Modality Therapy

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Combination Regimens

### **5-Fluorouracil + Cisplatin + Radiation Therapy (Herskovic regimen)**

5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on days 1–4

Cisplatin: 75 mg/m<sup>2</sup> IV on day 1

Repeat on weeks 1, 5, 8, and 11 (161).

Radiation therapy: 200 cGy/day for 5 days per week (total dose, 3,000 cGy), followed by a boost to the field of 2,000 cGy.

### **5-Fluorouracil + Cisplatin + Radiation Therapy (Hopkins/Yale regimen)**

#### **Preoperative Chemoradiation**

5-Fluorouracil: 225 mg/m<sup>2</sup>/day IV continuous infusion on days 1–30

Cisplatin: 20 mg/m<sup>2</sup>/day IV on days 1–5 and 26–30

Radiation therapy: 200 cGy/day to a total dose of 4,400 cGy

Chemotherapy is given concurrently with radiation therapy. Followed by esophagectomy and then adjuvant chemotherapy in patients who had total gross removal of disease with negative margins.

#### **Adjuvant Chemotherapy**

Paclitaxel: 135 mg/m<sup>2</sup> IV for 24 hours on day 1

Cisplatin: 75 mg/m<sup>2</sup> IV on day 2

Adjuvant chemotherapy is given 8–12 weeks after esophagectomy, and each cycle is given every 21 days for a total of 3 cycles (162).

#### **MAGIC Trial**

##### **Preoperative ECF Chemotherapy**

Epirubicin: 50 mg/m<sup>2</sup> IV on day 1

Cisplatin: 60 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 200 mg/m<sup>2</sup>/day IV continuous infusion on days 1–21

Repeat cycle every 21 days for 3 cycles (163).

Followed by esophagectomy and then adjuvant chemotherapy in patients who had total gross removal of disease with negative margins.

### **Adjuvant Chemotherapy**

Epirubicin: 50 mg/m<sup>2</sup> IV on day 1  
Cisplatin: 60 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 200 mg/m<sup>2</sup>/day IV continuous infusion on days 1–21

Repeat cycle every 21 days for 3 cycles (163).

### **Metastatic Disease**

#### ***5-Fluorouracil + Cisplatin***

5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on days 1–5

Cisplatin: 100 mg/m<sup>2</sup> IV on day 1

Repeat cycle on weeks 1, 5, 8, and 11 (164).

#### ***Irinotecan + Cisplatin***

Irinotecan: 65 mg/m<sup>2</sup> IV weekly for 4 weeks

Cisplatin: 30 mg/m<sup>2</sup> IV weekly for 4 weeks

Repeat cycle every 6 weeks (165).

#### ***Paclitaxel + Cisplatin***

Paclitaxel: 200 mg/m<sup>2</sup> IV over 24 hours on day 1

Cisplatin: 75 mg/m<sup>2</sup> IV on day 2

Repeat cycle every 21 days (166). G-CSF support is recommended.

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#### **Single-Agent Regimens**

##### ***Paclitaxel***

Paclitaxel: 250 mg/m<sup>2</sup> IV over 24 hours on day 1

Repeat cycle every 21 days (167). G-CSF support is recommended.

# GASTRIC CANCER

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## Adjuvant Therapy

One cycle of chemotherapy is administered as follows:

5-Fluorouracil: 425 mg/m<sup>2</sup> IV on days 1–5

Leucovorin: 20 mg/m<sup>2</sup> IV on days 1–5

Chemoradiotherapy is then started 28 days after the start of the initial cycle of chemotherapy as follows:

Radiation therapy: 180 cGy/day to a total dose of 4,500 cGy, starting on day 28

5-Fluorouracil: 400 mg/m<sup>2</sup> IV on days 1–4 and days 23–25 of radiation therapy

Leucovorin: 20 mg/m<sup>2</sup> IV on days 1–4 and days 23–25 of radiation therapy

Chemoradiotherapy is followed by 2 cycles of chemotherapy that are given 1 month apart and include (168):

5-Fluorouracil: 425 mg/m<sup>2</sup> IV on days 1–5

Leucovorin: 20 mg/m<sup>2</sup> IV on days 1–5

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## Combination Regimens

### **DCF**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1

Cisplatin: 75 mg/m<sup>2</sup> IV over 1–3 hours on day 1

5-FU: 750 mg/m<sup>2</sup>/day IV continuous infusion on days 1–5

Repeat cycle every 21 days (169).

### **CF**

Cisplatin: 100 mg/m<sup>2</sup> IV over 1–3 hours on day 1

5-FU: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on days 1–5

Repeat cycle every 28 days (170).

### **ECF**

Epirubicin: 50 mg/m<sup>2</sup> IV on day 1

Cisplatin: 60 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 200 mg/m<sup>2</sup>/day IV continuous infusion for 24 weeks

Repeat cycle every 21 days (171).

**EOF**

Epirubicin: 50 mg/m<sup>2</sup> IV on day 1

Oxaliplatin: 130 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 200 mg/m<sup>2</sup>/day IV continuous infusion for 24 weeks

Repeat cycle every 21 days (171).

**ECX**

Epirubicin: 50 mg/m<sup>2</sup> IV on day 1

Cisplatin: 60 mg/m<sup>2</sup> IV on day 1

Capecitabine: 625 mg/m<sup>2</sup> PO bid continuously

Repeat cycle every 21 days (171).

**EOX**

Epirubicin: 50 mg/m<sup>2</sup> IV on day 1

Oxaliplatin: 130 mg/m<sup>2</sup> IV on day 1

Capecitabine: 625 mg/m<sup>2</sup> PO bid continuously

Repeat cycle every 21 days (171).

**IP**

Irinotecan: 70 mg/m<sup>2</sup> IV on days 1 and 15

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 28 days (172).

**IPB**

Irinotecan: 65 mg/m<sup>2</sup> IV on days 1 and 8

Cisplatin: 30 mg/m<sup>2</sup> IV on days 1 and 8

Bevacizumab: 15 mg/kg IV on day 1

Repeat cycle every 21 days (173).

**Docetaxel + Cisplatin**

Docetaxel: 85 mg/m<sup>2</sup> IV on day 1

Cisplatin: 75 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (174).

**Capecitabine + Cisplatin**

Capecitabine: 1000 mg/m<sup>2</sup> PO bid on days 1–14  
Cisplatin: 80 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (175).

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Single-Agent Regimens

**5-Fluorouracil**

5-Fluorouracil: 500 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 28 days (176).

**Docetaxel**

Docetaxel: 100 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (177).

or

Docetaxel: 36 mg/m<sup>2</sup> IV weekly for 6 weeks  
Repeat cycle every 8 weeks (178).

## GASTROINTESTINAL STROMAL TUMOR (GIST)

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Single-Agent Regimens

**Imatinib**

Imatinib: 400 mg/day PO  
Continue treatment until disease progression (179). Increase dose to 600 mg/day if no response is seen.

**Sunitinib**

Sunitinib: 50 mg/day PO for 4 weeks  
Repeat cycle every 6 weeks (180).

# HEAD AND NECK CANCER

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## Combined Modality Therapy

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### Combination Regimens

#### **Cetuximab + Radiation Therapy**

Cetuximab: 400 mg/m<sup>2</sup> IV loading dose, one week before radiation therapy, then 250 mg/m<sup>2</sup> IV weekly

Radiation therapy: 200 cGy/day for 5 days per week (total dose, 7,000 cGy)

Cetuximab is given concurrently with radiation therapy (181).

#### **TPF Induction Chemotherapy Followed by Carboplatin + Radiation Therapy**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1

Cisplatin: 75–100 mg/m<sup>2</sup> IV on day 1

5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on days 1–4

Repeat cycle every 3 weeks for 3 cycles followed by:

Carboplatin: AUC of 1.5, IV weekly for 7 weeks during radiation therapy

Radiation therapy: 200 cGy/day to a total dose of 7,400 cGy

At the completion of chemoradiotherapy, surgical resection as indicated (182).

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### Combination Regimens

#### **TIP**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1

Ifosfamide: 1,000 mg/m<sup>2</sup> IV over 2 hours on days 1–3

Mesna: 400 mg/m<sup>2</sup> IV before ifosfamide and 200 mg/m<sup>2</sup> IV, 4 hours after ifosfamide

Cisplatin: 60 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21–28 days (183).

#### **TPF**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1

Cisplatin: 75–100 mg/m<sup>2</sup> IV over 24 hours on day 1

5-Fluorouracil: 1,000 mg/m<sup>2</sup> over 24 hours on days 1–4

Repeat cycle every 21 days (184).

**TIC**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1  
Ifosfamide: 1,000 mg/m<sup>2</sup> IV over 2 hours on days 1–3  
Mesna: 400 mg/m<sup>2</sup> IV before ifosfamide and  
200 mg/m<sup>2</sup> IV, 4 hours after ifosfamide  
Carboplatin: AUC of 6, IV on day 1  
Repeat cycle every 21–28 days (185).

**Paclitaxel + Carboplatin**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1  
Carboplatin: AUC of 6, IV on day 1  
Repeat cycle every 21 days (186).

**Paclitaxel + Cisplatin**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1  
Cisplatin: 75 mg/m<sup>2</sup> IV on day 2  
G-CSF: 5 µg/kg/day SC on days 4–10  
Repeat cycle every 21 days (187).

**PF**

Cisplatin: 100 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on  
days 1–5  
Repeat cycle every 21–28 days (188).

**PFL**

Cisplatin: 100 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 800 mg/m<sup>2</sup>/day IV continuous infusion on  
days 1–5  
Leucovorin: 50 mg/m<sup>2</sup> PO every 6 hours on days 1–5  
Repeat cycle every 21 days (189).

**PF-Larynx Preservation**

Cisplatin: 100 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on  
days 1–5  
Radiation therapy: 6,600–7,600 cGy in 180–200 cGy fractions  
Repeat cycle every 21–28 days for 3 cycles (190).

**Concurrent Chemoradiation Therapy for Laryngeal Preservation**

Cisplatin: 100 mg/m<sup>2</sup> IV on days 1, 22, and 43  
Radiation therapy: 7,000 cGy in 200 cGy fractions  
Administer cisplatin concurrently with radiation therapy (191).

**Chemoradiotherapy for Nasopharyngeal Cancer**

Cisplatin: 100 mg/m<sup>2</sup> IV on days 1, 22, and 43 during radiotherapy  
Radiation therapy: Total dose of 7,000 cGy in 180–200 cGy fractions

At the completion of chemoradiotherapy, chemotherapy is administered as follows:

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1  
5-Fluorouracil: 1,000 mg/m<sup>2</sup>/day IV continuous infusion on days 1–4

Repeat cycle every 28 days for a total of 3 cycles (192).

**VP**

Vinorelbine: 25 mg/m<sup>2</sup> IV on days 1 and 8  
Cisplatin: 80 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (193).

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Single-Agent Regimens

**Docetaxel**

Docetaxel: 100 mg/m<sup>2</sup> IV over 1 hour on day 1  
Repeat cycle every 21 days (194).

**Paclitaxel**

Paclitaxel: 250 mg/m<sup>2</sup> IV over 24 hours on day 1  
Repeat cycle every 21 days (195).

or

Paclitaxel: 137–175 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (195).

**Methotrexate**

Methotrexate: 40 mg/m<sup>2</sup> IV or IM weekly  
Repeat cycle every week (196).

***Vinorelbine***

Vinorelbine: 30 mg/m<sup>2</sup> IV weekly

Repeat cycle every week (197).

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## HEPATOCELLULAR CANCER

Single-Agent Regimens

***Sorafenib***

Sorafenib: 400 mg PO bid

Repeat cycle every week (198).

***Doxorubicin***

Doxorubicin: 20–30 mg/m<sup>2</sup> IV weekly

Repeat cycle every week (199).

***Cisplatin***

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1

Repeat cycle every week (200).

***Capecitabine***

Capecitabine: 1,000 mg/m<sup>2</sup> PO bid on days 1–14

Repeat cycle every 21 days (201). Dose may be reduced to 825–900 mg/m<sup>2</sup> PO bid on days 1–14. This dose reduction may decrease the risk of toxicity without compromising clinical efficacy.

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## KAPOSI'S SARCOMA

Combination Regimens

***BV***

Bleomycin: 10 U/m<sup>2</sup> IV on days 1 and 15

Vincristine: 1.4 mg/m<sup>2</sup> IV on days 1 and 15 (maximum, 2 mg)

Repeat cycle every 2 weeks (202).

***ABV***

Doxorubicin: 40 mg/m<sup>2</sup> IV on day 1

Bleomycin: 15 U/m<sup>2</sup> IV on days 1 and 15

Vinblastine: 6 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 28 days (203).

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Single-Agent Regimens

***Liposomal Daunorubicin***

DaunoXome: 40 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 14 days (204).

***Liposomal Doxorubicin***

Doxil: 20 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (205).

***Paclitaxel***

Paclitaxel: 135 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (206).

or

Paclitaxel: 100 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 2 weeks (207).

***Docetaxel***

Docetaxel: 25 mg/m<sup>2</sup> IV weekly for 8 weeks, then every  
other week  
Continue until disease progression (208).

***Interferon- $\alpha$***

Interferon  $\alpha$ -2a: 36 million IU/m<sup>2</sup> SC or IM, daily for  
8–12 weeks (209)

Interferon  $\alpha$ -2b: 30 million IU/m<sup>2</sup> SC or IM, 3 times weekly (210)

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## LEUKEMIA

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### ACUTE LYMPHOCYTIC LEUKEMIA

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Induction Therapy

***Linker Regimen (211, 212)***

Daunorubicin: 50 mg/m<sup>2</sup> IV every 24 hours on days 1–3  
Vincristine: 2 mg IV on days 1, 8, 15, and 22

Prednisone:	60 mg/m <sup>2</sup> PO divided into 3 doses on days 1–28
L-Asparaginase:	6,000 U/m <sup>2</sup> IM on days 17–28
If bone marrow on day 14 is positive for residual leukemia,	
Daunorubicin:	50 mg/m <sup>2</sup> IV on day 15
If bone marrow on day 28 is positive for residual leukemia,	
Daunorubicin:	50 mg/m <sup>2</sup> IV on days 29 and 30
Vincristine:	2 mg IV on days 29 and 36
Prednisone:	60 mg/m <sup>2</sup> PO on days 29–42
L-Asparaginase:	6,000 U/m <sup>2</sup> IM on days 29–35

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#### Consolidation Therapy

##### **Linker Regimen (211, 212)**

Treatment A (cycles 1, 3, 5, and 7)

Daunorubicin:	50 mg/m <sup>2</sup> IV on days 1 and 2
Vincristine:	2 mg IV on days 1 and 8
Prednisone:	60 mg/m <sup>2</sup> PO on days 1–14
L-Asparaginase:	12,000 U/m <sup>2</sup> on days 2, 4, 7, 9, 11, and 14
Treatment B (cycles 2, 4, 6, and 8)	

Teniposide: 165 mg/m<sup>2</sup> IV on days 1, 4, 8, and 11

Cytarabine: 300 mg/m<sup>2</sup> IV on days 1, 4, 8, and 11

Treatment C (cycle 9)

Methotrexate: 690 mg/m<sup>2</sup> IV over 42 hours

Leucovorin: 15 mg/m<sup>2</sup> IV every 6 hours for 12 doses beginning at 42 hours

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#### Maintenance Therapy

##### **Linker Regimen (211, 212)**

Methotrexate: 20 mg/m<sup>2</sup> PO weekly

6-Mercaptopurine: 75 mg/m<sup>2</sup> PO daily

Continue for a total of 30 months of complete response.

##### **CNS Prophylaxis**

Cranial irradiation: 1,800 rad in 10 fractions over 12–14 days

Methotrexate: 12 mg IT weekly for 6 weeks

Begin within 1 week of complete response.

In patients with documented CNS involvement at time of diagnosis, intrathecal chemotherapy should begin during induction chemotherapy.

