Chapter 31

Cancer

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KEY TERMS AND DEFINITIONS

Adjuvant—describes chemotherapy administered after radiation or surgery.

Antineoplastic—acting to prevent, inhibit, or halt the development of a neoplasm (a tumor).

Apoptosis—programmed cell death.

Benign—noncancerous; a term applied to a growth that does not spread or return if removed.

Body surface area (BSA)—a measurement of the external area of the body, generally expressed in square meters (m^2) and most often calculated from a patient's height and weight rather than actually measured; thought to be a more accurate indicator of the patient's actual size than weight alone.

Cancer—a disease state in which abnormal cells divide without control and are able to invade other tissues.

Carcinoma—cancer that begins in the skin or tissues that cover or line internal organs.

Cytotoxic—describes an agent (cytotoxin) that kills cells.

Cytoprotective—describes an agent that protects cells against damage from cytotoxins.

Emetogenic—causing nausea and vomiting.

Leukemia—cancer that starts in the bone marrow and causes abnormal cells to enter the blood.

Lymphoma—cancer that originates in the lymphatic cells of the immune system.

Malignant—cancerous.

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Myelosuppression—interference with the bone marrow's functions, especially production of blood cells and platelets.

Necrosis—death of living tissue.

Neoadjuvant—describes chemotherapy administered before radiation therapy or surgery.

Sarcoma—cancer that begins in the connective tissue.

Tumor—a growth or mass of unneeded cells in the body.

LEARNING OBJECTIVES

After completing this chapter, you should be able to

1. List the classes of agents used to treat cancer, including their place in therapy, and give examples of each.
2. Recognize the side effects of different types of chemotherapeutic agents.
3. Define medical terms used in chemotherapy management.
4. List the risk factors for chemotherapy-related nausea and vomiting and discuss medications used in its treatment.
5. Recognize look-alike/sound-alike medications used in treating the oncology patient.

The body consists of cells, which grow, divide, and reproduce according to the influences exerted by natural controls (hormones, enzymes) and external stimuli (chemicals, medications). Body cells are specialized, with functions ranging from the production of hormones (like those in the endocrine system) to attacking outside invaders (like many in the immune system). Normally, old cells that "wear out" or die are replaced and additional cells (like those in the blood and immune system) are produced when the body needs them. Sometimes, however, this natural cycle of cell production, death, and replacement is disrupted. It may be the result of an outside influence (hazardous chemical or drug) or an error in an internal process; often, it occurs when a cell's genetic material has suffered change or damage, called mutation. The outcome can be the formation of additional unneeded cells, which grow and reproduce (proliferate) in an uncontrolled manner not responsive to the body's normal regulation (eg, by hormones) and sometimes not even resembling the original tissues that produced them. The extra or abnormal cells can form a mass or clump of cells, called a **tumor**. Another name for a tumor is neoplasm, from the Greek roots for *new (neo)* and *growth (plasia)*.

Some tumors are self-contained. They grow in one place, and while they may cause discomfort or illness because they crowd or interfere with other tissues or even produce natural chemicals in excess of what the body needs, they do not spread to other places or invade body organs and can often be removed and do not return. Such tumors are termed **benign** and are not cancerous. Other tumors, however, are not as well-behaved. They grow uncontrollably, invade and damage body organs and systems, and may even spread (metastasize), traveling through the blood and lymphatic systems and starting new growths called metastases in other parts of the body. These tumors are termed **malignant** or metastatic and their spread is called metastasis. While malignant tumors can also be removed, they sometimes grow back, either in the same place or in some other area of the body.

CASE STUDY

Mrs. Sullivan is a 45-year-old female patient who had surgery to remove a tumor from her large intestine.

Cancer is the term used for diseases in which abnormal cells divide without control and are able to invade other tissues. Unlike many other conditions covered in this text (eg, diabetes), cancer is not really a single disease state, but a term that refers to a group of diseases, usually designated by the type of cell or body tissue from or in which it originates. There are more than 100 different types of cancer.[1]

CASE?

Mrs. Sullivan's tumor started in the lining of her colon. What type of neoplasm is this cancer likely to be?

Some cancers are labeled with the name of the organ in which they began, such as prostate cancer, breast cancer, lung cancer, and colorectal cancer. Basal cell cancer is a malignancy of the basal cells of the skin; melanoma

originates in the melanocytes of the skin. **Lymphoma** starts with the cells of the immune system. A more specific designation specifies the type of tissue a cancer represents. **Carcinoma** is a cancer that begins in the lining around an internal organ. **Sarcoma** originates in the connective tissue and may have a more descriptive prefix, with osteosarcoma being a bone cancer, myosarcoma a muscle cancer, and liposarcoma a fatty tissue cancer.

Cancers are also sometimes classified based on the type of cell that makes up the malignancy. Neuroendocrine tumors have been diagnosed in several celebrities in recent years. Regardless of where in the body they form, they have this designation because they release hormones in response to nervous system stimulation. A subgroup of these, carcinoid tumors, usually originate in the gastrointestinal (GI) system or lungs but may spread to other body organs.[1]

While all cancers are made of malignant cells and are often referred to as malignancies, they are not necessarily all tumors. Like **leukemia**, which starts in the blood-cell-forming tissues, some cancers proliferate in a malignant way without forming a solid tumor mass; in the case of leukemia, the extra cells crowd out normal cells in the bone marrow and may circulate in the bloodstream.[2]

More than 1.8 million new cases of cancer are diagnosed each year in the United States.[1] Not all cancer is fatal, but more than 600,000 Americans die from cancer annually.[1] Although people are warned that many things can cause cancer, the National Cancer Institute's (NCI's) list of the most common risk factors includes tobacco, sunlight, ionizing radiation, certain chemicals, some infectious agents, certain hormones, alcohol, poor diet, lack of physical activity, and being overweight.[1] Family history and growing older are also predisposing factors. As the NCI points out, however, most people with risk factors will never develop cancer, but avoiding the risks wherever possible reduces the chance of getting it.

Once diagnosed, most cancers can be treated in some way to reduce their impact, prolong life, or even eliminate them. The branch of medicine devoted to the study and treatment of cancer is oncology, and a doctor who practices in this area is known as an oncologist. The most common cancer treatments involve one or more of the following: surgery (operation to remove the tumor), radiation (x-rays and other high energy used to kill cancer cells and shrink tumors), and medication. Because the medications are chemicals aimed at the cancerous cells (neoplasms), this form of treatment is called **antineoplastic** chemotherapy. At times, chemotherapy and or radiation therapy may be given before the main treatment (usually surgery) to reduce the tumor size. This is known as **neoadjuvant** therapy, which helps to increase the overall chances of success of the main treatment. Likewise, chemotherapy and or radiation therapy can be administered after the main treatment (surgery or radiation), and this is known as **adjuvant** therapy. It is given to destroy any residual cancerous cells that may have been left behind from the main treatment and reduce the risk of recurrence.

In addition to chemotherapy, another approach in the treatment of cancer is the use of immunotherapy (or biotherapy). Immunotherapies are medications that target specific parts of the immune system to aid in its ability to detect cancer cells, amplify immune responses, slow cancerous growth, and eradicate cancerous cells. Immunotherapy can be given in conjunction with chemotherapy or alone depending on the disease being treated. Since this is a pharmacology text, we will focus on chemotherapy as well as some immunotherapies for the treatment of cancer.

ANTINEOPLASTIC MEDICATIONS

Much of the cancer chemotherapy in current use is **cytotoxic**, meaning that it kills cells. As noted in Chapter 27, Bacterial Infections, the medications used to kill cells must be more harmful to the unwanted cells (whether bacterial or cancerous) they are intended to destroy than to the normal cells of the body. In general, cancer cells divide more rapidly than most normal cells, and many antineoplastic medications (as well as the radiation therapy mentioned above) target this difference. As a result, tumor cells are more sensitive than most normal cells to the actions of the medications used to treat cancer. Normal cells most likely to be affected by antineoplastic agents are the ones that reproduce the most frequently (scalp hair, white blood cells [WBCs], mouth, and GI lining); this accounts for some of the most common side effects (hair loss, neutropenia, oral ulcers, diarrhea).