Methotrexate:	12 mg IT weekly for 10 doses
Cranial irradiation:	2,800 rad

Induction Therapy

**Larson Regimen (213)**

Induction (weeks 1–4)

Cyclophosphamide:	1,200 mg/m <sup>2</sup> IV on day 1
Daunorubicin:	45 mg/m <sup>2</sup> IV on days 1–3
Vincristine:	2 mg IV on days 1, 8, 15, and 22
Prednisone:	60 mg/m <sup>2</sup> /day PO on days 1–21
L-Asparaginase:	6,000 IU/m <sup>2</sup> SC on days 5, 8, 11, 15, 18, 22

Early Intensification (weeks 5–12)

Methotrexate:	15 mg IT on day 1
Cyclophosphamide:	1,000 mg/m <sup>2</sup> IV on day 1
6-Mercaptopurine:	60 mg/m <sup>2</sup> /day PO on days 1–14
Cytarabine:	75 mg/m <sup>2</sup> IV on days 1–4 and 8–11
Vincristine:	2 mg IV on days 15 and 22
L-Asparaginase:	6,000 IU/m <sup>2</sup> SC on days 15, 18, 22, and 25

Repeat the early intensification cycle once.

**CNS Prophylaxis and Interim Maintenance (weeks 13–25)**

Cranial irradiation:	2,400 cGy on days 1–12
Methotrexate:	15 mg IT on days 1, 8, 15, 22, and 29
6-Mercaptopurine:	60 mg/m <sup>2</sup> /day PO on days 1–70
Methotrexate:	20 mg/m <sup>2</sup> PO on days 36, 43, 50, 57, and 64

Late Intensification (weeks 26–33)

Doxorubicin:	30 mg/m <sup>2</sup> IV on days 1, 8, and 15
Vincristine:	2 mg IV on days 1, 8, and 15
Dexamethasone:	10 mg/m <sup>2</sup> /day PO on days 1–14
Cyclophosphamide:	1,000 mg/m <sup>2</sup> IV on day 29
6-Thioguanine:	60 mg/m <sup>2</sup> /day PO on days 29–42
Cytarabine:	75 mg/m <sup>2</sup> on days 29, 32, 36–39

Prolonged Maintenance (continue until 24 months after diagnosis)

Vincristine:	2 mg IV on day 1
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Prednisone: 60 mg/m<sup>2</sup>/day PO on days 1–5  
Methotrexate: 20 mg/m<sup>2</sup> PO on days 1, 8, 15, and 22  
6-Mercaptopurine: 80 mg/m<sup>2</sup>/day PO on days 1–28  
Repeat maintenance cycle every 28 days.

### ***Hyper-CVAD Regimen***

Cyclophosphamide: 300 mg/m<sup>2</sup> IV over 3 hours every 12 hours for 6 doses on days 1–3  
Mesna: 600 mg/m<sup>2</sup> IV over 24 hours on days 1–3 ending 6 hours after the last dose of cyclophosphamide  
Vincristine: 2 mg IV on days 4 and 11  
Doxorubicin: 50 mg/m<sup>2</sup> IV on day 4  
Dexamethasone: 40 mg PO or IV on days 1–4 and 11–14  
Alternate cycles every 21 days with the following:  
Methotrexate: 200 mg/m<sup>2</sup> IV over 2 hours, followed by 800 mg/m<sup>2</sup> IV over 24 hours on day 1  
Leucovorin: 15 mg IV every 6 hours for 8 doses, starting 24 hours after the completion of methotrexate infusion  
Cytarabine: 3,000 mg/m<sup>2</sup> IV over 2 hours every 12 hours for 4 doses on days 2–3  
Methylprednisolone: 50 mg IV bid on days 1–3  
Alternate 4 cycles of hyper-CVAD with 4 cycles of high-dose methotrexate and cytarabine therapy (214).

### ***CNS Prophylaxis***

Methotrexate: 12 mg IT on day 2  
Cytarabine: 100 mg IT on day 8  
Repeat with each cycle of chemotherapy, depending on the risk of CNS disease.

### ***Supportive Care***

Ciprofloxacin: 500 mg PO bid  
Fluconazole: 200 mg/day PO  
Acyclovir: 200 mg PO bid  
G-CSF: 10 µg/kg/day starting 24 hours after the end of chemotherapy (i.e., on day 5 of hyper-CVAD)

therapy and on day 4 of high-dose methotrexate and cytarabine therapy)

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Single-Agent Regimens

**Clofarabine**

Clofarabine: 52 mg/m<sup>2</sup> IV for 5 days

Repeat cycle every 2–6 weeks (215).

**Imatinib**

Imatinib: 600 mg PO daily

Continue until disease progression (216).

**Dasatinib**

Dasatinib: 70 mg PO bid

Continue until disease progression (217).

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## ACUTE MYELOGENOUS LEUKEMIA

Induction Regimens

**Ara-C + Daunorubicin (7 + 3) (218)**

Cytarabine: 100 mg/m<sup>2</sup>/day IV continuous infusion on days 1–7

Daunorubicin: 45 mg/m<sup>2</sup> IV on days 1–3

**Ara-C + Idarubicin (219)**

Cytarabine: 100 mg/m<sup>2</sup>/day IV continuous infusion on days 1–7

Idarubicin: 12 mg/m<sup>2</sup> IV on days 1–3

**Ara-C + Doxorubicin (220)**

Cytarabine: 100 mg/m<sup>2</sup>/day IV continuous infusion on days 1–7

Doxorubicin: 30 mg/m<sup>2</sup> IV on days 1–3

**AIDA (acute promyelocytic leukemia only) (221)**

ATRA: 45 mg/m<sup>2</sup> PO daily

Idarubicin: 12 mg/m<sup>2</sup> IV on days 2, 4, 6, and 8

**Mitoxantrone + Etoposide (salvage regimen) (222)**

Mitoxantrone:	10 mg/m <sup>2</sup> /day IV on days 1–5
Etoposide:	100 mg/m <sup>2</sup> /day IV on days 1–5

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Consolidation Regimens

**Ara-C + Daunorubicin (5 + 2) (223)**

Cytarabine:	100 mg/m <sup>2</sup> /day IV continuous infusion on days 1–5
Daunorubicin:	45 mg/m <sup>2</sup> IV on days 1 and 2

**Ara-C + Idarubicin (224)**

Cytarabine:	100 mg/m <sup>2</sup> IV continuous infusion on days 1–5
Idarubicin:	13 mg/m <sup>2</sup> IV on days 1 and 2

Repeat cycle every 21–28 days.

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Single-Agent Regimens

**Cladribine (225)**

Cladribine:	0.1 mg/kg/day IV continuous infusion on days 1–7
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**High-Dose Cytarabine**

Cytarabine:	3,000 mg/m <sup>2</sup> IV over 3 hours, every 12 hours on days 1, 3, and 5
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Repeat cycle every 28 days (226).

**ATRA (acute promyelocytic leukemia only) (227)**

ATRA:	45 mg/m <sup>2</sup> PO daily in 1–2 divided doses
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**Gemtuzumab**

Gemtuzumab:	9 mg/m <sup>2</sup> IV as a 2-hour infusion
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Repeat with a second dose 14 days after administration of the first dose (228). Premedicate with diphenhydramine 50 mg PO and acetaminophen 650–1,000 mg PO, 1 hour before drug infusion. Once the infusion is completed, give 2 additional doses of acetaminophen 650–1,000 mg PO every 4 hours.

## CHRONIC LYMPHOCYTIC LEUKEMIA

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### Combination Regimens

#### **CVP**

Cyclophosphamide: 400 mg/m<sup>2</sup> PO on days 1–5 (or 800 mg/m<sup>2</sup> IV on day 1)  
Vincristine: 1.4 mg/m<sup>2</sup> IV on day 1 (maximum dose, 2 mg)  
Prednisone: 100 mg/m<sup>2</sup> PO on days 1–5  
Repeat cycle every 21 days (229).

#### **CF**

Cyclophosphamide: 1,000 mg/m<sup>2</sup> IV on day 1  
Fludarabine: 20 mg/m<sup>2</sup> IV on days 1–5  
Bactrim DS: 1 tablet PO bid  
Repeat cycle every 21–28 days (230).

#### **FP**

Fludarabine: 30 mg/m<sup>2</sup> IV on days 1–5  
Prednisone: 30 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 28 days (231).

#### **CP**

Chlorambucil: 30 mg/m<sup>2</sup> PO on day 1  
Prednisone: 80 mg PO on days 1–5  
Repeat cycle every 28 days (229).

#### **FR**

Fludarabine: 25 mg/m<sup>2</sup> IV on days 1–5  
Rituximab: 375 mg/m<sup>2</sup> IV on days 1 and 4 of cycle 1 and then on day 1 thereafter  
Repeat cycle every 28 days for 6 cycles (232).

#### **FCR**

Fludarabine: 25 mg/m<sup>2</sup> IV on days 1–3  
Cyclophosphamide: 250 mg/m<sup>2</sup> IV on days 1–3

Rituximab: 375–500 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 28 days (233).

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Single-Agent Regimens

**Alemtuzumab**

Alemtuzumab: 30 mg/day IV, 3 times per week  
Repeat weekly for up to a maximum of 23 weeks (234). Premedicate with diphenhydramine 50 mg PO and acetaminophen 625 mg PO 30 minutes before drug infusion. Patients should be placed on Bactrim DS PO bid and famciclovir 250 mg PO bid from day 8 through 2 months following completion of therapy.

**Chlorambucil**

Chlorambucil: 6–14 mg/day PO as induction therapy and then 0.7 mg/kg PO for 2–4 days  
Repeat cycle every 21 days (235).

**Cladribine**

Cladribine: 0.09 mg/kg/day IV continuous infusion on days 1–7  
Repeat cycle every 28–35 days (236).

**Fludarabine**

Fludarabine: 20–30 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 28 days (237).

**Prednisone**

Prednisone: 20–30 mg/m<sup>2</sup>/day PO for 1–3 weeks (238).

**Rituximab**

Rituximab: 375 mg/m<sup>2</sup> IV weekly for 4 weeks  
Repeat cycle every 6 months for a total of 4 courses (239).

**Pentostatin**

Pentostatin: 4 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 14 days (240).

## CHRONIC MYELOGENOUS LEUKEMIA

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### Combination Regimens

#### **Interferon + Cytarabine**

Interferon  $\alpha$ -2b: 5 million IU/m<sup>2</sup> SC daily

Cytarabine: 20 mg/m<sup>2</sup> SC daily for 10 days

Repeat cytarabine on a monthly basis (241). The dose of interferon should be reduced by 50% when the neutrophil count drops below 1,500/mm<sup>3</sup>, the platelet count drops below 100,000/m<sup>3</sup>, or both. Interferon and cytarabine should both be discontinued when the neutrophil count drops below 1,000/mm<sup>3</sup>, platelet count drops below 50,000/mm<sup>3</sup>, or both.

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### Single-Agent Regimens

#### **Imatinib**

Imatinib: 400 mg/day PO (chronic phase); 600 mg/day PO (accelerated phase blast crisis) (242)

#### **Dasatinib**

Dasatinib: 70 mg PO bid (243)

#### **Busulfan**

Busulfan: 1.8 mg/m<sup>2</sup>/day PO (244)

#### **Hydroxyurea**

Hydroxyurea: 1–5 gm/day PO (245)

#### **Interferon $\alpha$ -2a**

Interferon  $\alpha$ -2a: 9 million units/day SC (246)

## HAIRY CELL LEUKEMIA

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#### **Cladribine**

Cladribine: 0.09 mg/kg/day IV continuous infusion on days 1–7

Administer one cycle (247).

#### **Pentostatin**

Pentostatin: 4 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 14 days for 6 cycles (248).

**Interferon  $\alpha$ -2a**

Interferon  $\alpha$ -2a: 3 million IU SC or IM, 3 times per week  
Continue treatment for up to 1 to 1.5 years (249).

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## LUNG CANCER

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### NON-SMALL CELL LUNG CANCER

#### Adjuvant Therapy

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##### Combination Regimens

**Paclitaxel + Carboplatin**

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1  
Carboplatin: AUC of 6, IV on day 1  
Repeat cycle every 21 days for 4 cycles (250).

**Vinorelbine + Cisplatin**

Vinorelbine: 25 mg/m<sup>2</sup> IV weekly for 16 weeks  
Cisplatin: 50 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cisplatin every 28 days for 4 cycles (251).

#### Metastatic Disease

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##### Combination Regimens

**Carboplatin + Paclitaxel (PC)**

Carboplatin: AUC of 6, IV on day 1  
Paclitaxel: 200 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (252).

**Carboplatin + Paclitaxel + Bevacizumab (PCB)**

Carboplatin: AUC of 6, IV on day 1  
Paclitaxel: 200 mg/m<sup>2</sup> IV over 3 hours on day 1  
Bevacizumab: 15 mg/kg IV on day 1  
Repeat cycle every 21 days (252).

**Gemcitabine + Cisplatin + Bevacizumab (GCB)**

Gemcitabine: 1,250 mg/m<sup>2</sup> IV on days 1 and 8

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1  
Bevacizumab: 7.5 or 15 mg/kg IV on day 1  
Repeat cycle every 21 days for a total of 6 cycles (253).

**Cisplatin + Paclitaxel**

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1  
Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (254).

**Docetaxel + Carboplatin**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Carboplatin: AUC of 6, IV on day 1  
Repeat cycle every 21 days (255).

**Docetaxel + Cisplatin**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Cisplatin: 75 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (256).

**Docetaxel + Gemcitabine**

Docetaxel: 100 mg/m<sup>2</sup> IV on day 8  
Gemcitabine: 1,100 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 21 days (257). G-CSF support is required from day 9 to day 15.

**Gemcitabine + Cisplatin**

Gemcitabine: 1,250 mg/m<sup>2</sup> IV on days 1 and 8  
Cisplatin: 100 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (258).

**Gemcitabine + Carboplatin**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1 and 8  
Carboplatin: AUC of 5, IV on day 1  
Repeat cycle every 21 days (259).

**Gemcitabine + Vinorelbine**

Gemcitabine: 1,200 mg/m<sup>2</sup> IV on days 1 and 8

Vinorelbine: 30 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 21 days (260).

**Vinorelbine + Cisplatin**

Vinorelbine: 30 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Cisplatin: 120 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 28 days (261).

**Vinorelbine + Carboplatin**

Vinorelbine: 25 mg/m<sup>2</sup> IV on days 1 and 8  
Carboplatin: AUC of 6, IV on day 1  
Repeat cycle every 28 days (262).

**EP**

Etoposide: 120 mg/m<sup>2</sup> IV on days 1–3  
Cisplatin: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21–28 days (263).

**EP and Docetaxel**

Cisplatin: 50 mg/m<sup>2</sup> IV on days 1, 8, 29, and 36  
Etoposide: 50 mg/m<sup>2</sup> IV on days 1–5 and 29–33  
Administer concurrent thoracic radiotherapy, followed 4–6 weeks after the completion of combined modality therapy by  
Docetaxel: 75 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days for 3 cycles (264). Dose of docetaxel can be escalated to 100 mg/m<sup>2</sup> IV on subsequent cycles in the absence of toxicity.

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Single-Agent Regimens

**Paclitaxel**

Paclitaxel: 225 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (265).

or

Paclitaxel: 80–100 mg/m<sup>2</sup> IV weekly for 3 weeks  
Repeat cycle every 28 days after 1-week rest (266).

**Docetaxel**

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (267).

or

Docetaxel: 36 mg/m<sup>2</sup> IV weekly for 6 weeks

Repeat cycle every 8 weeks after 2-week rest (268). Premedicate with dexamethasone 8 mg PO at 12 hours and immediately before docetaxel infusion and 12 hours after each dose.

### ***Pemetrexed***

Pemetrexed: 500 mg/m<sup>2</sup> IV on day 1

Folic acid at 350–1,000 µg PO q day beginning one week prior to therapy and vitamin B12 at 1,000 µg IM beginning 1–2 weeks prior to first dose of therapy and repeated every 3 cycles. Repeat cycle every 21 days (269).

### ***Gemcitabine***

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15

Repeat cycle every 28 days (270).

### ***Vinorelbine***

Vinorelbine: 25 mg/m<sup>2</sup> IV every 7 days

Repeat every 7 days (271).

### ***Gefitinib***

Gefitinib: 250 mg/day PO

Continue treatment until disease progression (272).

### ***Erlotinib***

Erlotinib: 150 mg PO

Continue treatment until disease progression (273).