Antineoplastic chemotherapy treatments work to disrupt the cell cycle in an attempt to cause enough changes in the cellular makeup that the cell cannot divide, or to damage the cellular makeup enough to cause the cell to die. (These changes can also affect normal cells, the reason for special handling precautions.) Some chemotherapeutic agents are cell-phase specific (meaning they act on cells at a specific stage of growth and division) while others can be given at any time in a cell's life and cause these changes.

Antineoplastic chemotherapy must be precisely dosed to maximize its therapeutic activity and minimize its side effects. **Body surface area (BSA)** is a measurement of the external area of the body, generally expressed in

square meters (m^2) and most often calculated from a patient's height and weight rather than actually measured. Because it is thought to be a more accurate indicator of the patient's actual size than weight alone, it is used in dose calculations for dangerous drugs requiring extra precision, including many cancer chemotherapy agents.

Chemotherapy most often requires a combination of a number of drugs in addition to other treatments such as surgery and radiation therapy. Depending on the type of drug used, it may be administered by mouth, intravenously, or directly into the affected organ. Doses are generally calculated using BSA, resulting in more specific dosing. Antineoplastics are classified by the way they work and how they affect the cancer cell. Usually, chemotherapy will be prescribed as a regimen consisting of a combination of antineoplastic drugs of different types, with different mechanisms of action. We will begin with a discussion of the various classes of agents and move on to how they can be used together for the treatment of various cancers.

Alkylating Agents

An alkylating agent works by binding to DNA, the genetic material of the cell. It interferes with the DNA replication necessary for the cell to grow and divide, slowing or stopping the growth of a tumor. Agents in this group are not cycle specific (see above); they can do their damage at any point in the cell's life cycle. Their action is most evident in fast-growing and replicating cells, but this means they also suppress the cells of normal bone marrow. With increasing doses of alkylating agents, there is usually a corresponding increase in side effects, especially **myelosuppression**, an interference with the bone marrow's production of blood cells and platelets. Other side effects common to alkylating agents include decreased appetite, hair loss (alopecia), mouth sores (mucositis), and diarrhea. With prolonged use, serious side effects of sterility and secondary cancers have been reported.

Among the first alkylating agents (and antineoplastic therapies overall) were the nitrogen mustards—derivatives of the poisonous gas used in World War I that were noted to suppress production of blood cells in the bone marrow of soldiers who had been exposed. These include chlorambucil, mechlorethamine, and melphalan, as well as two more commonly used agents, cyclophosphamide and ifosfamide. In addition to sharing the side effects common to the other alkylating agents, cyclophosphamide and ifosfamide have a relative **emetogenic** risk, meaning they may cause nausea and vomiting (N&V) proportional to their prescribed doses. Their most serious and characteristic side effect, however, is hemorrhagic cystitis, a damaging inflammation of the bladder that can be complicated by serious bleeding. For this reason, patients receiving these drugs are hydrated ahead of time with large volumes of intravenous (IV) and/or oral fluids to dilute the dangerous chemicals they produce, which are toxic to the bladder.

The **cytoprotective** agent (see Table 31-3) mesna, administered to reduce the damage to normal cells, reacts with the inflammatory byproduct of the alkylating agents to form a stable compound, which can be excreted without causing cystitis. It is always included in regimens containing ifosfamide, and sometimes used with cyclophosphamide therapy as well. Mesna has no antineoplastic activity and few significant side effects. There are no indications for its use either alone or to prevent side effects from other antineoplastics.

PRACTICE POINT

The dose of mesna is based on the dose of ifosfamide. Usually, an IV dose equal to 20% of the ifosfamide dose is administered prior to beginning the ifosfamide infusion and is followed either by additional 20% IV doses at 4 and 8 hours (total 60%) or 40% oral doses at 2 and 6 hours (total 100%). There are other dosing regimens, some even involving mesna mixed and administered with the ifosfamide in the same large-volume bag.

ALERT!

Ifosfamide is never administered without a concurrent order for mesna in the regimen. Mesna must precede or at least accompany the ifosfamide; giving it later reduces its effectiveness.

PRACTICE POINT

Mesna is not cytotoxic and handling it alone (without ifosfamide or cyclophosphamide) does not require any of the precautions necessary for hazardous drugs.

Another type of alkylating agent is a complex incorporating the heavy metal platinum to bind with DNA in the targeted cells. While all the medications in this class have the same mechanism of action, the part of the drug to which the platinum is attached influences the kinds of cancer each is used to treat, and the expected side effects. The original agent in this group, cisplatin, is indicated in treating cancers of the ovary, bladder, and testis, but has been used in regimens to treat many other types of cancers as well. It is considered highly emetogenic and doses are usually preceded by medications to prevent N&V with follow-up treatment over the next 3 to 5 days. Cisplatin can cause severe kidney damage, along with depletion of body potassium and magnesium. To accomplish dilution of the drug in the kidneys, patients generally receive large volumes of fluid both before and after doses. Dosing is adjusted downward for patients with poor kidney function.

ALERT!

Usual doses of cisplatin do not exceed 100 mg/m^2; anything above that must be confirmed with the prescriber and/or against the protocol in use.

PRACTICE POINT

Patient may have orders for 1,000–2,000 mL of normal saline to be administered both before and after cisplatin doses; sometimes potassium chloride and magnesium sulfate are added to these to replace expected losses.

Compared to most other alkylating agents, cisplatin is less myelosuppressive, so decreases in WBCs and platelets are not usually as severe, though anemia may result from long-term dosing regimens. Cisplatin has, however, been linked to nervous system toxicities, including hearing loss and weakness, numbness, or pain in the hands and feet, termed peripheral neuropathy.

Carboplatin also incorporates platinum, and its mechanism of action is similar to that of cisplatin; it is indicated for ovarian cancer, but sometimes is used in treatment regimens for other neoplasms as well. It is less emetogenic, less neurotoxic, and less nephrotoxic than cisplatin but has a higher incidence of myelosuppression (with decreases in WBCs, red blood cells [RBCs], and platelets) and causes more hypersensitivity reactions.

Oxaliplatin is the newest agent of this group and is indicated for colon and colorectal cancers. Like cisplatin, it has been associated with peripheral neuropathy. Neither carboplatin nor oxaliplatin administration requires prehydration with large volumes of fluid. The trade names, dosage forms, routes of administration, usual doses, and indications for these and other alkylating agents (including bendamustine, carmustine, lomustine, busulfan, procarbazine, streptozocin, temozolomide, and thiotepa) are detailed in **Medication Table 31-1** (Medication Tables are located at the end of the chapter).

ALERT!

Serious and even fatal hypersensitivity reactions (anaphylaxis) have been associated with administration of platinum compounds.

PRACTICE POINT

Needles and IV sets containing aluminum must not be used in preparation or administration of platinum antineoplastics, as they can react with the medication, causing inactivation and precipitation.

PRACTICE POINT

Oxaliplatin is incompatible with normal saline and must only be diluted in dextrose as any other diluent may cause it to precipitate.

ALERT!

LOOK-ALIKE/SOUND-ALIKE—Cisplatin and carboplatin are look-alike/sound-alike drugs.

CASE?

Mrs. Sullivan must go to the oncology center every other Monday and Tuesday to get IV chemotherapy. One of the medications she receives is oxaliplatin. What must the pharmacy technician consider in preparing her doses?

Antimetabolites

An antimetabolite is a drug similar to natural cellular chemicals included in DNA and RNA. It works by inhibiting the synthesis of DNA, thus interfering with the division and functioning of cells, because its chemical resemblance enables it to be used by the cell in place of the molecule normally used in a given reaction but with a harmful result. This prevention of normal cell division and reproduction leads to programmed cell death, called **apoptosis**. Because antimetabolites are not specific to the functions of cancer cells, they are also cytotoxic to rapidly dividing healthy cells, and that is the basis of most of their side effects.[2]

The first group of antimetabolites is termed folate antagonists. When it was discovered that a diet with reduced levels of the B vitamin folic acid led to a decrease in leukemia cell counts, researchers worked to develop a drug treatment that would interfere with the functions of folates in the body. This led to the synthesis of methotrexate, which is chemically similar to folic acid and can replace it in the body processes that produce a form of folate that can be used during DNA synthesis. Methotrexate still plays a significant role as a treatment for sarcoma, leukemias and sometimes breast cancer. Methotrexate is very toxic at high doses. As noted earlier, normal cells are not immune from its effects, although tumor cells seem to retain it in higher concentrations than healthy ones. Methotrexate is less emetogenic than many other chemotherapeutic agents, although dose-related N&V can occur. Serious side effects include myelosuppression, as well as nephrotoxicity (kidney damage), central nervous system (CNS) toxicity, and liver toxicity.