## **SMALL CELL LUNG CANCER**

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### Combination Regimens

#### ***EP***

Etoposide: 80 mg/m<sup>2</sup> IV on days 1–3

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (274).

### **EC**

Etoposide: 100 mg/m<sup>2</sup> IV on days 1–3  
Carboplatin: AUC of 6, IV on day 1  
Repeat cycle every 28 days (275).

### **Irinotecan + Cisplatin**

Irinotecan: 60 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Cisplatin: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 28 days (276).

### **Carboplatin + Paclitaxel + Etoposide**

Carboplatin: AUC of 6, IV on day 1  
Paclitaxel: 200 mg/m<sup>2</sup> IV over 1 hour on day 1  
Etoposide: 50 mg alternating with 100 mg PO on days 1–10  
Repeat cycle every 21 days (277).

### **CAV**

Cyclophosphamide: 1,000 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 40 mg/m<sup>2</sup> IV on day 1  
Vincristine: 1 mg/m<sup>2</sup> IV on day 1 (maximum, 2 mg)  
Repeat cycle every 21 days (278).

### **CAE**

Cyclophosphamide: 1,000 mg/m<sup>2</sup> IV on day 1  
Doxorubicin: 45 mg/m<sup>2</sup> IV on day 1  
Etoposide: 50 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 21 days (279).

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### Single-Agent Regimens

#### **Etoposide**

Etoposide: 160 mg/m<sup>2</sup> PO on days 1–5  
Repeat cycle every 28 days (280).

or

Etoposide: 50 mg/m<sup>2</sup>/day PO on days 1–21  
Repeat cycle as tolerated (281).

**Paclitaxel**

Paclitaxel: 80–100 mg/m<sup>2</sup> IV weekly for 3 weeks  
Repeat cycle every 28 days (282).

**Topotecan**

Topotecan: 1.5 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 21 days (283).

## LYMPHOMA

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### HODGKIN'S DISEASE

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**ABVD**

Doxorubicin: 25 mg/m<sup>2</sup> IV on days 1 and 15  
Bleomycin: 10 U/m<sup>2</sup> IV on days 1 and 15  
Vinblastine: 6 mg/m<sup>2</sup> IV on days 1 and 15  
Dacarbazine: 375 mg/m<sup>2</sup> IV on days 1 and 15  
Repeat cycle every 28 days (284).

**MOPP**

Nitrogen mustard: 6 mg/m<sup>2</sup> IV on days 1 and 8  
Vincristine: 1.4 mg/m<sup>2</sup> IV on days 1 and 8  
Procarbazine: 100 mg/m<sup>2</sup> PO on days 1–14  
Prednisone: 40 mg/m<sup>2</sup> PO on days 1–14  
Repeat cycle every 28 days (285).

**MOPP/ABVD Hybrid**

Nitrogen mustard: 6 mg/m<sup>2</sup> IV on days 1 and 8  
Vincristine: 1.4 mg/m<sup>2</sup> IV on day 1 (maximum dose, 2 mg)  
Procarbazine: 100 mg/m<sup>2</sup> PO on days 1–14  
Prednisone: 40 mg/m<sup>2</sup> PO on days 1–14  
Doxorubicin: 35 mg/m<sup>2</sup> IV on day 8  
Bleomycin: 10 U/m<sup>2</sup> IV on day 8  
Hydrocortisone: 100 mg IV given before bleomycin  
Vinblastine: 6 mg/m<sup>2</sup> IV on day 8  
Repeat cycle every 28 days (286).

### **MOPP Alternating with ABVD**

See MOPP and ABVD regimens outlined above.

#### **Stanford V**

Nitrogen mustard:	6 mg/m <sup>2</sup> IV on day 1
Doxorubicin:	25 mg/m <sup>2</sup> IV on days 1 and 15
Vinblastine:	6 mg/m <sup>2</sup> IV on days 1 and 15
Vincristine:	1.4 mg/m <sup>2</sup> IV on days 8 and 22
Bleomycin:	5 U/m <sup>2</sup> IV on days 8 and 22
Etoposide:	60 mg/m <sup>2</sup> IV on days 15 and 16
Prednisone:	40 mg PO every other day

Repeat cycle every 28 days (287). In patients >50 years of age, vinblastine dose reduced to 4 mg/m<sup>2</sup> and vincristine dose reduced to 1 mg/m<sup>2</sup> on weeks 9 and 12. Dose of prednisone tapered starting on week 10. Prophylactic Bactrim DS PO bid and acyclovir 200 mg PO tid.

#### **EVA**

Etoposide:	200 mg/m <sup>2</sup> IV on days 1–5
Vincristine:	2 mg/m <sup>2</sup> IV on day 1
Doxorubicin:	50 mg/m <sup>2</sup> IV on day 2

Repeat cycle every 28 days (288).

#### **EVAP**

Etoposide:	120 mg/m <sup>2</sup> IV on days 1, 8, and 15
Vinblastine:	4 mg/m <sup>2</sup> IV on days 1, 8, and 15
Cytarabine:	30 mg/m <sup>2</sup> IV on days 1, 8, and 15
Cisplatin:	40 mg/m <sup>2</sup> IV on days 1, 8, and 15

Repeat cycle every 28 days (289).

#### **Mini-BEAM**

BCNU:	60 mg/m <sup>2</sup> IV on day 1
Etoposide:	75 mg/m <sup>2</sup> IV on days 2–5
Ara-C:	100 mg/m <sup>2</sup> IV every 12 hours on days 2–5
Melphalan:	30 mg/m <sup>2</sup> IV on day 6

Repeat cycle every 4–6 weeks (290).

#### **BEACOPP**

Bleomycin:	10 mg/m <sup>2</sup> IV on day 8
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Etoposide: 100 mg/m<sup>2</sup> IV on days 1–3  
Doxorubicin: 25 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 650 mg/m<sup>2</sup> IV on day 1  
Vincristine: 1.4 mg/m<sup>2</sup> IV on day 8 (maximum, 2 mg)  
Procarbazine: 100 mg/m<sup>2</sup> PO on days 1–7  
Prednisone: 40 mg/m<sup>2</sup> PO on days 1–14  
Repeat cycle every 21 days (291).

**BEACOPP Escalated**

Bleomycin: 10 mg/m<sup>2</sup> IV on day 8  
Etoposide: 200 mg/m<sup>2</sup> IV on days 1–3  
Doxorubicin: 35 mg/m<sup>2</sup> IV on day 1  
Cyclophosphamide: 1,200 mg/m<sup>2</sup> IV on day 1  
Vincristine: 1.4 mg/m<sup>2</sup> IV on day 8 (maximum dose, 2 mg)  
Procarbazine: 100 mg/m<sup>2</sup> PO on days 1–7  
Prednisone: 40 mg/m<sup>2</sup> PO on days 1–14  
Repeat cycle every 21 days (292). G-CSF, at dose of 5 µg/kg/day SC, starting on day 8 and continue until neutrophil recovery.

**Gemcitabine**

Gemcitabine: 1,250 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Repeat cycle every 28 days (293).

## NON-HODGKIN'S LYMPHOMA

### Low-Grade

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Combination Regimens

**CVP**

Cyclophosphamide: 400 mg/m<sup>2</sup> PO on days 1–5 (or 800 mg/m<sup>2</sup> IV on day 1)  
Vincristine: 1.4 mg/m<sup>2</sup> IV on day 1 (maximum, 2 mg)  
Prednisone: 100 mg/m<sup>2</sup> PO on days 1–5  
Repeat cycle every 21 days (294).

**CHOP**

Cyclophosphamide: 750 mg/m<sup>2</sup> IV on day 1

Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1  
Vincristine: 1.4 mg/m<sup>2</sup> IV on day 1 (maximum, 2 mg)  
Prednisone: 100 mg/m<sup>2</sup> PO on days 1–5  
Repeat cycle every 21 days (295).

**CNOP**

Cyclophosphamide: 750 mg/m<sup>2</sup> IV on day 1  
Mitoxantrone: 10 mg/m<sup>2</sup> IV on day 1  
Vincristine: 1.4 mg/m<sup>2</sup> IV on day 1 (maximum, 2 mg)  
Prednisone: 50 mg/m<sup>2</sup> PO on days 1–5  
Repeat cycle every 21 days (296).

**FND**

Fludarabine: 25 mg/m<sup>2</sup> IV on days 1–3  
Mitoxantrone: 10 mg/m<sup>2</sup> IV on day 1  
Dexamethasone: 20 mg PO on days 1–5  
Bactrim DS: 1 tablet PO bid, 3 times per week  
Repeat cycle every 21 days (297).

**FC**

Fludarabine: 20 mg/m<sup>2</sup> IV on days 1–5  
Cyclophosphamide: 1,000 mg/m<sup>2</sup> IV on day 1  
Bactrim DS: 1 tablet PO bid  
Repeat cycle every 21–28 days (298).

**Bortezomib (mantle cell lymphoma)**

Bortezomib: 1.3 mg/m<sup>2</sup> IV on days 1, 4, 8, and 11  
Repeat cycle every 21 days for up to 17 cycles (299).

**R-FCM**

Rituximab: 375 mg/m<sup>2</sup> IV on day 0  
Fludarabine: 25 mg/m<sup>2</sup> IV on days 1–3  
Cyclophosphamide: 200 mg/m<sup>2</sup> IV on days 1–3  
Mitoxantrone: 8 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 4 weeks for a total of 4 cycles (300).

## Intermediate-Grade

### **CHOP**

Cyclophosphamide:	750 mg/m <sup>2</sup> IV on day 1
Doxorubicin:	50 mg/m <sup>2</sup> IV on day 1
Vincristine:	1.4 mg/m <sup>2</sup> IV on day 1 (maximum, 2 mg)
Prednisone:	100 mg PO on days 1–5

Repeat cycle every 21 days (295).

### **CHOP + Rituximab (GELA Study)**

Cyclophosphamide:	750 mg/m <sup>2</sup> IV on day 1
Doxorubicin:	50 mg/m <sup>2</sup> IV on day 1
Vincristine:	1.4 mg/m <sup>2</sup> IV on day 1 (maximum, 2 mg)
Prednisone:	40 mg/m <sup>2</sup> PO on days 1–5
Rituximab:	375 mg/m <sup>2</sup> IV on day 1

Repeat cycle every 21 days (301). Rituximab is to be administered first followed by cyclophosphamide, doxorubicin, and vincristine.

or

### **CHOP + Rituximab (Nebraska regimen)**

Cyclophosphamide:	750 mg/m <sup>2</sup> IV on day 3
Doxorubicin:	50 mg/m <sup>2</sup> IV on day 3
Vincristine:	1.4 mg/m <sup>2</sup> IV on day 3 (maximum, 2 mg)
Prednisone:	100 mg PO on days 3–7
Rituximab:	375 mg/m <sup>2</sup> IV on day 1

Repeat cycle every 21 days (302).

### **CNOP**

Cyclophosphamide:	750 mg/m <sup>2</sup> IV on day 1
Mitoxantrone:	10 mg/m <sup>2</sup> IV on day 1
Vincristine:	1.4 mg/m <sup>2</sup> IV on day 1 (maximum, 2 mg)
Prednisone:	100 mg PO on days 1–5

Repeat cycle every 21 days (303).

### **EPOCH**

Etoposide:	50 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4
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Prednisone:	60 mg/m <sup>2</sup> PO on days 1–5
Vincristine:	0.4 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4
Cyclophosphamide:	750 mg/m <sup>2</sup> IV on day 5, begin after infusion
Doxorubicin:	10 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4
Bactrim DS:	1 tablet PO bid, 3 times per week
Repeat cycle every 21 days (304).	

### ***EPOCH + Rituximab***

Etoposide:	50 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4
Prednisone:	60 mg/m <sup>2</sup> PO bid on days 1–5
Vincristine:	0.4 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4
Cyclophosphamide:	750 mg/m <sup>2</sup> IV on day 5, begin after infusion
Doxorubicin:	10 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4
Rituximab:	375 mg/m <sup>2</sup> IV on day 1
Repeat cycle every 21 days (305). Rituximab is to be administered first followed by infusions of etoposide, doxorubicin, and vincristine. Prophylaxis with Bactrim DS 1 tab PO bid, 3 times per week to reduce the risk of <i>Pneumocystis carinii</i> infection.	

### ***MACOP-B***

Methotrexate:	400 mg/m <sup>2</sup> IV on weeks 2, 6, and 10
Leucovorin:	15 mg/m <sup>2</sup> PO every 6 hours for 6 doses, beginning 24 hours after methotrexate
Doxorubicin:	50 mg/m <sup>2</sup> IV on weeks 1, 3, 5, 7, 9, and 11
Cyclophosphamide:	350 mg/m <sup>2</sup> IV on weeks 1, 3, 5, 7, 9, and 11
Vincristine:	1.4 mg/m <sup>2</sup> IV on weeks 2, 4, 6, 8, 10, and 12
Prednisone:	75 mg/day PO for 12 weeks with taper over the last 2 weeks
Bleomycin:	10 U/m <sup>2</sup> IV on weeks 4, 8, and 12
Bactrim DS:	1 tablet PO bid
Ketoconazole:	200 mg/day PO
Administer one cycle (306).	

***m-BACOD***

Methotrexate:	200 mg/m <sup>2</sup> IV on days 8 and 15
Leucovorin:	10 mg/m <sup>2</sup> PO every 6 hours for 8 doses, beginning 24 hours after methotrexate
Bleomycin:	4 U/m <sup>2</sup> IV on day 1
Doxorubicin:	45 mg/m <sup>2</sup> IV on day 1
Cyclophosphamide:	600 mg/m <sup>2</sup> IV on day 1
Vincristine:	1 mg/m <sup>2</sup> IV on day 1 (maximum, 2 mg)
Dexamethasone:	6 mg/m <sup>2</sup> PO on days 1–5

Repeat cycle every 21 days (307).

***ProMACE/CytaBOM***

Prednisone:	60 mg/m <sup>2</sup> PO on days 1–14
Doxorubicin:	25 mg/m <sup>2</sup> IV on day 1
Cyclophosphamide:	650 mg/m <sup>2</sup> IV on day 1
Etoposide:	120 mg/m <sup>2</sup> IV on day 1
Cytarabine:	300 mg/m <sup>2</sup> IV on day 8
Bleomycin:	5 U/m <sup>2</sup> IV on day 8
Vincristine:	1.4 mg/m <sup>2</sup> IV on day 8
Methotrexate:	120 mg/m <sup>2</sup> IV on day 8
Leucovorin rescue:	25 mg/m <sup>2</sup> PO every 6 hours for 6 doses, beginning 24 hours after methotrexate
Bactrim DS:	1 tablet PO bid on days 1–21

Repeat cycle every 21 days (308).

***ESHAP (salvage regimen)***

Etoposide:	40 mg/m <sup>2</sup> IV on days 1–4
Methylprednisolone:	500 mg IV on days 1–4
Cisplatin:	25 mg/m <sup>2</sup> /day IV continuous infusion on days 1–4
Cytarabine:	2,000 mg/m <sup>2</sup> IV on day 5 after completion of cisplatin and etoposide

Repeat cycle every 21 days (309).

***DHAP (salvage regimen)***

Cisplatin:	100 mg/m <sup>2</sup> IV continuous infusion over 24 hours on day 1
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Cytarabine: 2,000 mg/m<sup>2</sup> IV over 3 hours every 12 hours for 2 doses on day 2 after completion of cisplatin infusion

Dexamethasone: 40 mg PO or IV on days 1–4

Repeat cycle every 3–4 weeks (310).

**ICE (salvage regimen)**

Ifosfamide: 5,000 mg/m<sup>2</sup> IV continuous infusion for 24 hours on day 2

Etoposide: 100 mg/m<sup>2</sup> IV on days 1–3

Carboplatin: AUC of 5, IV on day 2

Mesna: 5,000 mg/m<sup>2</sup> IV in combination with ifosfamide dose

Repeat cycle every 14 days (311). G-CSF is administered at 5 µg/kg on days 5–12.

**MINE (salvage regimen)**

Mesna: 1,330 mg/m<sup>2</sup> IV administered at same time as ifosfamide on days 1–3, then 500 mg IV 4 hours after ifosfamide on days 1–3

Ifosfamide: 1,330 mg/m<sup>2</sup> IV on days 1–3

Mitoxantrone: 8 mg/m<sup>2</sup> IV on day 1

Etoposide: 65 mg/m<sup>2</sup> IV on days 1–3

Repeat cycle every 21 days (312).

**R-GemOx (salvage regimen)**

Rituximab: 375 mg/m<sup>2</sup> IV on day 1

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on day 2

Oxaliplatin: 50 mg/m<sup>2</sup> IV on day 2

Repeat cycle every 2 weeks for a total of 8 cycles (313).

**High-Grade**

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**Magrath Protocol (Burkitt's lymphoma)**

Cyclophosphamide: 1,200 mg/m<sup>2</sup> IV on day 1

Doxorubicin: 40 mg/m<sup>2</sup> IV on day 1

Vincristine: 1.4 mg/m<sup>2</sup> IV on day 1 (maximum, 2 mg)

Prednisone:	40 mg/m <sup>2</sup> PO on days 1–5
Methotrexate:	300 mg/m <sup>2</sup> IV on day 10, for 1 hour, then 60 mg/m <sup>2</sup> IV on days 10 and 11, for 41 hours
Leucovorin rescue:	15 mg/m <sup>2</sup> IV every 6 hours for 8 doses, starting 24 hours after methotrexate on day 12
Intrathecal Ara-C:	30 mg/m <sup>2</sup> IT on day 7, cycle 1 only 45 mg/m <sup>2</sup> IT on day 7, all subsequent cycles
Intrathecal Methotrexate:	12.5 mg IT on day 10, all cycles
Repeat cycle every 28 days (314).	
or	

**Regimen A (CODOX-M) (315)**

Cyclophosphamide:	800 mg/m <sup>2</sup> IV on day 1 and 200 mg/m <sup>2</sup> IV on days 2–5
Doxorubicin:	40 mg/m <sup>2</sup> IV on day 1
Vincristine:	1.5 mg/m <sup>2</sup> IV on days 1 and 8 in cycle 1 and on days 1, 8, and 15 in cycle 3
Methotrexate:	1,200 mg/m <sup>2</sup> IV over 1 hour, followed by 240 mg/m <sup>2</sup> /hour for the next 23 hours on day 10
Leucovorin:	192 mg/m <sup>2</sup> IV starting at hour 36 after the start of the infusion and 12 mg/m <sup>2</sup> IV every 6 hours thereafter until serum MTX levels <50 nM

**CNS Prophylaxis**

Cytarabine:	70 mg IT on days 1 and 3
Methotrexate:	12 mg IT on day 15

**Regimen B (IVAC)**

Ifosfamide:	1,500 mg/m <sup>2</sup> IV on days 1–5
Etoposide:	60 mg/m <sup>2</sup> IV on days 1–5
Cytarabine:	2 g/m <sup>2</sup> IV every 12 hours on days 1 and 2 for a total of 4 doses
Methotrexate:	12 mg IT on day 5

**Stanford Regimen (small non-cleaved cell and Burkitt's lymphoma)**

Cyclophosphamide:	1,200 mg/m <sup>2</sup> IV on day 1
Doxorubicin:	40 mg/m <sup>2</sup> IV on day 1

Vincristine:	1.4 mg/m <sup>2</sup> IV on day 1 (maximum, 2 mg)
Prednisone:	40 mg/m <sup>2</sup> PO on days 1–5
Methotrexate:	3 g/m <sup>2</sup> IV over 6 hours on day 10
Leucovorin rescue:	25 mg/m <sup>2</sup> IV or PO every 6 hours for 12 doses, beginning 24 hours after methotrexate
Intrathecal Methotrexate:	12 mg IT on days 1 and 10
Repeat cycle every 21 days (316).	

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#### Single-Agent Regimens

##### **Rituximab**

Rituximab:	375 mg/m <sup>2</sup> IV on days 1, 8, 15, and 22
Repeat one additional cycle (317).	

##### **Ibritumomab Tiuxetan Regimen**

Rituximab:	250 mg/m <sup>2</sup> IV on days 1 and 8
<sup>111</sup> In-Ibritumomab tiuxetan:	5 mCi of <sup>111</sup> In, 1.6 mg of ibritumomab tiuxetan IV on day 1
<sup>90</sup> Y-Ibritumomab tiuxetan:	0.4 mCi/kg IV over 10 min on day 8 after the day 8 rituximab dose

The dose of <sup>90</sup>Y-ibritumomab tiuxetan is capped at 32 mCi (318).

##### **Fludarabine**

Fludarabine:	25 mg/m <sup>2</sup> IV on days 1–5
Repeat cycle every 28 days (319).	

##### **Cladribine**

Cladribine:	0.5–0.7 mg/kg SC on days 1–5 or 0.1 mg/kg IV on days 1–7
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Repeat cycle every 28 days (320).

## PRIMARY CNS LYMPHOMA

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Methotrexate:	3.5 g/m <sup>2</sup> IV over 2 hours every other week for 5 doses
Intrathecal Methotrexate:	12 mg IT weekly every other week after IV MTX
Leucovorin:	10 mg IV every 6 hours for 12 doses, starting 24 hours after IV MTX 10 mg IV every

12 hours for 8 doses, starting 24 hours after IT MTX

Vincristine: 1.4 mg/m<sup>2</sup> IV every other week along with IV MTX

Procarbazine: 100 mg/m<sup>2</sup>/day PO for 7 days on 1st, 3rd, and 5th cycle of IV MTX

Once chemotherapy is completed, whole-brain radiation therapy is administered to a total dose of 45 cGy (321).

### **High-Dose Methotrexate**

Methotrexate: 8 g/m<sup>2</sup> IV on day 1

Repeat cycle every 2 weeks for up to 8 cycles, followed by 8 gm/m<sup>2</sup> IV on day 1 every month for up to 100 months (322).

### **Temozolomide**

Temozolomide: 150 mg/m<sup>2</sup>/day PO on days 1–5

Repeat cycle every 4 weeks (323).

## **MALIGNANT MELANOMA**

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### **Adjuvant Therapy**

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#### **Interferon $\alpha$ -2b**

Interferon  $\alpha$ -2b: 20 million IU/m<sup>2</sup> IV, 5 times weekly for 4 weeks, then 10 million IU/m<sup>2</sup> SC, 3 times weekly for 48 weeks

Treat for a total of one year (324).

### **Metastatic Disease**

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#### Combination Regimens

#### **DTIC + BCNU + Cisplatin**

Dacarbazine: 220 mg/m<sup>2</sup> IV on days 1–3

Carmustine: 150 mg/m<sup>2</sup> IV on day 1

Cisplatin: 25 mg/m<sup>2</sup> IV on days 1–3

Repeat cycle with dacarbazine and cisplatin every 21 days and carmustine every 42 days (325).

**IFN + DTIC**

Interferon  $\alpha$ -2b: 15 million IU/m<sup>2</sup> IV on days 1–5, 8–12, and 15–19 as induction therapy  
Interferon  $\alpha$ -2b: 10 million IU/m<sup>2</sup> SC 3 times weekly after induction therapy  
Dacarbazine: 200 mg/m<sup>2</sup> IV on days 22–26  
Repeat cycle every 28 days (326).

**Temozolomide + Thalidomide**

Temozolomide: 75 mg/m<sup>2</sup>/day PO for 6 weeks  
Thalidomide: 200–400 mg/m<sup>2</sup>/day PO for 6 weeks  
Repeat cycle every 10 weeks (327).

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Single-Agent Regimens

**Dacarbazine**

Dacarbazine: 250 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 21 days (328).  
or  
Dacarbazine: 850 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 3–6 weeks (329).

**Interferon- $\alpha$**

Interferon  $\alpha$ -2b: 20 million IU/m<sup>2</sup> IM, 3 times weekly for 12 weeks (330).

**Aldesleukin**

Aldesleukin (IL-2): 100,000 IU/kg IV on days 1–5 and 15–19  
Repeat cycle every 28 days (331).

**Temozolomide**

Temozolomide: 150 mg/m<sup>2</sup> PO on days 1–5  
Repeat cycle every 28 days (332). If well tolerated, can increase dose to 200 mg/m<sup>2</sup> PO on days 1–5.

## MALIGNANT MESOTHELIOMA

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### Combination Regimens

#### **Doxorubicin + Cisplatin**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1

Cisplatin: 60 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21–28 days (333).

#### **CAP**

Cyclophosphamide: 500 mg/m<sup>2</sup> IV on day 1

Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1

Cisplatin: 80 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (334).

#### **Gemcitabine + Cisplatin**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15

Cisplatin: 100 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 28 days (335).

#### **Gemcitabine + Carboplatin**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15

Carboplatin: AUC of 5, IV on day 1

Repeat cycle every 28 days (336).

#### **Pemetrexed + Cisplatin**

Pemetrexed: 500 mg/m<sup>2</sup> IV on day 1

Cisplatin: 75 mg/m<sup>2</sup> IV on day 1

Folic acid at 350–1,000 µg PO q day beginning one week prior to therapy and vitamin B12 at 1,000 µg IM to start 1–2 weeks prior to first dose of therapy and repeated every 3 cycles. Repeat cycle every 21 days (337).

## MULTIPLE MYELOMA

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### Combination Regimens

#### **MP**

Melphalan: 8–10 mg/m<sup>2</sup> PO on days 1–4

Prednisone: 60 mg/m<sup>2</sup> on days 1–4

Repeat cycle every 42 days (338).

**MPT**

Melphalan: 0.25 mg/kg days 1–4  
Prednisone: 1.5 mg/kg days 1–4  
Thalidomide: 50–100 mg/day continuously  
Repeat cycle every 28 days (339).

or

Melphalan: 0.25 mg/kg/day PO on days 1–4  
Prednisone: 2 mg/kg/day PO on days 1–4  
Thalidomide: 100–400 mg PO q day  
Repeat cycle every 42 days (340).

**VAD**

Vincristine: 0.4 mg/day IV continuous infusion on days 1–4  
Doxorubicin: 9 mg/m<sup>2</sup>/day IV continuous infusion on days 1–4  
Dexamethasone: 40 mg PO on days 1–4, 9–12, and 17–20  
Repeat cycle every 28 days (341).

**Thalidomide + Dexamethasone**

Thalidomide: 200 mg/day PO  
Dexamethasone: 40 mg/day PO on days 1–4, 9–12, and 17–20 for first 4 cycles and then 40 mg/day PO on days 1–4  
Repeat cycle every 28 days (342).

**Lenalidomide + Dexamethasone**

Lenalidomide: 25 mg/day PO on days 1–21  
Dexamethasone: 40 mg/day PO on days 1–4, 9–12, and 17–20 (first 4 cycles) and then 40 mg/day PO on days 1–4 with future cycles

Repeat cycles every 28 days (343).

or

Lenalidomide: 25 mg/day PO on days 1–21  
Dexamethasone: 40 mg/m<sup>2</sup>/day PO on days 1, 8, 15, and 22  
Repeat cycle every 28 days (344).

**Bortezomib + Liposomal Doxorubicin**

Bortezomib: 1.3 mg/m<sup>2</sup> IV on days 1, 4, 8, and 11

Doxil: 30 mg/m<sup>2</sup> IV on day 4

Repeat cycle every 21 days (345).

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Single-Agent Regimens

**Dexamethasone**

Dexamethasone: 40 mg IV or PO on days 1–4, 9–12, and 17–20

Repeat cycle every 21 days (346).

**Melphalan**

Melphalan: 90–140 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 28–42 days (347).

**Thalidomide**

Thalidomide: 200–800 mg PO daily

Continue treatment until disease progression or undue toxicity (348).

**Bortezomib**

Bortezomib: 1.3 mg/m<sup>2</sup> IV on days 1, 4, 8, and 11

Repeat cycle every 21 days (349).

If progressive disease after 2 cycles or stable disease after 4 cycles, may add Dexamethasone at 20 mg PO daily on the day of and the day after Bortezomib.

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## MYELODYSPLASTIC SYNDROME

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Single-Agent Regimens

**Azacitidine**

Azacitidine: 75 mg/m<sup>2</sup> SC daily for 7 days

Repeat cycle every 6 weeks. Patients should be treated for at least 4 cycles (350).

**Decitabine**

Decitabine: 15 mg/m<sup>2</sup> IV continuous infusion over 3 hours every 8 hours for 3 days

Repeat cycle every 4 weeks. Patients should be treated for at least 4 cycles (351).

or

Decitabine: 20 mg/m<sup>2</sup> IV continuous infusion over 1 hour  
for 5 days

Repeat cycle every 4–6 weeks. Patients should be treated for at least 4 cycles (352).

### ***Lenalidomide***

Lenalidomide: 10 mg PO daily

Continue until disease progression (353).

or

Lenalidomide: 10 mg PO daily for 21 days

Repeat cycle every 28 days (353).

## **OVARIAN CANCER (Epithelial)**

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Combination Regimens

### **CC**

Carboplatin: 300 mg/m<sup>2</sup> IV on day 1

Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 28 days (354).

### **CP**

Cisplatin: 100 mg/m<sup>2</sup> IV on day 1

Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 28 days (355).

### **CT**

Cisplatin: 75 mg/m<sup>2</sup> IV on day 2

Paclitaxel: 135 mg/m<sup>2</sup> IV over 24 hours on day 1

Repeat cycle every 21 days (356).

### ***Carboplatin + Paclitaxel***

Carboplatin: AUC of 6–7.5, IV on day 1

Paclitaxel: 175 mg/m<sup>2</sup> IV over 3 hours on day 1

Repeat cycle every 21 days (357).

**Carboplatin + Docetaxel**

Carboplatin: AUC of 6, IV on day 1  
Docetaxel: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (358).

**Gemcitabine + Liposomal Doxorubicin**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1 and 8  
Doxil: 30 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (359).

**Gemcitabine + Cisplatin**

Gemcitabine: 800–1,000 mg/m<sup>2</sup> IV on days 1 and 8  
Cisplatin: 30 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 21 days (360).

**Gemcitabine + Carboplatin**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1 and 8  
Carboplatin: AUC of 4, IV on day 1  
Repeat cycle every 21 days (361).

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Single-Agent Regimens

**Altretamine**

Altretamine: 260 mg/m<sup>2</sup>/day PO in 4 divided doses after meals and at bedtime  
Repeat cycle every 14–21 days (362).

**Liposomal Doxorubicin**

Liposomal  
Doxorubicin: 50 mg/m<sup>2</sup> IV over 1 hour on day 1  
Repeat cycle every 28 days (363).

**Paclitaxel**

Paclitaxel: 135 mg/m<sup>2</sup> IV over 3 hours on day 1  
Repeat cycle every 21 days (364).

### **Topotecan**

Topotecan: 1.5 mg/m<sup>2</sup> IV on days 1–5

Repeat cycle every 21 days (365).

### **Gemcitabine**

Gemcitabine: 800 mg/m<sup>2</sup> IV weekly for 3 weeks

Repeat cycle every 4 weeks (366).

### **Etoposide**

Etoposide: 50 mg/m<sup>2</sup>/day PO on days 1–21

Repeat cycle every 28 days (367).

## **OVARIAN CANCER (Germ Cell)**

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Combination Regimens

### **BEP**

Bleomycin: 30 U IV on days 2, 9, and 16

Etoposide: 100 mg/m<sup>2</sup> IV on days 1–5

Cisplatin: 20 mg/m<sup>2</sup> IV on days 1–5

Repeat cycle every 21 days (368).

## **PANCREAS CANCER**

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### **Adjuvant Therapy**

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Combination Regimens

### **Gemcitabine**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15

Repeat cycle every 28 days for a total of 6 cycles (369).

### **Locally Advanced Disease**

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Combination Regimens

### **5-Fluorouracil + Radiation Therapy (GITSG regimen)**

5-Fluorouracil: 500 mg/m<sup>2</sup>/day IV on days 1–3 and 29–31,  
then weekly beginning on day 71

Radiation therapy: Total dose, 4,000 cGy  
Chemotherapy and radiation therapy started on the same day and given concurrently (370).