PRACTICE POINT

Recall from Chapter 13 that methotrexate is also used in the treatment of rheumatoid arthritis. Dosing and duration of therapy are different when it is used to treat cancer.

PRACTICE POINT

Methotrexate causes nephrotoxicity by precipitation in the renal tubules. The chance of this can be reduced by hydration, so some patients, especially those receiving high doses, may have orders for 3,000 mL/m^2 per day, as well as receiving alkalinizing agents to increase urinary pH. Some patients may receive an antidote, glucarpidase, which is a recombinant bacterial enzyme that hastens the metabolism of methotrexate into its inactive components, preventing toxic side effects.

Leucovorin (folinic acid) is the active form of folate in the body and may be administered along with the methotrexate to reduce the myelosuppression and some (though not all) other side effects associated with treatment. It does not appear to prevent some of the toxicities, including those to the liver and kidneys. The use of leucovorin in this way is sometimes termed *leucovorin rescue*.

ALERT!

Patients receiving methotrexate should avoid prolonged exposure to sunlight or sunlamps and avoid alcohol.

PRACTICE POINT

Leucovorin, also known as folinic acid or citrovorum factor and administered as the calcium salt, is not a hazardous substance and its preparation and administration do not call for any extra precautions.

Pemetrexed is another folic acid antagonist indicated for the treatment of malignant mesothelioma and some lung cancers and used in combination with cisplatin. It works by disrupting folate-dependent metabolic processes essential for the rapid growth of tumors. It is usually scheduled on the first day of a 21-day cycle, as one dose every 3 weeks.

Common side effects include nausea, fatigue, and myelosuppression. Administration has also been associated with skin rash, and many patients are pretreated with an oral corticosteroid (often dexamethasone) the day before and the day of treatment, as well as the day after.

CASE?

Another drug Mrs. Sullivan receives at the oncology center is IV leucovorin. What precautions are necessary when the pharmacy technician prepares and labels this medication?

PRACTICE POINT

Folic acid supplementation (alone or as part of a multiple vitamin) reduces pemetrexed toxicity, and patients are usually instructed to begin this a full week before the first pemetrexed dose. These patients also receive intramuscular (IM) vitamin B_{12} during the week before the first dose and every 9 weeks (with the scheduled pemetrexed dose) thereafter.

CASE?

The third drug (in addition to the leucovorin and oxaliplatin) Mrs. Sullivan receives during her treatment sessions is 5-FU. Is the leucovorin considered a "rescue medication"?

Another group of antimetabolite agents are known as pyrimidine antagonists or analogs because they chemically resemble natural substances known as pyrimidines and replace them in the enzyme reactions that lead to DNA replication. These include fluorouracil (5-FU), capecitabine, and cytarabine. 5-FU is one of the older chemotherapy agents still in use and, since it is distributed generically, is fairly inexpensive (although it has recently been subject to intermittent shortages due to manufacturing delays). 5-FU is used for the treatment of cancers of the breast, pancreas, stomach, colon, skin, and rectum. 5-FU may be applied to the skin via a cream to treat actinic keratoses and is sometimes used for basal cell carcinomas (a type of skin cancer) associated with chronic, prolonged sun exposure and sun damage. Ironically, leucovorin, the agent that is used to "rescue" patients from the effects of methotrexate, is often combined with 5-FU to increase its potency (and, as a result, some of its side effects, too). The most prominent side effects of 5-FU are related to the GI tract, especially lesions of the mouth, known as mucositis, and diarrhea. While it is less likely to cause the most common chemotherapy-associated reactions (nausea, vomiting, and alopecia) compared to many agents, it has been associated with myelosuppression, eye problems, and skin conditions. High doses can also cause cardiac symptoms.

ALERT!

Both 5-FU and capecitabine interact with warfarin to increase its anticoagulant effects and the danger of bleeding if INR (international normalized ratio) is not monitored and doses adjusted. Patients taking phenytoin may also require a decrease in dosage to avoid toxic phenytoin blood levels.

PRACTICE POINT

5-FU is sometimes administered by IV infusion (diluted in a large-volume IV bag of normal saline or 5% dextrose) and sometimes ordered as an IV injection (given undiluted and often prepared in the pharmacy for dispensing in a syringe).

Capecitabine is indicated for breast and colorectal cancer. It is a modified form of 5-FU for oral administration and is converted by the body's enzymes to 5-FU, so it has similar actions and side effects, although it is associated with less myelosuppression. Cytarabine (also known as Ara-C and cytosine arabinoside) is another older antimetabolite still in use. It is a cycle-specific agent, meaning that its action is restricted to proliferating cells. It is indicated for the treatment of leukemias and lymphomas. Side effects include myelosuppression, alopecia, diarrhea, mucositis, rash, and conjunctivitis. Some patients experience flu-like symptoms (muscle pains, fever). It is moderately emetogenic, and neurologic toxicities have been noted.

Gemcitabine is a pyrimidine antimetabolite related to cytarabine and indicated for pancreatic, breast, and some lung cancers. It has fewer side effects than cytarabine and is considered less emetogenic, but it still may cause skin conditions and flu-like symptoms. Another pyrimidine is floxuridine, used to treat cancers of the GI tract.

ALERT!

When cytarabine is being prepared for intrathecal (spinal) administration, only the preservative-free solution (labeled PF) or the liposomal suspension can be used. Technicians must be sure to choose the correct preparation as errors could be fatal.

The final group of antimetabolites is known as purine analogs, after the nucleic acids (purines) they resemble and with which they interfere in cellular processes. These include mercaptopurine, thioguanine, fludarabine, cladribine, and pentostatin. They are used primarily in the treatment of leukemias and are detailed in Medication Table 31-1.

Antitumor Antibiotics

Antitumor (or antineoplastic) antibiotics are derived from microorganisms. They are capable of disrupting cellular functions, primarily blocking cell growth by inhibiting DNA synthesis, and delaying or inhibiting cell division. The anthracycline antibiotics are derived from a fungus. Doxorubicin and daunorubicin are the natural fungal products, while idarubicin and epirubicin are chemically similar compounds.[3] Inside dividing cells, they block important enzymes (topoisomerases) to produce DNA breaks in cells exposed to them, resulting in apoptosis. Anthracyclines are used in the treatment of a variety of cancers, including leukemias (doxorubicin, daunorubicin, idarubicin), breast cancer (doxorubicin and epirubicin), and Hodgkin's disease/lymphomas, sarcomas, neuroblastoma, thyroid, lung, ovarian, breast, gastric, and bladder cancer (doxorubicin).

The anthracyclines may be highly or moderately emetogenic depending on the dose, and common side effects include myelosuppression, mucositis, and alopecia. The anthracyclines are vesicants, which means they can cause **necrosis** (death) to living tissue exposed to these agents. For this reason, they must be administered by skilled personnel, and any escape of the medication outside of the vein and into the surrounding tissue, known as extravasation, must be treated immediately to avoid permanent damage.

PRACTICE POINT

Anthracyclines may cause red-orange discoloration of the urine, provided they are chromophores, or chemicals that produce an intense color because of their underlying molecular composition.