**RTOG 9704 Chemoradiation Regimen**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Followed by concurrent chemoradiation:  
5-Fluorouracil: 250 mg/m<sup>2</sup>/day IV continuous infusion during radiation therapy  
Radiation therapy: 180 cGy/day to a total dose of 5,040 cGy  
Chemotherapy and radiation therapy started on the same day and given concurrently.  
After chemoradiation:  
Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Repeat cycle every 4 weeks for a total of 3 cycles (371).

**Metastatic Disease**

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Combination Regimens

**5-Fluorouracil + Leucovorin**

5-Fluorouracil: 425 mg/m<sup>2</sup> IV on days 1-5  
Leucovorin: 20 mg/m<sup>2</sup> IV on days 1-5  
Repeat cycle every 28 days (372).

**Gemcitabine + Capecitabine (GEM-CAP)**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1 and 8  
Capecitabine: 650 mg/m<sup>2</sup> PO bid on days 1-14  
Repeat cycle every 21 days (373).

or

Gemcitabine: 1,000 mg/m<sup>2</sup> IV on days 1, 8, and 15  
Capecitabine: 880 mg/m<sup>2</sup> PO bid on days 1-21  
Repeat cycle every 28 days (374).

**Gemcitabine + Docetaxel + Capecitabine (GTX)**

Gemcitabine: 750 mg/m<sup>2</sup> IV over 75 minutes days 4 and 11  
Docetaxel: 30 mg/m<sup>2</sup> IV on days 4 and 11

Capecitabine: 1,000–1,500 mg/m<sup>2</sup> PO bid on days 1–14  
Repeat cycle every 2 weeks (375).

**Gemcitabine + Oxaliplatin**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV over 100 minutes on day 1  
Oxaliplatin: 100 mg/m<sup>2</sup> over 2 hours on day 2  
Repeat cycle every 2 weeks (376).

or

Gemcitabine: 1,000 mg/m<sup>2</sup> IV over 100 minutes on day 1  
Oxaliplatin: 100 mg/m<sup>2</sup> over 2 hours on day 1  
Repeat cycle every 2 weeks (377).

**Gemcitabine + Erlotinib**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV weekly for 7 weeks, then  
1 week rest, subsequent cycles 1,000 mg/m<sup>2</sup>  
IV weekly for 3 weeks with 1 week rest  
Erlotinib: 100 mg PO daily  
Repeat 3-week cycles every 28 days (378).

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Single-Agent Regimens

**Gemcitabine**

Gemcitabine: 1,000 mg/m<sup>2</sup> IV weekly for 7 weeks, then  
1 week rest, subsequent cycles 1,000 mg/m<sup>2</sup>  
IV weekly for 3 weeks with 1 week rest  
Repeat 3-week cycle every 28 days (379).

or

Gemcitabine: 1,000 mg/m<sup>2</sup> IV over 100 min at 10 mg/m<sup>2</sup>/  
min on days 1, 8, and 15  
Repeat cycle every 28 days (380).

**Capecitabine**

Capecitabine: 1,250 mg/m<sup>2</sup> PO bid on days 1–14  
May decrease dose to 850–1,000 mg/m<sup>2</sup> PO bid on days 1–14 to reduce the  
risk of toxicity without compromising clinical efficacy.  
Repeat cycle every 21 days (381).

# PROSTATE CANCER

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## Combination Regimens

### **Flutamide + Leuprolide (382)**

Flutamide: 250 mg PO tid  
Leuprolide: 7.5 mg IM every 28 days or 22.5 mg IM every 12 weeks

### **Flutamide + Goserelin (383)**

Flutamide: 250 mg PO tid  
Goserelin: 10.8 mg SC every 12 weeks

### **Estramustine + Etoposide**

Estramustine: 15 mg/kg/day PO in 4 divided doses on days 1–21  
Etoposide: 50 mg/m<sup>2</sup>/day PO in 2 divided doses on days 1–21  
Repeat cycle every 28 days (384).

### **Estramustine + Vinblastine**

Estramustine: 600 mg/m<sup>2</sup> PO daily on days 1–42  
Vinblastine: 4 mg/m<sup>2</sup> IV weekly for 6 weeks  
Repeat cycle every 8 weeks (385).

### **Paclitaxel + Estramustine**

Paclitaxel: 120 mg/m<sup>2</sup> IV continuous infusion on days 1–4  
Estramustine: 600 mg/m<sup>2</sup> PO daily, starting 24 hours before paclitaxel  
Repeat cycle every 21 days (386).

### **Mitoxantrone + Prednisone**

Mitoxantrone: 12 mg/m<sup>2</sup> IV on day 1  
Prednisone: 5 mg PO bid daily  
Repeat cycle every 21 days (387).

### **Docetaxel + Estramustine**

Docetaxel: 35 mg/m<sup>2</sup> IV on day 2 of weeks 1 and 2

Estramustine: 420 mg PO for the first 4 doses and 280 mg PO for the next 5 doses on days 1–3 of weeks 1 and 2

Repeat cycle every 21 days (388). Decadron is administered at 4 mg PO bid on days 1–3 of weeks 1 and 2.

or

Docetaxel: 60 mg/m<sup>2</sup> IV on day 2

Estramustine: 280 mg PO tid on days 1–5

Repeat cycle every 21 days (389).

### ***Docetaxel + Prednisone***

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1

Prednisone: 5 mg PO bid

Repeat cycle every 21 days for up to a total of 10 cycles (390).

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### Single-Agent Regimens

#### ***Paclitaxel***

Paclitaxel: 135–170 mg/m<sup>2</sup> IV as a 24-hour infusion on day 1

Repeat cycle every 3 weeks (391).

or

Paclitaxel: 150 mg/m<sup>2</sup> IV as a 1-hour infusion weekly for 6 weeks

Repeat cycle every 8 weeks (392).

#### ***Docetaxel***

Docetaxel: 75 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (393).

or

Docetaxel: 20–40 mg/m<sup>2</sup> weekly for 3 weeks

Repeat cycle every 4 weeks (394).

#### ***Estramustine***

Estramustine: 14 mg/kg/day PO in 3–4 divided doses (395)

#### ***Goserelin***

Goserelin: 3.6 mg SC on day 1

Repeat cycle every 28 days (396).

or

Goserelin: 10.8 mg SC on day 1

Repeat cycle every 12 weeks (396).

***Goserelin (Adjuvant Therapy)***

Goserelin: 3.6 mg SC on day 1

Repeat cycle every 28 days for 24 months (397).

***Leuprolide***

Leuprolide: 7.5 mg IM on day 1

Repeat cycle every 28 days (398).

or

Leuprolide: 22.5 mg IM on day 1

Repeat cycle every 12 weeks (399).

***Bicalutamide***

Bicalutamide: 50 mg PO daily

In patients refractory to other antiandrogen agents, may start with a higher dose of 150 mg PO daily (400).

***Flutamide***

Flutamide: 250 mg PO tid (401)

***Nilutamide***

Nilutamide: 300 mg PO on days 1–30, then 150 mg PO daily (402)

***Prednisone***

Prednisone: 5 mg PO bid (387)

***Ketoconazole***

Ketoconazole: 1,200 mg PO daily (403)

***Aminoglutethimide***

Aminoglutethimide: 250 mg PO qid, if tolerated may increase to 500 mg PO qid (404)

# RENAL CELL CANCER

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## Combination Regimens

### **Bevacizumab + Interferon- $\alpha$**

Bevacizumab: 10 mg/kg IV every 2 weeks  
Interferon  $\alpha$ -2a: 9 million units SC tid for 1 year  
Continue bevacizumab until disease progression (405).

### **Interferon- $\alpha$ + IL-2**

Interferon  $\alpha$ -2a: 9 million units SC on days 1-4, weeks 1-4  
Interleukin-2: 12 million units SC on days 1-4, weeks 1-4  
Repeat cycle every 6 weeks (406).

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## Single-Agent Regimens

### **Sunitinib**

Sunitinib: 50 mg PO daily for 4 weeks  
Repeat cycle every 6 weeks (407).

### **Sorafenib**

Sorafenib: 400 mg PO bid  
Continue until disease progression (408).

### **Temsirolimus**

Temsirolimus: 25 mg IV weekly  
Continue until disease progression (409).

### **Low-dose IL-2**

Interleukin-2: 3 million units/day IV continuous infusion on days 1-5  
Repeat cycle every 14 days for 1 month (410).

### **Interferon- $\alpha$**

Interferon  $\alpha$ -2a: 5-15 million units SC daily or 3-5 times per week (411)

## SOFT TISSUE SARCOMAS

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### Combination Regimens

#### **AD**

- Doxorubicin: 15 mg/m<sup>2</sup>/day IV continuous infusion on days 1-4
- Dacarbazine: 250 mg/m<sup>2</sup>/day IV continuous infusion on days 1-4
- Repeat cycle every 21 days (412).

#### **MAID**

- Mesna: 2,500 mg/m<sup>2</sup>/day IV continuous infusion on days 1-4
- Doxorubicin: 20 mg/m<sup>2</sup>/day IV continuous infusion on days 1-3
- Ifosfamide: 2,500 mg/m<sup>2</sup>/day IV continuous infusion on days 1-3
- Dacarbazine: 300 mg/m<sup>2</sup>/day IV continuous infusion on days 1-3
- Repeat cycle every 21 days (413).

#### **CYVADIC**

- Cyclophosphamide: 500 mg/m<sup>2</sup> IV on day 1
- Vincristine: 1.5 mg/m<sup>2</sup> IV on day 1 (maximum, 2 mg)
- Doxorubicin: 50 mg/m<sup>2</sup> IV on day 1
- Dacarbazine: 750 mg/m<sup>2</sup> IV on day 1
- Repeat cycle every 21 days (414).

#### **Gemcitabine + Docetaxel**

- Gemcitabine: 900 mg/m<sup>2</sup> IV over 90 minutes on days 1 and 8
- Docetaxel: 100 mg/m<sup>2</sup> IV on day 8
- Repeat cycle every 21 days (415).

#### **Gemcitabine + Navelbine**

- Gemcitabine: 800 mg/m<sup>2</sup> IV over 90 minutes on days 1 and 8

Vinorelbine: 25 mg/m<sup>2</sup> IV on days 1 and 8  
Repeat cycle every 21 days (416).

**CAV Alternating with IE (Ewing's sarcoma)**

Cyclophosphamide: 1,200 mg/m<sup>2</sup> IV on day 1

Doxorubicin: 75 mg/m<sup>2</sup> IV on day 1

Vincristine: 2 mg IV on day 1

and

Ifosfamide: 1,800 mg/m<sup>2</sup> IV on days 1–5

Etoposide: 100 mg/m<sup>2</sup> IV on days 1–5

Alternate CAV with IE every 21 days for a total of 17 cycles (417). When the cumulative dose of doxorubicin reaches 375 mg/m<sup>2</sup>, switch to dactinomycin at 1.25 mg/m<sup>2</sup>.

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Single-Agent Regimens

**Doxorubicin**

Doxorubicin: 75 mg/m<sup>2</sup> IV on day 1

Repeat cycle every 21 days (414).

**Gemcitabine**

Gemcitabine: 1,200 mg/m<sup>2</sup> IV on days 1 and 8

Repeat cycle every 21 days (415).

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## TESTICULAR CANCER

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### Adjuvant Therapy

**PEB**

Cisplatin: 20 mg/m<sup>2</sup> IV on days 1–5

Etoposide: 100 mg/m<sup>2</sup> IV on days 1–5

Bleomycin: 30 U IV on days 2, 9, and 16

Repeat cycle every 28 days for a total of 2 cycles (418). Adjuvant therapy of stage II testicular cancer treated with orchiectomy and retroperitoneal lymph node dissection.

## Advanced Disease

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### **BEP**

Bleomycin: 30 U IV on days 2, 9, and 16  
Etoposide: 100 mg/m<sup>2</sup> IV on days 1–5  
Cisplatin: 20 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 21 days (419).

### **EP**

Etoposide: 100 mg/m<sup>2</sup> IV on days 1–5  
Cisplatin: 20 mg/m<sup>2</sup> IV on days 1–5  
Repeat cycle every 21 days (420).

### **PVB**

Cisplatin: 20 mg/m<sup>2</sup> IV on days 1–5  
Vinblastine: 0.15 mg/kg IV on days 1 and 2  
Bleomycin: 30 units IV on days 2, 9, and 16  
Repeat cycle every 21 days (421).

### **VAB-6**

Vinblastine: 4 mg/m<sup>2</sup> IV on day 1  
Dactinomycin: 1 mg/m<sup>2</sup> IV on day 1  
Bleomycin: 30 U IV on day 1, then 20 U/m<sup>2</sup> continuous infusion on days 1–3  
Cisplatin: 20 mg/m<sup>2</sup> IV on day 4  
Cyclophosphamide: 600 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (422).

### **VeIP (salvage regimen)**

Vinblastine: 0.11 mg/kg IV on days 1 and 2  
Ifosfamide: 1,200 mg/m<sup>2</sup> IV on days 1–5  
Cisplatin: 20 mg/m<sup>2</sup> IV on days 1–5  
Mesna: 400 mg/m<sup>2</sup> IV, given 15 minutes before first ifosfamide dose, then 1,200 mg/m<sup>2</sup>/day IV continuous infusion for 5 days  
Repeat cycle every 21 days (423).

### **VIP (salvage regimen)**

Etoposide (VP-16): 75 mg/m<sup>2</sup> IV on days 1–5

Ifosfamide:	1,200 mg/m <sup>2</sup> IV on days 1–5
Cisplatin:	20 mg/m <sup>2</sup> IV on days 1–5
Mesna:	400 mg/m <sup>2</sup> IV, given 15 minutes before first ifosfamide dose, then 1,200 mg/m <sup>2</sup> /day IV continuous infusion for 5 days

Repeat cycle every 21 days (423).

**TIP (salvage regimen)**

Paclitaxel:	250 mg/m <sup>2</sup> IV over 24 hours on day 1
Ifosfamide:	1,500 mg/m <sup>2</sup> IV on days 2–5
Cisplatin:	25 mg/m <sup>2</sup> IV on days 1–5
Mesna:	500 mg/m <sup>2</sup> IV, given before ifosfamide dose, and at 4 and 8 hours after ifosfamide on days 2–5

Repeat cycle every 21 days for a total of 4 cycles (424). Filgrastim 5 µg/kg SC should be given on days 7–18.

**Paclitaxel + Gemcitabine**

Paclitaxel:	100 mg/m <sup>2</sup> IV on days 1, 8, and 15
Gemcitabine:	1,000 mg/m <sup>2</sup> IV on days 1, 8, and 15

Repeat cycle every 28 days for a total of 6 cycles (425).

## THYMOMA

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**CAP**

Cyclophosphamide:	500 mg/m <sup>2</sup> IV on day 1
Doxorubicin:	50 mg/m <sup>2</sup> IV on day 1
Cisplatin:	50 mg/m <sup>2</sup> IV on day 1

Repeat cycle every 21 days (426).

**Cisplatin + Etoposide**

Cisplatin:	60 mg/m <sup>2</sup> IV on day 1
Etoposide:	120 mg/m <sup>2</sup> IV on days 1–3

Repeat cycle every 21 days (427).

**ADOC**

Cisplatin:	50 mg/m <sup>2</sup> IV on day 1
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Doxorubicin: 40 mg/m<sup>2</sup> IV on day 1  
Vincristine: 0.6 mg/m<sup>2</sup> IV on day 3  
Cyclophosphamide: 700 mg/m<sup>2</sup> IV on day 4  
Repeat cycle every 28 days (428).

## THYROID CANCER

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### Combination Regimens

#### **Doxorubicin + Cisplatin**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Cisplatin: 40 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (429).

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### Single-Agent Regimens

#### **Doxorubicin**

Doxorubicin: 60 mg/m<sup>2</sup> IV on day 1  
Repeat cycle every 21 days (429).

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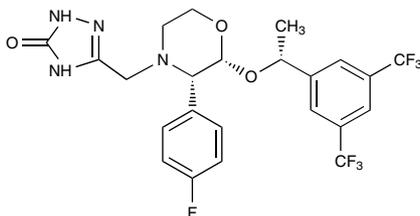
# 5

## *Antiemetic Agents for the Treatment of Chemotherapy-Induced Nausea and Vomiting*

M. Sitki Copur, Laurie J. Harrold, Manuel F. Roasado,  
Edward Chu, and Arthur L. Levy

This chapter presents an overview of the common antiemetic agents as well as selected regimens for the treatment of chemotherapy-induced nausea and vomiting. The specific agents are organized alphabetically, and the various regimens selected are used in clinical practice in the medical oncology community. It should be emphasized that not all of the drugs and dosages in the regimens have been officially approved by the Food and Drug Administration (FDA). This chapter should serve as a quick reference for physicians and healthcare providers and provides several options for treating both acute and delayed nausea and vomiting. It is not intended to be an all-inclusive review of antiemetic agents and treatment regimens, and neither is it intended to endorse and/or prioritize any particular drug or regimen.

# Aprepitant



## Trade Name

Emend

## Classification

Substance P/NK<sub>1</sub> receptor antagonist

## Category

Antiemetic agent

## Drug Manufacturer

Merck

## Mechanism of Action

- Selective high-affinity antagonist of substance P/neurokinin  $\text{I}$  (NK<sub>1</sub>) receptors.
- Inhibits the acute and delayed phases of chemotherapy-induced emesis.
- Little to no affinity for 5-HT<sub>3</sub>, dopamine, or corticosteroid receptors.

## Absorption

Well absorbed by the gastrointestinal (GI) tract, and oral bioavailability is on the order of 60%–65%. Peak plasma levels reached in four hours. Ingestion of food does not alter the extent of absorption.

## Distribution

Crosses the blood-brain barrier and enters the central nervous system (CNS). Greater than 95% of drug is bound to plasma proteins.

A

# A

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## Metabolism

Undergoes extensive metabolism in the liver, principally by the CYP<sub>3A4</sub> liver microsomal system. The main route of elimination of parent drug is via liver metabolism. The parent drug and its metabolites are not renally excreted. The elimination half-life ranges from 9–13 hours.

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## Indications

Prevention of acute and delayed nausea and vomiting associated with highly emetogenic cancer chemotherapy.

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## Dosage Range

Oral: Recommended dose is 125 mg PO given one hour before chemotherapy and 80 mg PO on days two and three after chemotherapy.

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## Special Considerations

1. Use with caution in patients on chronic warfarin anticoagulation. Coagulation parameters, PT/INR, should be closely monitored in the 2-week period, especially at days 7 and 10, following aprepitant therapy.
2. Patients should be advised to report to their physician the use of any non-prescription or herbal medications, as significant drug interactions can occur with aprepitant and other drugs.
3. Well-tolerated in patients with mild to moderate liver dysfunction. Caution should be exercised in patients with severe hepatic insufficiency (Child-Pugh score >9).
4. No dose adjustment is required for patients with renal insufficiency and/or those undergoing hemodialysis.
5. Pregnancy category B. Breast-feeding should be avoided.

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## Toxicity 1

Fatigue is most common side effect. CNS effects include headache and insomnia.

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## Toxicity 2

GI side effects include constipation and/or diarrhea.

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## Toxicity 3

Hiccups observed in 10% of patients.

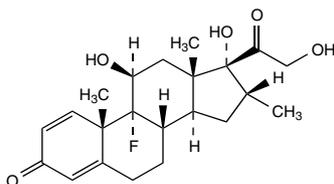
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## Toxicity 4

Anorexia.

# Dexamethasone

D



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## Trade Name

Decadron

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## Classification

Glucocorticoid steroid

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## Category

Antiemetic agent

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## Drug Manufacturer

Merck

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## Mechanism of Action

- Precise mechanism of action in preventing and/or treating chemotherapy-induced nausea and vomiting is not known.
- Suppresses prostaglandin release from hypothalamus, which may then inhibit the subsequent process of nausea and vomiting.
- Possesses anti-inflammatory and immunosuppressive effects with minimal mineralocorticoid properties.

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## Absorption

Well absorbed by the GI tract, and oral bioavailability is on the order of 60%–70%. Peak plasma levels are observed in 1–2 hours after doses of 0.5–3.0 mg and are independent of the route of administration.

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## Distribution

Dexamethasone binds corticosteroid-binding globulin and corticosteroid-binding albumin to significantly less extent than does hydrocortisone.

# D

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## Metabolism

Metabolism occurs primarily in the liver, and about 20% of the drug is conjugated to the glucuronide metabolite. The main route of elimination is through renal excretion with biliary excretion playing a minor role. The elimination half-life is 3–4 hours.

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## Indications

Treatment of nausea and vomiting associated with cancer chemotherapy in combination with other antiemetics, including serotonin (5-HT<sub>3</sub>) receptor antagonists, metoclopramide, and lorazepam.

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## Dosage Range

1. The optimum dosage of dexamethasone for the prevention and/or treatment of cancer chemotherapy-induced nausea and vomiting has not been established.
2. Oral: Recommended dose is 4 mg PO every 4–6 hours for four doses with first dose given 1–6 hours before chemotherapy.
3. Intravenous (IV): Recommended dose is 10–20 mg IV before chemotherapy and then 10–20 mg IV every 4–6 hours.

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## Special Considerations

1. Contraindicated in patients with an underlying psychiatric disorder, including psychosis and depression.
2. Efficacy of dexamethasone may be decreased when used in the presence of drugs that induce the liver microsomal P<sub>450</sub> system, including phenytoin, phenobarbital, and carbamazepine. In this setting, the dose of drug may need to be increased.
3. Use with caution in patients with liver impairment and/or hypothyroidism as increased drug effects may be observed.
4. Patients should be cautioned about possible neuropsychiatric side effects, including mood changes, euphoria, depression, insomnia, and in extreme cases, psychosis.

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## Toxicity 1

Electrolyte abnormalities with hypokalemia and hyperglycemia.

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## Toxicity 2

Fluid retention, leg edema, hypertension, and rarely, exacerbation of congestive heart failure (CHF).

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**Toxicity 3**

Neuropsychiatric effects, including mood changes, euphoria, headache, insomnia, depression, and psychosis.

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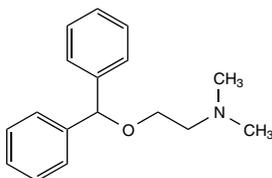
**Toxicity 4**

Increased white blood count (WBC) secondary to demargination.

D

# D

## Diphenhydramine



### Name

Benadryl

### Classification

Antihistamine

### Category

Antiemetic agent

### Manufacturer

Parke-Davis

### Mechanism of Action

- Antihistamine with anticholinergic and sedative effects. Competes with histamine for receptor sites on effector cells.
- Blocks the chemoreceptor trigger zone and decreases vestibular stimulation.

### Absorption

Well absorbed by the GI tract, and oral bioavailability is on the order of 40%–60%. Peak plasma levels reached in 1–4 hours.

### Distribution

Widely distributed throughout the body, including the CNS. Crosses the placenta and is excreted in breast milk. About 80%–85% of drug is bound to plasma proteins.

### Metabolism

Metabolism occurs in the liver, principally to diphenylmethoxyacetic, which may then undergo conjugation. The main route of elimination of parent drug and its metabolites is through renal excretion. The elimination half-life ranges from 2.5–9 hours.

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### Indications

1. Prevention of nausea and vomiting associated with cancer chemotherapy in combination with other antiemetics, including 5-HT<sub>3</sub> receptor antagonists, metoclopramide, and lorazepam.
2. Active treatment of motion sickness.
3. Prevention and/or treatment of allergic, hypersensitivity reactions.
4. Temporary relief of cough caused by minor irritation of upper airways.
5. Treatment of parkinsonism.

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### Dosage Range

1. Oral: Recommended dose is 25–50 mg PO before chemotherapy and then every 4–6 hours thereafter.
2. IV: Recommended dose is 25–50 mg IV before chemotherapy.

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### Special Considerations

1. Use with caution in patients with a history of increased intraocular pressure, narrow-angle glaucoma, bladder-neck obstruction, bronchial asthma, cardiovascular disease, and/or hypertension.
2. Use with caution in elderly patients as they are more likely to exhibit altered sensorium with drowsiness and confusion.
3. Patients should be advised against performing activities that require mental alertness, including operating heavy machinery and driving.
4. Useful to treat and/or prevent extrapyramidal side effects related to antiemetic therapy.
5. Pregnancy category B. Breast-feeding should be avoided.

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### Toxicity 1

CNS effects are most commonly observed with sedation, drowsiness, dizziness, and confusion. Alterations in coordination, irritability, and insomnia.

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### Toxicity 2

Dryness of mucous membranes, including mouth, nose, and throat.

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### Toxicity 3

Hypotension, palpitations, and tachycardia.

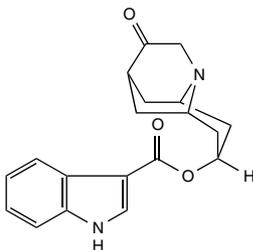
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### Toxicity 4

Anorexia.

# D

## Dolasetron



### Trade Name

Anzemet

### Classification

5-HT<sub>3</sub> receptor antagonist

### Category

Antiemetic agent

### Drug Manufacturer

Aventis

### Mechanism of Action

- Competitive, highly selective antagonist of type 3, 5-HT<sub>3</sub> receptors.
- 5-HT<sub>3</sub> receptors are present centrally, in the chemoreceptor trigger zone of the area postrema of brain, and peripherally, on vagal nerve terminals. Antiemetic action of dolasetron may be mediated centrally, peripherally, or at both sites.
- Does not have direct dopamine-receptor antagonist activity.
- Effective in acute nausea and vomiting but plays only a limited role in delayed emesis.

### Absorption

Well absorbed by the GI tract. Oral bioavailability is approximately 75%. Food does not affect oral absorption.

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### Distribution

Widely distributed in the body. Approximately 70%–80% of drug is bound to plasma proteins.

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### Metabolism

Parent drug is rarely detected in plasma due to rapid and complete metabolism to hydrodolasetron, which is further metabolized in the liver, the cytochrome P450 microsomal system. Main routes of metabolism include hydroxylation and glucuronidation. Hydrodolasetron is eliminated by both renal and hepatic excretion, with about 60% of an administered dose recovered in the urine and 30% in the feces. The mean elimination half-life in adult cancer patients is approximately eight hours.

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### Indications

1. Prevention of nausea and vomiting associated with initial and repeat courses of moderately emetogenic cancer chemotherapy.
  2. Prevention of postoperative nausea and vomiting.
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### Dosage Range

1. Oral: Recommended dose is 100 mg PO once daily given one hour before chemotherapy.
  2. Prevention of postoperative nausea and vomiting: 100 mg PO within two hours before surgery.
  3. IV: Recommended dose is 1.8 mg/kg IV as a single dose administered 30 minutes before chemotherapy. As an alternative, a fixed dose of 100 mg IV can be administered 30 minutes before chemotherapy.
- 

### Special Considerations

1. No dose adjustment is required in elderly patients or in those with hepatic and/or renal impairment.
  2. Use with caution in patients who have or may develop cardiac conduction abnormalities, including those with prolonged PR and QT intervals. Baseline electrocardiograms should be performed before administration of dolasetron and chemotherapy.
  3. Use with caution in patients who are receiving antiarrhythmic agents or other drugs that can prolong the PR, QRS, and QT intervals.
  4. Careful monitoring of electrolytes, including potassium and magnesium, is required to reduce the occurrence of arrhythmias.
  5. Pregnancy category B. Breast-feeding should be avoided.
- 

### Toxicity 1

Headache is most common side effect (18%–25%).

# D

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## Toxicity 2

Diarrhea and/or abdominal pain.

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## Toxicity 3

Fever, fatigue, and dizziness.

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## Toxicity 4

Hypotension, chest pain, orthostatic hypotension, syncope, bradycardia and Mobitz I atrioventricular (AV) block, and atrial arrhythmias, including atrial flutter and atrial fibrillation.

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## Toxicity 5

Agitation, sleep disorder, confusion, depersonalization, anxiety, and abnormal dreams.

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## Toxicity 6

Transient elevations in liver function tests (LFTs). Usually clinically asymptomatic.

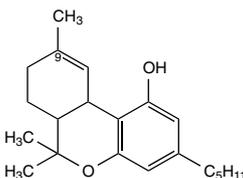
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## Toxicity 7

Hypersensitivity reactions with dyspnea, skin rash, urticaria, bronchospasm, and hypotension have been reported in rare instances.

# Dronabinol

D



## Name

Marinol

## Classification

Cannabinoid

## Category

Antiemetic agent

## Manufacturer

Roxane and Unimed

## Mechanism of Action

- Precise mechanism of action in preventing and/or treating cancer chemotherapy-induced nausea and vomiting is not known.
- Complex effects on the CNS with central sympathomimetic activity.
- Binding to cannabinoid receptors in CNS may contribute to its antiemetic effect.
- Inhibition of vomiting control mechanism in the medulla oblongata.

## Absorption

Nearly completely absorbed (90%–95%) by the GI tract. Onset of action occurs within 0.5–1 hours after ingestion. Peak plasma levels are observed in 2–4 hours with 3–6 hours duration of action.

## Distribution

Because of extensive first-pass metabolism in the liver, only 10% of an administered dose reaches the systemic circulation. Highly bound to plasma proteins (97%).

# D

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## Metabolism

Undergoes extensive first-pass metabolism in the liver microsomal system. Both active and inactive metabolites are formed. The main active metabolite is 11-hydroxy-delta tetrahydrocannabinol (THC). Dronabinol and the 11-hydroxy metabolite are present in nearly equal concentrations in plasma. The main route of elimination is via biliary excretion. The elimination half-life of the parent drug is 25–36 hours, while that of the 11-hydroxy metabolite is 15–18 hours.

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## Indications

1. Treatment of nausea and vomiting associated with cancer chemotherapy in patients who have failed to respond to conventional antiemetic agents.
2. Stimulates appetite and prevents weight loss in patients with AIDS.

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## Dosage Range

Recommended dose is 5–15 mg/m<sup>2</sup> PO 1–3 hours before chemotherapy and then every 4–6 hours PO thereafter.

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## Special Considerations

1. Use with caution in elderly patients due to an increased risk of neuropsychoactive effects.
2. Use with caution in patients with a history of alcohol and/or substance abuse.
3. Prescriptions should be limited to only one course of chemotherapy.
4. Use with caution in patients with underlying psychiatric disorders, including mania, depression, or schizophrenia.
5. Patients should be cautioned about possible neuropsychiatric side effects, including mood changes, euphoria, depression, insomnia, and in extreme cases, psychosis.
6. Pregnancy category C.

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## Toxicity 1

Mood changes, drowsiness, confusion, and dizziness. Impairment in perception, coordination, and sensory function. Visual distortions, nightmares, hallucinations, and depersonalization are also observed.

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## Toxicity 2

Orthostatic hypotension, tachycardia, facial flush, conjunctival injection, and palpitations.

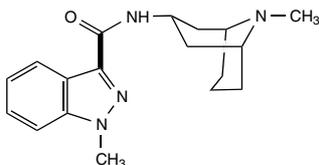
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## Toxicity 3

Dry mouth, abdominal pain, and diarrhea occur in less than 10% of patients.

# Granisetron

G



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## Trade Name

Kytril

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## Classification

5-HT<sub>3</sub> receptor antagonist

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## Category

Antiemetic agent

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## Drug Manufacturer

Roche

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## Mechanism of Action

- Competitive, highly selective antagonist of type 3, 5-HT receptors.
- 5-HT<sub>3</sub> receptors are present centrally, in the chemoreceptor trigger zone of the area postrema of brain, and peripherally, on vagal nerve terminals. Antiemetic action of granisetron may be mediated centrally, peripherally, or at both sites.
- Does not have direct dopamine-receptor antagonist activity.
- Effective in preventing acute chemotherapy-induced nausea and vomiting.

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## Absorption

Well absorbed by the GI tract. Bioavailability is 60%. Absorption is decreased in the presence of food (AUC decreased by 5%; C<sub>max</sub> increased by 30%).

---

## Distribution

Distributes freely between plasma and red blood cells. Approximately 65% of drug is bound by plasma proteins.

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## Metabolism

Undergoes extensive metabolism in the liver by the cytochrome P450 microsomal system. Main routes of metabolism include N-demethylation and oxidation followed by conjugation. Some of the metabolites may have 5-HT<sub>3</sub> antagonist activity. About 11% of an administered dose is recovered as the parent compound in the urine. The mean elimination half-life in adult cancer patients ranges from 2.94 to 6.23 hours.