While these antineoplastics have long been used to treat a variety of cancers, they have an additional toxic effect that does not appear to be antineoplastic but is, instead, somewhat selective for cardiac muscle tissue. The cardiotoxicity they produce can be *early* (acute) or *late* (delayed). The acute type takes the form of dangerous arrhythmias or pericarditis (inflammation of the tissue surrounding the heart), which can develop during treatment or shortly afterward; it is not necessarily related to the dose. The cardiotoxicity and vesicant properties of the anthracyclines are thought to be related to the creation of free radicals, which are molecular fragments that are highly reactive and have the potential to be damaging to the body's normal cells, particularly the heart muscle.[4] The chronic form can be delayed for months, and its incidence is related to the total (accumulated) dose

PRACTICE POINT

The brand name of doxorubicin is Adriamycin, and it represents the A in many of the cancer chemotherapy regimens known by their acronyms, such as the breast cancer regimen AC (Adriamycin and cyclophosphamide).

PRACTICE POINT

Cardiac function is monitored in patients receiving these agents, and immediate discontinuation of treatment may diminish the risk of serious heart damage.

the patient received during the course of therapy and can ultimately result in congestive heart failure.

PRACTICE POINT

With doxorubicin therapy, lifetime maximum dosages are limited to 450–550 mg/m^2 to reduce the risk of delayed cardiac toxicity. Good recordkeeping is vital to documenting the accumulated dose.

Dexrazoxane is a cytoprotective agent (see Table 31-3) that reduces the damage by free radicals created in anthracycline exposure. When used as a cardiac protectant, it is administered prior to chemotherapy as a dose 10 times the dose of doxorubicin. If given to reduce tissue damage from extravasation, the dose is based on BSA and administered on 3 consecutive days. While dexrazoxane is a specific antidote for doxorubicin, it has been used with other anthracyclines.[4]

Doxorubicin and daunorubicin are also available as liposomal formulations, with the active drug *encapsulated* in a layer of phospholipids, which lengthen duration of activity and presumably facilitate entrance selectively into tumor cells. This enables lower dosing, with a reduced risk of both vesicant effects and cardiotoxicity.

PRACTICE POINT

Unlike many other medications considered cytoprotectives and antidotes, dexrazoxane is a hazardous substance and must be handled, prepared, and dispensed as such and reconstituted using the supplied diluent (sodium lactate).

ALERT!

LOOK-ALIKE/SOUND-ALIKE—Conventional and liposomal dosage forms of doxorubicin and daunorubicin are not interchangeable, but the generic names/active ingredients are similar so care must be taken to select the right product for dispensing.

Bleomycin is an antibiotic agent used in combination chemotherapy regimens to treat Hodgkin's lymphoma and testicular and ovarian cancers. It is only mildly emetogenic and not associated with myelosuppression. Common side effects of this agent include hypersensitivity reactions, flu-like symptoms, and mucositis. Its most serious toxicity is lung damage. Mitoxantrone is an antibiotic agent used to treat prostate cancer and leukemia. (Recall from Chapter 6 that it is also indicated for multiple sclerosis.) Compared with the anthracyclines, mitoxantrone is associated with less heart damage, nausea, and vomiting; it is not a vesicant (although it may cause vein irritation). Side effects are myelosuppression, alopecia, and mucositis. The antitumor antibiotics mentioned above and others are detailed in Medication Table 31-1.

PRACTICE POINT

Mitoxantrone may cause a blue-green discoloration of the urine.

Natural Cytotoxins

In addition to the antibiotics discussed above, some other cytotoxins used to treat cancer are natural products. These agents are derived mostly from plants and include the vinca alkaloids and taxanes, which are active against a wide variety of tumors. They are considered *antimitotics* because they interfere with mitosis (cell division). They are also known as *microtubule-targeting agents* because the cell component with which they interfere is the microtubule. The vinca alkaloids are obtained from the *Vinca rosea* (periwinkle) plant, which was first thought to be useful in the treatment of diabetes. They act by interfering with the dividing cell's separation of chromosomes in preparation for replication; this action and their disruption of other processes results in apoptosis in cells exposed to them. Vincristine can be used for certain leukemias, lymphomas, and sarcomas. Vinblastine can be used used in testicular cancer and lymphomas, as well as Kaposi's sarcoma associated with HIV infection. Vinorelbine is another agent in this class, although it is a synthetic (not natural) analog of the periwinkle derivatives. It is indicated in the treatment of some lung cancers and is also used to treat malignancies of the breast, cervix, and uterus. Vinca alkaloids, while having a relatively low emetogenic effect, are vesicants and are associated with mucositis and myelosuppression. Vinca alkaloids, particularly vincristine, can cause nervous system

toxicities, including peripheral neuropathy and damage to motor, sensory, cranial (head), and autonomic nerves. These toxicities result in additional problems including unpleasant sensations, problems with GI motility, facial muscle spasms, and urinary retention. Other toxicities include impaired liver function, hearing, and vision.

The taxanes are another class of naturally derived anticancer agents that bind to internal cell structures, rendering them nonfunctional, inhibiting cell division, and causing apoptosis. Paclitaxel was first extracted from the bark of the Pacific yew (*Taxus brevifolia*, thus the *taxane* designation) during an NCI initiative for screening potentially valuable plant substances.[5] Docetaxel was synthesized from an extract of European yew needles and has activity similar to paclitaxel. Taxanes are used extensively for breast, ovarian, lung, head, and neck tumors.

ALERT!

Vinca alkaloids have been associated with fatalities when accidentally administered intrathecally (spinal administration). Because the doses are often small volumes given as IV injections, they have been traditionally prepared and dispensed in syringes, which can make them seem like intrathecal rather than IV doses. Vinca alkaloids must carry the warning FOR INTRAVENOUS USE ONLY. FATAL IF GIVEN BY OTHER ROUTES.

Paclitaxel and docetaxel are generally well tolerated and only mildly emetogenic. They are myelosuppressive and associated with hair loss (sometimes over the whole body) and peripheral neuropathy. Paclitaxel can cause muscle and joint aches, mucositis, and cardiac irregularities. Premedication with diphenhydramine, steroids (such as dexamethasone), and a histamine-2 blocker (such as ranitidine) is required before doses of conventional paclitaxel to prevent hypersensitivity reactions, but another dosage form binding the drug to a protein eliminates the need for this. Docetaxel sometimes causes a rash (especially on the hands and arms) and nail disorders. Steroids (usually oral) are generally begun the day prior to a docetaxel dose to reduce fluid retention and prevent edema. Taxanes should only be diluted in PVC-free IV bags and administered via PVC-free tubing due to the risk of leaching plasticizers found within PVC-containing equipment (eg, diethylhexyl phthalate, DEHP).

ALERT!

The protein-bound form of paclitaxel (Abraxane) has different functional properties than the conventional drug. It must not be substituted for other paclitaxel formulations.

A plant substance known as podophyllotoxin has been chemically modified to produce antineoplastic medications with a mechanism of action similar to the anthracycline antibiotics discussed earlier. Etoposide (VP-16) is used as an IV or orally administered treatment for testicular and lung cancers, and teniposide is administered IV for childhood leukemias. These drugs do not have the cardiac toxicities associated with the anthracyclines but are moderately emetogenic and cause alopecia, mucositis, and hypersensitivity reactions.

Another group of agents derived from plants are the camptothecins. These drugs also block a topoisomerase (although not the same one as the anthracyclines and podophyllotoxins) and are used in the treatment of colon cancer (irinotecan) and ovarian cancer (topotecan). Drugs from this group, along with their brand names, pronunciations, routes of administration, indications, and usual doses, can be found in Medication Table 31-1.

ALERT!

LOOK-ALIKE/SOUND-ALIKE—Paclitaxel and docetaxel are look-alike/sound-alike drugs.

Hormonal Agents

Hormonal agents have been used to treat several types of cancers. Hormonal therapy interferes at the cellular level with growth stimulatory receptor proteins. The mechanisms of action, however, may differ from one agent to the next. Hormone therapy usually consists of drugs or surgery to decrease the production of male hormones (androgens) or female hormones (estrogens) thereby stopping or limiting the growth of prostate or breast cancer. These cancers are hormone-sensitive or hormone-dependent, meaning that their growth is related to the presence or stimulation of androgens or estrogens. Hormone therapy has the advantage of being specific for tissues that are responsive to hormonal effects and can stop or slow the growth of cancers without having cytotoxicity.

Androgens, estrogens, and agents that mimic or block them have been used in the therapy of malignancies of the prostate, breast, and endometrium (uterine lining). Tests are available to show whether cancer cells have estrogen, progesterone, or testosterone receptors to enable a choice of therapy likely to block the way these hormones stimulate the cancer growth.

There are several groups of hormonal agents used in cancer treatment. The aromatase inhibitors work by blocking the enzyme aromatase. Aromatase enables the body to turn natural androgen into small amounts of estrogen. Three commonly used aromatase inhibitors are anastrozole, exemestane, and letrozole. They are used to treat breast cancers shown to have estrogen receptors *(ER-positive)* and only in postmenopausal women (whose primary source of estrogen is the aromatase-mediated reaction, unlike premenopausal women whose ovaries produce estrogen without the intervention of aromatase). The major side effects of these agents are hot flashes, muscle and joint pain, headache, fatigue, hyperlipidemia, and changes in liver enzyme levels.

PRACTICE POINT

The aromatase inhibitors are also used to treat ovulation disorders; that role was discussed in Chapter 11.

Another type of hormonal therapy is termed antiestrogen and involves interfering with the actions of natural estrogens, often by blocking the receptors to which they attach. This group (used to treat ER-positive breast cancer) includes tamoxifen (also used to prevent breast cancer), fulvestrant, and toremifene (also used for endometrial cancers). Megestrol is a progestin (see Chapter 11) that interferes with normal hormonal activity and is indicated for the treatment of breast and endometrial cancers. Antiestrogens cause hot flashes, fluid retention, weight changes, and depression. Antiandrogens (flutamide, nilutamide, bicalutamide, abiraterone, and abarelix) block the testosterone receptors of prostate cancer cells. Their actions were discussed in detail in Chapter 11. Hormonal cancer treatments are listed in Medication Table 31-1.

Additional hormonal therapies include luteinizing hormone-releasing hormone (LHRH) analogs (goserelin, leuprolide) and antagonists (degarelix). LHRH agents (also known as gonadotropin-releasing hormone [GnRH] agents) work by binding to receptors within the pituitary gland, ultimately halting the production of testosterone or estrogen through either negative feedback (analogs) or direct blockade (antagonist). These agents are used in advanced breast and prostate cancers. LHRH analogs and antagonists can cause fluid retention, gastrointestinal issues, decreased libido, impotence, and hot flashes.

PRACTICE POINT

Megestrol is also used to stimulate the appetite of oncology patients and thus promote weight gain. When used for this indication, doses are generally much higher than those prescribed for the treatment of breast or endometrial cancer.

Small Molecule Targeted Agents

Intracellular signaling pathways allow cancerous cells to signal growth and trigger division. These pathways rely on enzymes known as kinases that work to transfer a phosphate group from adenosine triphosphate (ATP, known as the energy currency of the cell) to various proteins within the cell, a process known as phosphorylation. This acts as a switch to turn on signaling cascades to start such cellular events as growth and division. At times, these kinases can become mutated and left in the "on" position, causing rapid, uncontrolled growth. Kinase inhibitors work by blocking the site where ATP would normally bind, therefore preventing the switch from turning on. There are various types of kinase inhibitors and most inhibit more than one specific kinase, which leads to stray side effects depending on where they are found. Gene rearrangement tests are conducted to check for the presence of kinase mutations to determine whether a patient may benefit from a specific kinase inhibitor. Almost all kinase inhibitors are taken orally.

In some circumstances, cancerous cells may become resistant to the effects of a kinase inhibitor by reconfiguring the site at which they bind, ultimately preventing the drug from working. This has led to the development of different generations of kinase inhibitors that are able to overcome the resistance developed by certain cancerous cells. For example, crizotinib is a first-generation kinase inhibitor of anaplastic lymphoma kinase (ALK), which is found in certain lymphomas and lung cancers. Over the course of crizotinib therapy, some patients may develop resistance to its effects, at which time they are placed on second or third generations of ALK inhibitors (alectinib, brigatinib, ceritinib, and

lorlatinib) that bypass the developed resistance and continue to work accordingly. More information on specific kinase inhibitors and their associated side effects are found in Medication Table 31-2.

Biologic Therapies

Biologic therapies are treatments using substances made from living organisms.[1] Recombinant DNA technology has enabled the manufacture of these substances (or agents with similar action and structure) in laboratories and manufacturing facilities. The type of biologic therapy most frequently used in cancer treatment is immunotherapy, which can actually boost, direct, or restore the body's ability to fight neoplasms.

Monoclonal antibodies are specific antibodies (introduced in Chapter 30) directed against antigens located on the surfaces of tumor cells. Several agents of this type are available to treat various cancers. Because each has a different and very specific target, side effects vary, but fever, chills, and headache occur with many of them, and several are commonly administered after premedication with some combination of acetaminophen, an antihistamine (usually diphenhydramine), and/or a corticosteroid (often dexamethasone). These therapies are identified by the –mab suffix in their names (ie, rituxi**mab**, cetuxi**mab**, atezolizu**mab**, etc.). Their names also describe the composition of the monoclonal antibody, as follows: (1) chimeric, or constructed utilizing cellular machinery from another mammal—a mouse in most cases (as noted with the **–x**imab suffix); (2) partially human (ie, humanized), or constructed with nonhuman cellular machinery though more similar in structure to natural human monoclonal antibodies (as noted with the **–zu**mab suffix); and (3) fully human, or constructed with viral machinery that encodes exact copies of human antibodies (as noted with the **–u**mab suffix).[6] The derivations of each monoclonal antibody can help to determine the risk of infusion reactions as those derived from outside sources (ie, chimeric) have a greater chance of causing infusion-related reactions.[6] Some monoclonal antibodies have been associated with serious, even fatal, infusion or other reactions. Monoclonal antibodies used to treat cancer, with their pronunciations, brand names, usual doses, and indications, are listed in Medication Table 31-2.

PRACTICE POINT

Monoclonal antibodies are biological products that maintain their activity only when handled, stored, and prepared exactly as directed. Most bear warnings that vials and solutions must be handled gently or even the prohibition "DO NOT SHAKE" as shaking can render them inactive.

PRACTICE POINT

Rituximab is a chimeric monoclonal antibody that is known to cause frequent infusion-related reactions (including fatal incidences) particularly with the first infusion. It's strongly recommended that individuals be pretreated with acetaminophen and an antihistamine prior to infusion.

ALERT!

LOOK-ALIKE/SOUND-ALIKE—Rituximab and cetuximab are look-alike/sound-alike drugs.

Cytokines are naturally occurring substances in the immune system. Some suppress immune response, while others stimulate it. Interferons (IFNs) are cytokines that suppress cell proliferation and increase immune system activity against target cells. Their use as antivirals is discussed in Chapter 28, but they are also used in the treatment of some cancers, including hairy cell leukemia, melanoma, chronic myeloid leukemia, and AIDS-related Kaposi's sarcoma.

Interleukins are cytokines that stimulate interferon production as well as increasing the activity of "killer" cells in the immune system. These actions can be directed against tumor cells. While many interleukins have been identified, interleukin-2 (IL-2) is the most widely studied in cancer treatment. Recombinant IL-2 is indicated for the treatment of renal cell carcinoma and metastatic melanoma. A related product, denileukin diftitox combines human IL-2 with portions of the diphtheria toxin molecule and causes apoptosis of certain cells. It is indicated for the treatment of some lymphomas.

As previously mentioned, a subclass of biologic therapy known as immunotherapies has been pivotal in the current approach to treating cancer. Immunotherapies work to invigorate the inherent immune system to seek and destroy

cancerous cells by upregulating the body's own immune cell activities (particularly T cells). One such target is known as programed cell death protein 1 (PD-1), which is found on normal healthy cells, which ultimately downregulates immune system responses by acting as an inhibitory signal (similar to a key turning off a car).[7] Naturally, PD-1 functions to reduce overreaction in the immune system when it encounters various stimuli. However, PD-1 can be used by cancer cells to hide and evade immune responses that would normally eliminate such abnormal cells. Blocking PD-1 proteins on cancer cells from interacting with immune cells (T and B cells) allows for the detection of cancer cells and triggering of cancer cell death. Immunotherapies may be used as an individual treatment or as part of a regimen in multiple cancers. Examples of such agents and their uses are detailed in Medication Table 31-2.