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## Indications

1. Prevention of nausea and vomiting associated with initial and repeat courses of emetogenic cancer chemotherapy, including high-dose cisplatin.
2. Prevention of nausea and vomiting associated with radiation, including total body irradiation and fractionated abdominal radiation. (Oral solution and tablets only.)
3. Prevention of PONV (injection only).

---

## Dosage Range

1. Oral: Recommended dose is 2 mg PO once daily given one hour before chemotherapy. An alternative regimen is 1 mg PO bid with the first one mg dose given one hour before chemotherapy and the second dose given twelve hours after the first dose.
2. For the prevention of radiotherapy-induced nausea and vomiting, 2 mg PO once daily (oral) to be taken within one hour of radiation therapy.
3. IV: Recommended dose is 10 µg/kg IV administered 30 minutes before chemotherapy, only on days of chemotherapy.
4. IV: Recommended dose for prevention of PONV is 1 mg IV, administered over 30 seconds, before induction of anesthesia or immediately before reversal of anesthesia.

---

## Special Considerations

1. No dose adjustment is required in elderly patients or in those with hepatic and/or renal impairment.
2. There appears to be little difference in clinical efficacy between oral dosing of 1 mg bid or a single daily dose of 2 mg.
3. Granisetron is especially effective when combined with dexamethasone in treating cisplatin-associated nausea and vomiting.
4. Granisetron does not induce or inhibit the liver microsomal P450 system.

5. Granisetron can be administered by IV in pediatric patients ages 2–16.
6. Pregnancy category B. It is not known whether granisetron is excreted in human milk. Caution should be exercised when granisetron is administered to a nursing woman.

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**Toxicity 1**

Headache is the most common side effect (15%–20%).

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**Toxicity 2**

Constipation, diarrhea, and/or abdominal pain.

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**Toxicity 3**

Asthenia.

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**Toxicity 4**

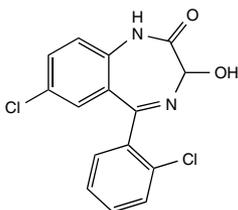
Transient elevations in LFTs. Usually clinically asymptomatic.

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**Toxicity 5**

Hypersensitivity reactions with dyspnea, skin rash, urticaria, bronchospasm, and hypotension have been reported in rare instances.

# Lorazepam



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## Name

Ativan

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## Classification

Benzodiazepine

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## Category

Antiemetic agent

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## Manufacturer

Elkins-Sinn and Watson

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## Mechanism of Action

- Interacts with the  $\gamma$ -aminobutyric acid (GABA)-benzodiazepine receptor complex, which is widely expressed in the brain.
- Exhibits relatively high affinity for GABA recognition site and enhances the binding affinity of GABA for its receptor site on the same receptor complex.
- Intensity of action, including antianxiety effects, sedation, and reduction of seizure activity, appears to be directly related to the occupancy status of the receptor.

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## Absorption

Well absorbed by the GI tract with an oral bioavailability of nearly 90%. Peak concentrations in plasma occur approximately two hours following oral or intramuscular (IM) administration. Absorption after IM injection is rapid and complete.

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## Distribution

Widely distributed in body tissues and crosses the blood-brain barrier. Lorazepam and its metabolites cross the placenta and are distributed into milk. Approximately 90% of parent drug and its metabolites are bound to plasma proteins.

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### Metabolism

Undergoes extensive conjugation in the liver to the glucuronide metabolite, which is then excreted mainly into the urine. The mean half-lives of unconjugated lorazepam and its major metabolite, lorazepam glucuronide, are 12 and 18 hours, respectively.

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### Indications

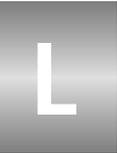
1. Management of nausea and vomiting associated with emetogenic cancer chemotherapy either alone or in combination with other drugs, such as 5-HT<sub>3</sub> receptor antagonists and/or corticosteroids.
  2. Management of anxiety disorders and acute relief of symptoms of anxiety and/or anxiety associated with depressive symptoms.
  3. Management of preoperative anxiety.
  4. Management of status epilepticus.
- 

### Dosage Range

1. Dosage of lorazepam must be individualized, and the smallest effective dose should be used, especially in those with low serum albumin.
  2. Recommended oral dose as an antiemetic agent is 2.5 mg of lorazepam PO on the evening before and just after initiation of chemotherapy.
  3. Recommended IV dose is 1.5 mg/m<sup>2</sup> (maximum, 3 mg) IV administered 45 minutes before the initiation of chemotherapy.
- 

### Special Considerations

1. Contraindicated in patients with known hypersensitivity to benzodiazepines or any ingredients in the formulation.
2. Contraindicated in patients with acute angle-closure glaucoma.
3. Use with caution in geriatric patients, debilitated patients, and patients with underlying pulmonary disease.
4. Use with caution in patients with liver impairment.
5. Patients should be warned about the possibility of impaired ability to perform activities that require mental alertness or physical coordination, including operating machinery and driving.
6. Pregnancy category D.



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**Toxicity 1**

Sedation, depression, headache, sleep disturbance, dizziness, weakness, and unsteadiness are most commonly observed.

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**Toxicity 2**

Changes in appetite, nausea, and GI symptoms may occur infrequently.

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**Toxicity 3**

Reduction in blood pressure without clinical significance.

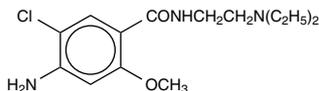
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**Toxicity 4**

Transient amnesia or memory impairment.

# Metoclopramide

M



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## Trade Name

Reglan

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## Classification

Substituted benzamide

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## Category

Antiemetic agent

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## Drug Manufacturer

Baxter and Geneva

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## Mechanism of Action

- Precise mechanism of antiemetic action is unclear.
- Acts centrally by directly blocking the dopamine receptors in the chemoreceptor trigger zone of the area postrema of brain.
- Acts peripherally to enhance the action of acetylcholine at muscarinic synapses.
- Stimulates GI motility through increasing gastric emptying via cholinergic excitatory processes.
- Inhibits 5-HT<sub>3</sub> receptors at high doses.

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## Absorption

Rapidly and completely absorbed by the GI tract. Peak plasma levels occur 1–2 hours after an oral dose.

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## Distribution

Extensively distributed to body tissues and crosses the blood-brain barrier. Distributes into the placenta and found in breast milk. Approximately 30% of drug is bound by plasma proteins.

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## Metabolism

Precise metabolism of drug has not been clearly established. Main routes of metabolism involve conjugation with glucuronic acid and sulfuric acid.

# M

Primary route of elimination is through the kidneys. About 85% of an administered dose is recovered as the parent compound and metabolites in the urine. Only 5% is eliminated via biliary excretion. The mean elimination half-life in adult cancer patients is approximately 5–6 hours.

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## Indications

1. Prevention and/or treatment of nausea and vomiting associated with cancer chemotherapy.
2. Prevention of postoperative nausea and vomiting.
3. Treatment of GI motility disorders, diabetic gastroparesis, and/or gastroesophageal reflux.

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## Dosage Range

1. Oral: Recommended dose is 20–40 mg PO every 4–6 hours as needed.
2. IV: Recommended dose is 1–2 mg/kg IV administered 30 minutes before chemotherapy and repeated every 4–6 hours as needed.

---

## Special Considerations

1. Contraindicated in patients with pheochromocytoma as it may induce a hypertensive crisis.
2. Contraindicated in patients with seizure disorders because the frequency and severity of seizures may be increased.
3. Use with caution in patients with renal impairment. Dose adjustment is required in patients with decreased renal function.
4. Use with caution in patients with Parkinson's disease as symptoms may be worsened with metoclopramide.
5. Extrapyramidal symptoms typically occur within 24–48 hours of metoclopramide treatment. Most commonly seen with high-dose therapy and in pediatric patients and young adults. Diphenhydramine 50 mg IV or IM can provide immediate relief.
6. Use with caution in patients with a history of mental depression and/or suicidal tendencies as exacerbation or worsening of underlying depression may occur.
7. Pregnancy category B. Breast-feeding should be avoided.

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## Toxicity 1

Headache, fatigue, drowsiness, restlessness, and insomnia are the most common side effects (10%–15%).

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## Toxicity 2

Diarrhea and/or abdominal pain.

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**Toxicity 3**

Dry mouth.

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**Toxicity 4**

Hypersensitivity reactions with dyspnea, skin rash, urticaria, bronchospasm, and hypotension.

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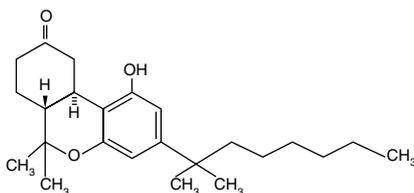
**Toxicity 5**

Extrapyramidal reactions with motor restlessness, tremor, akathisia, dystonia, and tardive dyskinesia.

M

## N

# Nabilone

**Name**

Cesamet

**Classification**

Cannabinoid

**Category**

Antiemetic agent

**Manufacturer**

Valeant Pharmaceuticals

**Mechanism of Action**

- Precise mechanism of action in preventing and/or treating cancer chemotherapy-induced nausea and vomiting is not known.
- Complex effects on the CNS with central sympathomimetic activity.
- Binding to cannabinoid receptors in CNS may contribute to its antiemetic effect.

**Absorption**

Nearly completely absorbed by the GI tract. Peak plasma levels are observed in 2 hours of ingestion. Food does not affect the rate or extent of absorption.

**Distribution**

Highly bound to plasma proteins (97%).

**Metabolism**

Undergoes extensive metabolism in the liver microsomal system. Precise information relating to the relative activities of the metabolites and parent drug has not been established. The main route of elimination is via biliary excretion, with approximately 60% of nabilone and its metabolites being

recovered in stool and approximately 24% being recovered in urine. The elimination half-life of the parent drug is 2 hours, whereas that of the metabolites is up to 35 hours.

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### Indications

1. Treatment of nausea and vomiting associated with cancer chemotherapy in patients who have failed to respond to conventional antiemetic agents.
2. Should not be used as the first antiemetic agent used for a patient.

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### Dosage Range

Recommended dose is 1–2 mg PO daily 1–3 hours before chemotherapy. The maximal daily dose is 6 mg given in divided doses two to three times a day during the entire course of chemotherapy.

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### Special Considerations

1. Use with caution in older patients and in those with hypertension or heart disease, as there is an increased risk of postural hypotension.
2. Use with caution in patients with a history of alcohol and/or substance abuse.
3. Use with caution in patients with underlying hepatic and/or renal dysfunction, as the safety aspects of this agent have not been investigated in these patient populations.
4. Use with caution in patients with underlying psychiatric disorders, including mania, depression, or schizophrenia.
5. Patients should be cautioned about possible neuropsychiatric side effects, including mood changes, euphoria, depression, insomnia, and in extreme cases, psychosis.
6. Patients should be warned not to drive, operate machinery, or engage in any type of hazardous activity while on treatment.
7. Pregnancy category C.

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### Toxicity 1

Mood changes, drowsiness, confusion, and vertigo. Impairment in perception, coordination, and sensory function. Visual distortions, nightmares, hallucinations, and depersonalization are also observed.

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### Toxicity 2

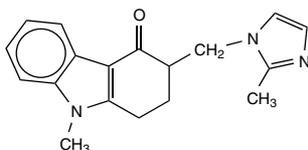
Orthostatic hypotension, tachycardia, facial flush, and palpitations.

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### Toxicity 3

Dry mouth, anorexia, and nausea/vomiting.

# Ondansetron



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## Name

Zofran

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## Classification

5-HT<sub>3</sub> receptor antagonist

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## Category

Antiemetic agent

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## Manufacturer

GlaxoSmithKline

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## Mechanism of Action

- Competitive, highly selective antagonist of type 3, 5-HT<sub>3</sub> receptors.
- 5-HT<sub>3</sub> receptors are present centrally, in the chemoreceptor trigger zone of the area postrema of brain, and peripherally, on vagal nerve terminals. Antiemetic action of ondansetron may be mediated centrally, peripherally, or at both sites.
- Does not have direct dopamine-receptor antagonist activity.
- Effective in acute nausea and vomiting but plays only a limited role in delayed emesis.

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## Absorption

Well absorbed by the GI tract. Mean bioavailability in healthy subjects from 48% to 75%.

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## Distribution

Nearly 40% of circulating drug is distributed in red blood cells.

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## Metabolism

Undergoes extensive metabolism in the liver by the cytochrome P450 microsomal system. The main metabolic pathway is hydroxylation followed by glucuronide or sulfate conjugation. Less than 5% of an administered

dose is recovered as the parent compound in the urine. The mean elimination half-life in adult cancer patients is 4 hours.

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### Indications

1. Treatment of nausea and vomiting associated with moderately or highly emetogenic cancer chemotherapy.
2. Prevention and/or management of postoperative nausea and vomiting.
3. Prevention of nausea and vomiting associated with radiotherapy in patients receiving total body irradiation or single high-dose fraction or daily fractions to the abdomen.

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### Dosage Range

1. Oral: Recommended dose is 8 mg PO bid with the first dose given 30 minutes before chemotherapy. Continue for 1–2 days after chemotherapy is completed.
2. For the prevention of radiotherapy-induced nausea and vomiting, 8 mg PO to be taken 1–2 hours before radiotherapy and then 8 mg PO every eight hours post radiotherapy.
3. IV: Recommended dose is a single 32 mg IV dose administered 30 minutes before chemotherapy or 0.15 mg/kg IV every four hours for three doses given 30 minutes before chemotherapy.

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### Special Considerations

1. Use with caution in patients with severe hepatic impairment as the clearance of ondansetron is decreased, resulting in an increased plasma half-life. Dose modification is warranted in such patients, and the total daily dose should not exceed 8 mg.
2. Ondansetron may, on rare occasions, cause hypersensitivity reactions. Patients should be warned of this possibility and be advised to contact their physician at the first sign of a skin rash or any other sign of hypersensitivity.
3. Use with caution in elderly patients, especially patients older than 75 years of age, as the plasma clearance may be decreased, resulting in increased drug levels.
4. Patients with phenylketonuria should be informed that oral tablets of ondansetron contain aspartame, which is metabolized in the GI tract to phenylalanine.
5. Pregnancy category B. Breast-feeding should be avoided.

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**Toxicity 1**

Fever, headache, malaise, and fatigue occur in 10% of patients.

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**Toxicity 2**

Constipation, diarrhea, and/or abdominal pain.

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**Toxicity 3**

Transient elevations in LFTs. Usually clinically asymptomatic.

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**Toxicity 4**

Local reaction at site of injection with pain, redness, and burning.

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**Toxicity 5**

Hypersensitivity reactions with dyspnea, skin rash, urticaria, bronchospasm, and hypotension have been reported in rare instances.

# Palonosetron

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## Trade Name

Aloxi

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## Classification

5-HT<sub>3</sub> receptor antagonist

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## Category

Antiemetic agent

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## Drug Manufacturer

MGI Pharma

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## Mechanism of Action

- Competitive, highly selective antagonist of type 3, 5-HT<sub>3</sub> receptors.
- 5-HT<sub>3</sub> receptors are present centrally, in the chemoreceptor trigger zone of the area postrema of brain, and peripherally, on vagal nerve terminals. Antiemetic action of palonosetron may be mediated centrally, peripherally, or at both sites.
- Does not have direct dopamine-receptor antagonist activity.
- Effective in both acute and delayed nausea and vomiting.

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## Absorption

Not available for oral use and is administered only via the parenteral route.

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## Distribution

Nearly 60% of circulating drug is bound to plasma proteins.

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## Metabolism

Undergoes metabolism by multiple routes with about 50% of parent drug metabolized to two main metabolites, N-oxide-palonosetron and 6-S-hydroxy-palonosetron. Each of these metabolites has less than 1% of the 5-HT<sub>3</sub> receptor antagonist activity of the parent compound. In vitro studies show that CYP2D6 is the main liver microsomal enzyme involved in palonosetron metabolism. The mean elimination half-life in adult cancer patients is 40 hours.

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## Indications

1. Prevention of acute nausea and vomiting associated with initial and repeat courses of moderately or highly emetogenic cancer chemotherapy.
2. Prevention of delayed nausea and vomiting associated with initial and repeat courses of moderately emetogenic cancer chemotherapy.