PRACTICE POINT

Many biotherapies now have available biosimilars that are mistakenly referred to as "generics." Biosimilars are biological products that are highly similar to products already approved by the Food and Drug Administration (FDA), and do not have clinically meaningful differences related to their safety and efficacy.[6] They are not referred to as generics because they are large protein structures and, given their complexity is challenging to make exact copies. The Purple book is a compendium of all known FDA approved and available biosimilars.[8]

Antineoplastic Therapy Regimens

The antineoplastic agents discussed in this chapter are seldom used alone. Cancer chemotherapy generally consists of a regimen, or combination, of medications in specific dose ranges and intervals designed to increase the likelihood of successful therapy, while decreasing the severity of the side effects. Medications from different groups, with different mechanisms of action, are chosen to attack the cancer cells in multiple ways, either simultaneously or sequentially.

There are numerous regimens (with more being developed in clinical trials) available, each of which has been studied for use in specific situations. Some cancer therapy is aimed at a cure, with complete eradication of the cancer. Other therapies are considered palliative and are used to diminish symptoms or even prolong life in patients whose cancers are unlikely to respond to the extent of complete cure. Some antineoplastic regimens are termed adjuvant therapy and are administered to prevent recurrence of disease that has been treated with surgery or radiation. These are often administered cyclically: weekly, every 21 days, monthly, or at some other customized interval (sometimes during only one day of the cycle and sometimes on two or more consecutive days). The interval scheduling is planned in part to allow the bone marrow to recover from a chemotherapy-induced nadir (the point at which blood cell counts are at their lowest). Most cancer treatment regimens and their specific indications can be found in the National Comprehensive Cancer Network® (NCCN) guidelines.[9] The NCCN guidelines are the most up-to-date treatment algorithms and are used extensively in oncologic practices in North America.[9]

CASE?

Mrs. Sullivan receives three different antineoplastics and has to visit the oncology center 2 days every other week. Why does she need so many drugs and doses?

CASE?

Mrs. Sullivan had her cancer removed before beginning antineoplastic medications. What is the term for the IV treatment she is receiving at the oncology center?

Chemotherapy regimens are sometimes given distinctive names, such as the Roswell Park Regimen (5-FU with folinic acid) for colorectal cancer, or they simply list the included drugs, such as the carboplatin/pemetrexed regimen for malignant mesothelioma. Many are acronyms that incorporate the first letters in the names (sometimes brand, sometimes generic) of the drugs included, such as FOLFOX6 (**fol**inic acid/**f**luorouracil/**ox**aliplatin) for colorectal cancer; TAC (**T**axotere–docetaxel/**A**driamycin-doxorubicin/**c**yclophosphamide) for breast cancer; or CHOP (**c**yclophosphamide/**h**ydroxydaunorubicin–doxorubicin/**O**ncovin–vincristine/**p**rednisone) for lymphoma.

SIDE EFFECT MANAGEMENT

As emphasized throughout this chapter, antineoplastic medications have many significant side effects. Because therapy must often continue for long periods of time to achieve the goals of treatment, management of these side effects is crucial to both the patient's quality of life and the ability to continue the treatment. Side effects frequently associated with chemotherapy and treated with pharmacologic intervention are N&V, mucositis, and myelosuppression.

Prevention and control of N&V are important parts of many chemotherapy regimens. N&V are unpleasant in themselves but can result in serious consequences, including nutritional depletion, anorexia, deterioration of patients' physical and mental status, decreased ability to function, and withdrawal from potentially useful and curative treatment. Emetogenic potential varies with the agents, and antiemetic therapy is chosen and dosed based on the antineoplastics used. Patients most at risk for hard-to-control N&V from chemotherapy are those who are under 50 years old, female (particularly those with persistent N&V symptoms during pregnancy), those who experienced uncontrolled symptoms during an earlier treatment, those who have a history of motion sickness, or those who have always abstained from alcoholic beverages. Antiemetics and their use in chemotherapy are discussed extensively in Chapter 21, as well as in the NCCN antiemesis guidelines for supportive care.[9]

CASE?

Mrs. Sullivan's physician has ordered a dose of ondansetron 8 mg by mouth twice daily in the weeks she receives chemotherapy. What is the purpose of this additional medication?

The mucosal lining of the GI tract, including the oral mucosa, has a rapid cell turnover rate and is thus highly susceptible to the toxic effects of cytotoxic agents. Oral mucositis describes inflammation of the oral mucosa; when this occurs, the oral cavity becomes red and swollen. Mucositis is managed with topical anesthetics (eg, viscous lidocaine, benzocaine gels, and mouthwash solutions containing diphenhydramine). Kaolin/pectin agents can be used to form a protective barrier and give relief, as well. If oral lesions become irritated or infected, additional management may be indicated. Some options are discussed in Chapter 36.

CASE?

Mrs. Sullivan received chemotherapy on Monday and Tuesday. On Friday, she comes to the pharmacy with a prescription for her sore mouth. Why might her mouth be so swollen? What might the oncologist have prescribed?

Myelosuppression, an interference with the bone marrow's functions, especially the production of blood cells and platelets, is one of the most common toxicities limiting the dose or continuation of therapy for antineoplastic agents. Neutrophils (detailed in Chapter 25) have a relatively short lifespan and are among the first type of cell to be depleted during therapy with myelosuppressive agents; when their count falls too low, patients suffer from neutropenia and are more susceptible to infection. This condition and its treatment are discussed in Chapter 26.

There are many additional adverse effects associated with antineoplastic chemotherapy. It is not unusual for patients receiving antineoplastics to receive preventive medications or to require treatment for the side effects; the prevention or treatment will vary with the regimen being used.

HANDLING CYTOTOXIC MEDICATIONS

Cytotoxic medications and some other antineoplastic agents are hazardous substances, and exposure to them during handling, storage, preparation, delivery, administration, and disposal can pose health risks to pharmacy and medical personnel. These risks include cancer (carcinogenicity), damage to a developing fetus (teratogenicity), fertility impairment (reproductive toxicity), organ toxicity, and damage to DNA (genotoxicity).

Personal protective equipment (PPE), including appropriate gloves, long-sleeved gowns with closed fronts and fitted cuffs, eye and face protection, and shoe coverings, should be worn during the preparation of hazardous agents.[10] The preparation and manipulation of these products in the pharmacy should be accomplished in a closed environment such as a biological safety cabinet or a barrier isolator. Procedures must be in place to treat accidental exposures, and equipment and supplies to clean up after spills must be readily available.

PRACTICE POINT

USP General Chapter provides standards for the safe handling of hazardous drugs to minimize the risk of exposure to healthcare personnel, patients, and the environment. Its standards apply to all healthcare personnel who receive, prepare, administer, transport, or otherwise come in contact with hazardous drugs and all the environments in which they are handled.[10]

CASE?

Mrs. Sullivan's medications include oxaliplatin, leucovorin, 5-FU, ondansetron, and viscous lidocaine. Which of these medications requires special handling, labeling, or disposal precautions? Why?

Cytotoxic preparations dispensed from the pharmacy should always bear a label warning those who will handle or administer them to wear gloves and dispose of them properly. Waste material from preparation and administration must be placed in puncture-proof containers with sealed lids labeled with an appropriate warning.[10]

PRACTICE POINT

Not all antineoplastic chemotherapy is considered hazardous, but technicians must determine ahead of time what precautions are indicated for the medications they are handling.

SUMMARY

Cancer is a disease state in which abnormal cells divide without control and are able to invade other tissues. It can result in serious illness and death, and there are a variety of treatments, including surgery, radiation, and medication. Pharmacotherapy for cancer consists of agents that are intended to kill cancer cells and/or prevent them from multiplying or to enhance the body's ability to fight the disease. Agents used in chemotherapy frequently have serious side effects, which may limit the administration of an effective dose, and must be managed appropriately. Many of the therapies are hazardous substances and require special handling, labeling, and disposal.

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REFERENCES

1. National Cancer Institute at the National Institutes of Health. Available at http://www.cancer.gov/. Accessed June 10, 2022.
2. DiPiro JT, Yee GC, Posey LM, et al., eds. *Pharmacotherapy: A Pathophysiologic Approach.* 11th ed. New York, NY: McGraw-Hill; 2020.
3. Wellstein A. General Principles in the Pharmacotherapy of Cancer. In: Brunton LL, Knollman BC, eds. *Goodman & Gilman's: The Pharmacological Basis of Therapeutics*, 14e. McGraw Hill; 2022. Accessed July 28, 2022 https://accesspharmacy-mhmedical-com.neomed.idm.oclc.org/content.aspx?bookid=3191&sectionid=266700746.
4. Wang RY. Chemotherapeutics. In: Nelson LS, Howland M, Lewin NA, Smith SW, Goldfrank LR, Hoffman RS, eds. *Goldfrank's Toxicologic Emergencies*, 11e. McGraw Hill; 2019. Accessed July 28, 2022. https://accesspharmacy-mhmedical-com.neomed.idm.oclc.org/content.aspx?bookid=2569&sectionid=210272633.
5. Frye DK, Taxane chemotherapy: Advances in treatment for breast cancer. *US Oncological Disease.* 2006;1(1):40-41.
6. Lu R-M, Hwang Y-C, Liu I-J, et al. Development of therapeutic antibodies for the treatment of diseases. *J Biomed Sci.* 2020;27(1). doi:10.1186/s12929-019-0592-z.
7. Messerschmidt JL, Prendergast GC, Messerschmidt GL. How cancers escape immune destruction and mechanisms of action for the new significantly active immune therapies: Helping nonimmunologists decipher recent advances. Oncologist. 2016;21(2):233-243. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4746082. Accessed June 10, 2022.
8. FDA Purple Book [database]. Silver Spring, MD: U.S. Food and Drug Administration. https://purplebooksearch.fda.gov/. Accessed July 10, 2021.
9. National Comprehensive Cancer Network. Guidelines: Antiemesis. https://www.nccn.org. Accessed June 10, 2022.

10. U. S. Pharmacopeia. USP General Chapter Hazardous Drugs – Handling in Healthcare Settings. https://www.usp.org/compounding/general-chapter-hazardous-drugs-handling-healthcare. Accessed June 23, 2020.
11. Lexi-Drugs [database]. Hudson, OH: Lexicomp; 2021. http://online.lexi.com/. Accessed June 10, 2022.

REVIEW QUESTIONS

1. What is cancer? How does it develop?
2. What are cytotoxic drugs, and why is this type of medication useful in the treatment of cancer?
3. How are hormonal therapies used in the treatment of cancer? Which types of cancer are they usually used to treat?
4. Discuss three common side effects of antineoplastic therapy.
5. Discuss special precautions pharmacy technicians must take in the preparation and handling of some antineoplastic medications and the reasons for these precautions.

MEDICATION TABLES

MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11]

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Abiraterone (a bir A ter one)	Zytiga, Yonsa	Hormone (antiandrogen)	Tablet	Oral	1,000 mg once daily	Prostate cancer
Anastrozole (an AS troe zole)	Arimidex	Aromatase inhibitor	Tablet	Oral	1 mg daily	Breast cancer
Arsenic trioxide (AR se nik tri OKS id)	Trisenox	Miscellaneous antineoplastic	Solution	IV	0.15 mg/kg/day	Acute promyelocytic leukemia
Asparaginase Erwinia (a SPEAR a ji nase er WIN i ah)	Erwinase	Enzyme	Powder for reconstitution	IV, IM	6,000 units/m^2/dose 3 times/week	Acute lymphoblastic leukemia (ALL)
Azacitidine (ay za SYE ti deen)	Vidaza	Antimetabolite (pyrimidine analog)	Powder for suspension	IV, SUBQ	75 mg/m^2/day for 7 days every 4 weeks	Myelodysplastic syndrome (MDS) Acute myeloid leukemia (AML)
	Onureg		Tablet	Oral	300 mg daily, days 1–14 of 28-day cycle	AML, maintenance
Bendamustine (ben da MUS teen)	Treanda	Alkylating agent	Powder for reconstitution	IV	100 mg/m^2 days 1–2 of 28-day cycle	Chronic lymphocytic leukemia (CLL), progressed indolent B cell non-Hodgkin's lymphoma (NHL)
	Belrapzo, Bendeka		Solution			
Bicalutamide (bye ka LOO ta mide)	Casodex	Hormone (antiandrogen)	Tablet	Oral	50 mg once daily	Prostate cancer
Bleomycin (blee oh MYE sin)		Antibiotic	Powder for reconstitution	IM, IV	10 units/m^2	Squamous cell carcinomas, Hodgkin's lymphoma, testicular cancer
Busulfan (bue SUL fan)	Busulfex, Myleran	Alkylating agent	Injection solution, tablet	IV, oral	4–8 mg/day	Chronic myelogenous leukemia (CML)
Cabazitaxel (ca baz i TAKS el)	Jevtana	Antimitotic (taxane)	Solution	IV	25 mg/m^2/dose once every 3 weeks	Prostate cancer
Capecitabine (ka pe SITE a been)	Xeloda	Antimetabolite (pyrimidine analog)	Tablet	Oral	1,250 mg/m^2 twice daily	Breast and colorectal cancer

Continued next page

MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Carboplatin (KAR boe pla tin)	Paraplatin	Alkylating agent (platinum complex)	Solution	IV	Calculated using the Calvert formula	Ovarian cancer, breast cancer, NSCLC, small cell lung cancer, head and neck cancer
Carmustine (kar MUS teen)	BiCNU	Alkylating agent	Powder for reconstitution	IV	150–200 mg/m^2 every 6 weeks	Brain tumors, Hodgkin's lymphoma, multiple myeloma, NHL
	Gliadel		Wafer for implantation	Brain implant	8 wafers surgically placed in the resection cavity	Glioblastoma, newly diagnosed high-grade malignant glioma
Chlorambucil (klor AM byoo sil)	Leukeran	Alkylating agent	Tablet	Oral	0.1 mg/kg/day for 3–6 weeks	CLL, Hodgkin's lymphoma, NHL
Cisplatin (SIS pla tin)	Generics only, formerly Platinol	Alkylating agent (platinum complex)	Injection solution	IV	10–100 mg/m^2 (variable depending on indication)	Bladder, testicular, ovarian cancer, lung cancer, head and neck cancer
Cladribine (KlA dri been)		Antimetabolite (purine analog)	Injection solution	IV, SUBQ	0.1 mg/kg/day	Hairy cell leukemia
Clofarabine (klo FARE a been)	Clolar	Antimetabolite (purine analog)	Injection solution	IV	Adults ≤21 yrs of age: 52 mg/m^2/day on days 1–5 repeated every 2–6 weeks based on tolerability	ALL in children
Cyclophosphamide (sye kloe FOS fa mide)	Formerly Cytoxan	Alkylating agent (nitrogen mustard)	Injection powder for reconstitution, tablet	IV, oral	Varies widely depending on indication	Lymphomas, leukemias, mycosis fungoides, multiple myeloma, neuroblastoma, breast cancer, ovarian cancer
Cytarabine ("Ara-C") (sye TARE a been)	Formerly Cytosar	Antimetabolite (pyrimidine analog)	Injection powder for reconstitution, solution	IV, intrathecal, SUBQ	100 mg/m^2/day for 7 days	Leukemias
Dacarbazine ("DTIC") (da KAR ba zeen)		Alkylating agent	Injection powder for reconstitution	IV	250–375 mg/m^2/dose	Malignant melanoma, Hodgkin's lymphoma
Dactinomycin (dak ti noe MYE sin)	Cosmegen	Antibiotic	Injection powder for reconstitution	IV	Varies widely depending on indication	Wilms' tumor, sarcomas, ovarian cancer, gestational trophoblastic neoplasm
Daunorubicin (daw noe ROO bi sin)		Antibiotic (anthracycline)	Injection powder for reconstitution	IV	30–60 mg/m^2/day	ALL, AML