P

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### Dosage Range

IV: Recommended dose is a single 0.25 mg IV dose administered 30 minutes before chemotherapy. Repeat dosing of drug within a 7 day interval is not recommended as the safety and efficacy of consecutive and/or alternate dosing in patients has not been evaluated.

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### Special Considerations

1. Use with caution in patients who have or may develop prolongation of cardiac conduction intervals, especially QTc. These include patients with hypokalemia or hypomagnesemia, patients taking diuretics with potential for inducing electrolyte abnormalities, patients with QT syndrome, patients taking anti-arrhythmic drugs or other drugs which lead to QT prolongation, and cumulative high dose anthracycline therapy.
2. Palonosetron may cause hypersensitivity reactions as have been observed with other 5-HT<sub>3</sub> receptor antagonists. Patients should be warned of this possibility and be advised to contact their physician at the first sign of a skin rash or any other sign of hypersensitivity.
3. Dose reduction is not required in patients with impaired liver and/or renal dysfunction.
4. Pregnancy category B. Breast-feeding should be avoided.

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### Toxicity 1

Headache occurs in 10% of patients.

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### Toxicity 2

Constipation, diarrhea, and/or abdominal pain.

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### Toxicity 3

Transient elevations in LFTs. Usually clinically asymptomatic.

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### Toxicity 4

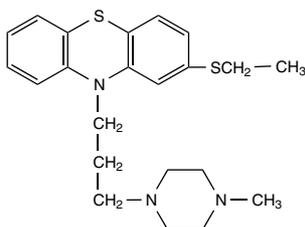
Somnolence, dizziness, insomnia, and fatigue. Anxiety and euphoric have also been observed.

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### Toxicity 5

Hypersensitivity reactions have been reported in rare instances.

## Prochlorperazine



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### Trade Name

Compazine

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### Classification

Phenothiazine

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### Category

Antiemetic agent

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### Drug Manufacturer

GlaxoSmithKline

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### Mechanism of Action

- Precise mechanism of antiemetic action is unclear.
- Blocks dopamine receptors in the chemoreceptor trigger zone.
- Inhibits vagal stimulation of the vomiting center by peripheral afferents.

---

### Absorption

Following oral administration of tablet form, onset of action is 30–40 minutes with 3–4 hours duration of action. Oral extended-release formulation prolongs duration of action up to 10–12 hours. Rectal suppository form has a 60-minute onset of action with 3–4 hours of duration. IM route has a 10–20 minutes onset of action and lasts for up to 12 hours.

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### Distribution

Large volume of distribution. Drug crosses the placenta and is excreted in breast milk.

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### Metabolism

Metabolism occurs in the liver with excretion mainly in the kidneys. Terminal elimination half-life is 7–8 hours.

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### Indications

1. Control of nausea and vomiting of various etiologies.
  2. Management of the manifestations of psychotic disorders.
  3. Acute treatment of generalized nonpsychotic anxiety.
- 

### Dosage Range

1. Oral: Recommended dose is 10 mg PO every 4–6 hours. For the slow-release form, dose ranges from 10 to 30 mg PO every 12 hours.
  2. Rectal: Recommended dose is 25 mg per rectum (PR) every 12 hours.
  3. IM: Recommended dose is 10–25 mg IM every 4–6 hours.
  4. IV: Recommended dose is 10–25 mg IV every 4–6 hours.
- 

### Special Considerations

1. Contraindicated in patients with known hypersensitivity to phenothiazines.
  2. Use with caution in patients who are receiving CNS depressants.
  3. Use with caution in elderly patients.
  4. Use with caution in patients with glaucoma.
  5. Patients should be advised to avoid heat exposure as prochlorperazine may interfere with thermoregulatory mechanisms.
  6. Use with caution in patients under the age of 35 years as there is an increased risk of dystonic reactions.
  7. Patients should be advised to avoid sun exposure to prevent photosensitivity reactions.
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### Toxicity 1

Drowsiness, sedation, insomnia, dizziness, and blurred vision.

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### Toxicity 2

Extrapyramidal reactions in the form of motor restlessness, tremor, akathisia, dystonia, pseudoparkinsonism, and tardive dyskinesia.

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### Toxicity 3

Dry mouth, constipation.

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**Toxicity 4**

Orthostatic hypotension.

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**Toxicity 5**

Mild photosensitivity, skin rash, and urticaria.

P

## COMMON ANTIEMETIC REGIMENS CHEMOTHERAPY-INDUCED NAUSEA AND VOMITING:

### Mildly Emetogenic Chemotherapy (Levels 1 and 2):

1. Prochlorperazine 10–25 mg PO, 5–25 IV, or 25 mg PR before chemotherapy and then 10–25 mg PO every 4–6 hours as needed.
2. Thiethylperazine 10 mg PO, 10 mg IM, or 10 mg PR every 4–6 hours as needed.
3. Ondansetron 8 mg PO bid with the first dose 30 minutes before the start of chemotherapy and a subsequent dose eight hours after the first dose or 32 mg IV.
4. Dexamethasone 4–8 mg PO or 10–20 mg IV.
5. Prochlorperazine 10–25 mg PO, 5–25 mg IV, or 25 mg PR before chemotherapy and then 10–25 mg PO every six hours as needed; dexamethasone 4 mg PO or 10–20 mg IV before chemotherapy and continue with 4 mg PO every six hours up to a total of four doses as needed.
6. Prochlorperazine 10–25 mg PO, 5–25 mg IV, or 25 mg PR before chemotherapy and then 10–25 mg PO every six hours as needed; dexamethasone 4 mg PO or 10–20 mg IV before chemotherapy and continue with 4 mg PO every six hours up to a total of four doses as needed; and lorazepam 1.5 mg/m<sup>2</sup> IV administered 45 minutes before chemotherapy.
7. Metoclopramide 20–40 mg PO and diphenhydramine 25–50 mg PO every 4–6 hours as needed.
8. Metoclopramide 1–2 mg/kg IV and diphenhydramine 25–50 mg IV every 4–6 hours as needed.

### Moderately Emetogenic Chemotherapy (Level 3):

1. Ondansetron 32 mg IV and dexamethasone 4–8 mg PO or 10–20 mg IV given 30 minutes before chemotherapy. In the next 1–2 mornings, give ondansetron 16 mg PO and dexamethasone 8 mg PO along with prochlorperazine 10 mg PO every six hours as needed.
2. Dolasetron 100 mg PO or IV and dexamethasone 8 mg IV 30 minutes before chemotherapy. In the next 1–2 mornings, give dolasetron 100 mg PO and dexamethasone 8 mg PO along with prochlorperazine 10 mg PO every six hours as needed.
3. Granisetron 1–2 mg PO one hour before chemotherapy or 1 mg or 10 µg/kg IV and dexamethasone 8 mg IV 30 minutes before chemotherapy. In the next 1–2 mornings, give granisetron 1 mg PO

and dexamethasone 8 mg PO along with prochlorperazine 10 mg PO every six hours as needed.

4. Aprepitant 125 mg PO taken 60 minutes before chemotherapy; dexamethasone 12 mg PO and ondansetron 32 mg IV given 30 minutes before chemotherapy.
5. Aprepitant 125 mg PO taken 60 minutes before chemotherapy; dexamethasone 12 mg PO and granisetron 1–2 mg PO or 10 µg/kg IV given 30 minutes before chemotherapy.
6. Dexamethasone 4–8 mg PO or 10–20 mg IV for one dose before chemotherapy; lorazepam 1.5 mg/m<sup>2</sup> IV before chemotherapy; and prochlorperazine 5–25 mg PO or IV before chemotherapy.
7. Palonosetron 0.25 mg IV given 30 minutes before chemotherapy.
8. Palonosetron 0.25 mg IV given 30 minutes before chemotherapy; aprepitant 125 mg PO taken 60 minutes before chemotherapy on day 1, and 80 mg PO on days 2–3; dexamethasone 12 mg PO taken 30 minutes before chemotherapy on day 1, and 8 mg PO on days 2–3.

### Highly Emetogenic Chemotherapy (Levels 4 and 5):

1. Ondansetron 32 mg IV and dexamethasone 10–20 mg IV plus lorazepam 1 mg PO or IV given 30 minutes before chemotherapy and then every six hours as needed. Ondansetron 16 mg PO and dexamethasone 8 mg PO in the next 2–3 mornings along with prochlorperazine 10 mg PO every six hours as needed.
2. Dolasetron 100 mg IV and dexamethasone 10–20 mg IV 30 minutes before chemotherapy or the same doses given orally one hour before chemotherapy. Dolasetron 100 mg PO and dexamethasone 8 mg PO in the next 2–3 mornings along with prochlorperazine 10 mg PO every six hours as needed.
3. Dolasetron 200 mg PO and dexamethasone 20 mg PO 30 minutes before chemotherapy.
4. Granisetron 1–2 mg or 10 µg/kg IV and dexamethasone 10–20 mg IV 30 minutes before chemotherapy. Granisetron 1 mg PO and dexamethasone 8 mg PO in the next 2–3 mornings along with prochlorperazine 10 mg PO every six hours as needed.
5. Aprepitant 125 mg PO taken 60 minutes before chemotherapy; dexamethasone 12 mg PO and ondansetron 32 mg IV given 30 minutes before chemotherapy.
6. Aprepitant 125 mg PO taken 60 minutes before chemotherapy; dexamethasone 12 mg PO and granisetron 1–2 mg PO or 10 µg/kg IV given 30 minutes before chemotherapy.

7. Metoclopramide 2–3 mg/kg IV, dexamethasone 10–20 mg IV; and diphenhydramine 25–50 mg IV to be given one hour before chemotherapy or orally at the same doses 30 minutes before chemotherapy. Metoclopramide 20–40 mg PO, dexamethasone 8 mg PO in the next 2–3 mornings along with prochlorperazine 10 mg PO every six hours as needed.
8. Metoclopramide 2–3 mg/kg IV before chemotherapy and then two hours post chemotherapy; dexamethasone 10–20 mg IV; diphenhydramine 25–50 mg IV; and lorazepam 1–2 mg IV.
9. Palonosetron 0.25 mg IV given 30 minutes before chemotherapy.
10. Palonosetron 0.25 mg IV given 30 minutes before chemotherapy; aprepitant 125 mg PO taken 60 minutes before chemotherapy on day 1, and 80 mg PO on days 2–3; dexamethasone 12 mg PO taken 30 minutes before chemotherapy on day 1, and 8 mg PO on days 2–3.

### **COMMON REGIMENS FOR DELAYED AND/OR BREAKTHROUGH NAUSEA AND VOMITING:**

1. Metoclopramide 40 mg PO every 4–6 hours and dexamethasone 4–8 mg PO every 4–6 hours for four days.
2. Metoclopramide 40 mg PO every 4–6 hours; dexamethasone 4–8 mg PO every 4–6 hours; and prochlorperazine 10–25 mg PO every 4–6 hours.
3. Aprepitant 80 mg PO and dexamethasone 8–12 mg PO once daily on days 2 and 3.
4. Aprepitant 80 mg PO daily, dexamethasone 8–12 mg PO daily, and ondansetron 8 mg PO bid on days 2 and 3.
5. Aprepitant 80 mg PO daily, dexamethasone 8–12 mg PO daily, and granisetron 1 mg PO bid on days 2 and 3.
6. Aprepitant 80 mg PO daily, dexamethasone 8–12 mg PO daily, and dolasetron 100 mg PO daily on days 2 and 3.
7. Ondansetron 8 mg PO bid for up to 2–3 days after chemotherapy.
8. Ondansetron (orally dissolving tablets) 8 mg sublingual every eight hours as needed.
9. Metoclopramide 20–40 mg PO and diphenhydramine 50 mg PO every 3–4 hours.
10. Prochlorperazine suppository 25 mg PR every 12 hours.

## Table 1. Emetogenic Potential of Chemotherapy Agents

<i>Level</i>	<i>Frequency of Emesis (%)</i>	<i>Agent</i>
5	>90	Actinomycin-D
		Altretamine
		Carmustine $\leq 250$ mg/m <sup>2</sup>
		Cisplatin >50 mg/m <sup>2</sup>
		Cyclophosphamide >1,500 mg/m <sup>2</sup>
		Dacarbazine >500 mg/m <sup>2</sup>
		Mechlorethamine
		Pentostatin
		Procarbazine
		Streptozocin
		4
Carmustine $\leq 250$ mg/m <sup>2</sup>		
Cisplatin <50 mg/m <sup>2</sup>		
Cyclophosphamide 750–1,500 mg/m <sup>2</sup>		
Cytarabine >1 g/m <sup>2</sup>		
Doxorubicin >60 mg/m <sup>2</sup>		
Irinotecan		
Melphalan (IV)		
3	30–60	Methotrexate >1,000 mg/m <sup>2</sup>
		Aldesleukin
		Arsenic trioxide
		Cyclophosphamide $\leq 750$ mg/m <sup>2</sup>
		Cyclophosphamide (oral)
		Cytarabine (conventional doses)
		Doxorubicin 20–60 mg/m <sup>2</sup>
		Epirubicin $\leq 90$ mg/m <sup>2</sup>
		5-Fluorouracil (high doses)
		Idarubicin
Ifosfamide		

**Table 1 (cont.)**

<b>Level</b>	<b>Frequency of Emesis (%)</b>	<b>Agent</b>
3	30–60	Imatinib
		Methotrexate 250–1,000 mg/m <sup>2</sup>
		Mitoxantrone <15 mg/m <sup>2</sup>
		Temozolomide
2	10–30	Albumin-bound paclitaxel
		Asparaginase
		Bexarotene
		Capecitabine
		Cetuximab
		Cytarabine <1 g/m <sup>2</sup>
		Daunorubicin
		Docetaxel
		Doxorubicin <20 mg/m <sup>2</sup>
		Etoposide
		5-Fluorouracil <1,000 mg/m <sup>2</sup>
		Gemcitabine
		Liposomal doxorubicin
		Lomustine
2	10–30	Methotrexate 50–250 mg/m <sup>2</sup>
		Mitomycin-C
		Paclitaxel
		Pemetrexed
		Thiotepa
		Topotecan
1	<10	Alemtuzumab
		Asparaginase
		Bevacizumab
		Bleomycin
		Bortezomib
		Busulfan
		Chlorambucil (oral)
		Cladribine

**Table 1 (cont.)**

<b>Level</b>	<b>Frequency of Emesis (%)</b>	<b>Agent</b>
1	<10	Decitabine Denileukin diftitox Dasatinib Erlotinib Fludarabine Gefitinib Gemtuzumab Hydroxyurea Interferon- $\alpha$ Lenalidomide Melphalan (oral) 6-Mercaptopurine Methotrexate $\leq 50$ mg/m <sup>2</sup> Rituximab Sorafenib Sunitinib Thalidomide 6-Thioguanine (oral) Trastuzumab Tretinoin Vinblastine Vincristine Vinorelbine

Adapted and taken from: Hesketh et al. *J Clin Oncol* 1997;15:103–109, Gralla et al. *J Clin Oncol* 1998;17:2971–2994, and Grunberg et al. *Support Care Cancer* 2005;13:80–84.

**Single agents are divided into five different levels of emetogenic potential. They are as follows:**

1. Level 1: <10% of patients experience acute (<24 hours after chemotherapy) emesis without antiemetic prophylaxis.
2. Level 2: 10%–30% of patients experience acute emesis without antiemetic prophylaxis.

3. Level 3: 30%–60% of patients experience acute emesis without antiemetic prophylaxis.
4. Level 4: 60%–90% of patients experience acute emesis without antiemetic prophylaxis.
5. Level 5: >90% of patients experience acute emesis without antiemetic prophylaxis.

**With regard to combination regimens, the emetogenic levels are determined by identifying the most emetogenic agent in the combination and then assessing the relative contribution of the other agents based on the following:**

1. Level 1 agents do not contribute to the emetogenic potential of the combination.
2. The presence of one or more level 2 agents increases the emetogenic potential of the combination by one level greater than the most emetogenic agent in the combination.
3. The presence of level 3 or level 4 agents increases the emetogenic potential of the combination by one level per given agent.

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*Note: Trade drug names are initially capitalized.*

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