Continued next page

MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Decitabine (dee SYE ta been)	Dacogen	Antimetabolite (pyrimidine analog)	Injection powder for reconstitution	IV	20 mg/m^2 over 1 hour once daily for 5 days every 4 weeks	AML, MDS
Degarelix (deg a REL ix)	Firmagon	Hormonal agent (GnRH antagonist)	Injection powder for reconstitution	SUBQ	80 mg every 28 days	Prostate cancer
Docetaxel (doe se TAKS el)		Antimitotic (taxane)	Injection powder for reconstitution, solution	IV	60–100 mg/m^2 every 3 weeks	Breast cancer, prostate cancer, non-small cell lung cancer (NSCLC), gastric adenocarcinoma, squamous cell head and neck cancer
Doxorubicin (doks oh ROO bi sin)	Adriamycin	Antibiotic (anthracycline)	Injection powder for reconstitution, solution	IV	60 mg/m^2/dose every 2 weeks	ALL, AML, lymphomas, soft tissue and bone sarcomas, thyroid cancer, small cell lung cancer, breast cancer, gastric cancer, ovarian cancer, bladder cancer, neuroblastoma, and Wilms' tumor
Doxorubicin liposomal (doks oh ROO bi sin lye po SO mal)	Doxil	Antibiotic (anthracycline)	Suspension	IV	20 mg/m^2 every 3 weeks	Kaposi's sarcoma, multiple myeloma, ovarian cancer, breast cancer
Epirubicin (ep i ROO bi sin)	Ellence	Antibiotic (anthracycline)	Injection powder for reconstitution, injection solution	IV	Dose varies, 3 or 4 weeks treatment cycles	Breast cancer
Eribulin (er i BUE lin)	Halaven	Antimitotic	Injection solution	IV	1.4 mg/m^2/dose on days 1 and 8 of a 21-day treatment cycle	Breast cancer
Estramustine (es tra MUS teen)	Emcyt	Antimitotic	Capsule	Oral	14 mg/kg/day in 3 or 4 divided doses	Prostate cancer
Etoposide (e toe POE side)	Toposar	Antimitotic (podophyllotoxin)	Injection solution	IV	35 mg/m^2/day for 5 days every 3-4 weeks	Testicular tumors, small cell lung cancer
	(generics)		Capsule	Oral	70–100 mg/m^2/day for 5 days every 3–4 weeks (rounded to the nearest 50 mg)	Small cell lung cancer

Continued next page

MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Etoposide phosphate (e toe POE side FOS fate	Etopophos	Antimitotic (podophyllotoxin)	Injection solution; formulated without polysorbate 80	IV	50–100 mg/m^2 days 1–3	Small cell lung cancer, testicular cancer
Exemestane (ex e MES tane)	Aromasin	Aromatase inhibitor	Tablet	Oral	25 mg once daily	Breast cancer (postmenopausal women)
Floxuridine (flox YOOR i deen)		Antimetabolite (pyrimidine analog)	Injection powder for reconstitution	Intra-arterial	0.1–0.6 mg/kg/day continuous intra-arterial administration for 14 days by an implantable pump	Hepatic metastases of colorectal and gastric cancers
Fludarabine (floo DARE a been)		Antimetabolite (purine analog)	Injection powder for reconstitution, injection solution	IV	25–40 mg/m^2 once daily for 5 days every 28 days	B cell CLL
Fluorouracil (5-FU) (flure oh YOOR a sil)		Antimetabolite (pyrimidine analog)	Injection solution	IV	500 mg/m^2 once weekly	Carcinomas of the breast, colon, rectum, pancreas, or stomach
Flutamide (FLOO ta mide)	Eulexin	Hormone (antiandrogen)	Capsule	Oral	250 mg 3 times/day	Prostate cancer
Fulvestrant (ful VES trant)	Faslodex	Hormonal agent (estrogen receptor antagonist)	Injection solution	IM	500 mg once monthly	Breast cancer (postmenopausal women)
Gemcitabine (jem SIT a been)	Infugem	Antimetabolite (pyrimidine analog)	Injection solution	IV	1,000 mg/m^2, weekly in 3 out of 4 weeks	Breast cancer, NSCLC, pancreatic cancer, ovarian cancer
Goserelin (GOE se rel in)	Zoladex	Hormonal agent (GnRH agonist)	Implant	SUBQ	28-day (3.6 mg) or 12-week (10.8 mg) implant	Prostate cancer, breast cancer
Histrelin (his TREL in)	Supprelin LA Vantas	Hormonal agent (GnRH agonist)	Implant	SUBQ	50 mg implant inserted every 12 months	Prostate cancer
Hydroxyurea (hye drox ee yoor EE a)	Droxia, Hydrea, Siklos	Antimetabolite	Capsule, tablet	Oral	20–30 mg/kg once daily	Melanoma, CML, ovarian cancer, squamous cell head and neck cancer, adjunct in the management of sickle cell anemia
Idarubicin (eye da ROO bi sin)	Idamycin PFS	Antibiotic (anthracycline)	Injection solution	IV	12 mg/m^2/day for 3 days	AML

Continued next page

MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Ifosfamide (eye FOS fa mide)	Ifex	Alkylating agent (nitrogen mustard)	Injection powder for reconstitution, solution	IV	1,200 mg/m^2/day for 5 days every 3 weeks	Testicular cancer
Irinotecan (eye rye no TEE kan)	Camptosar	Antimitotic (camptothecin)	Injection solution	IV	125 mg/m^2 over 90 minutes on days 1, 8, 15, and 22 of a 6-week treatment cycle	Carcinoma of the colon or rectum
Irinotecan liposomal (eye rye no TEE kan lye po SO mal)	Onyvide	Antimitotic (camptothecin)	Injection	IV	70 mg/m^2 over 90 minutes once every 2 weeks. NOTE: Not interchangeable with conventional irinotecan	Pancreatic cancer
Ixabepilone (ix ab EP i lone)	Ixempra	Antimitotic	Injection powder for reconstitution	IV	40 mg/m^2/dose over 3 hours every 3 weeks	Breast cancer
Letrozole (LET roe zole)	Femara	Aromatase inhibitor	Tablet	Oral	2.5 mg once daily	Breast cancer
Leucovorin (loo koe VOR in) ("Calcium folinate")		Cytoprotective (with methotrexate therapy)	Solution, tablet	IV, oral	15-25 mg every 6 hours × 10 doses beginning 24 hours after methotrexate administration	Reduces methotrexate toxicity
		Enzyme inhibitor (with 5-FU therapy)	Solution	IV	20–200 mg/m^2 prior to 5-FU	Colorectal cancer
Leuprolide (loo PROE lide)	Eligard, Lupron Depot-Ped, Lupron Depot, Camcevi	Hormonal agent (GnRH agonist)	Injection powder for reconstitution, injection solution, kit	IM, SUBQ	7.5 mg monthly, administered at 1-, 3-, 4-, or 6-month intervals	Prostate cancer
Lomustine (loe MUS teen)	Gleostine	Alkylating agent	Capsule	Oral	130 mg/m^2 every 6 weeks	Metastatic brain tumors, Hodgkin's disease
Megestrol (me JES trol)		Hormone (progestin)	Suspension, tablet	Oral	Varies widely according to protocols	Breast and endometrial carcinoma; also used as appetite stimulant

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MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Melphalan (MEL fa lan)	Evomela, Alkeran	Alkylating agent	Injection powder for reconstitution, tablet	IV, oral	Varies widely depending on indication	Multiple myeloma, ovarian cancer
Mercaptopurine (mer kap toe PURE een)	Purixan	Antimetabolite (purine analog)	Suspension, tablet	Oral	1.5–2.5 mg/kg/day	ALL
Methotrexate (meth oh TREX ate)	Trexall, others	Antimetabolite (antifolate)	Injection powder for reconstitution, injection solution, tablet	IV, IM, oral intrathecal	Varies widely depending on indication	Trophoblastic neoplasms, ALL, meningeal leukemia, breast cancer, head and neck cancer, cutaneous T-cell lymphoma, lung cancer, NHL, osteosarcoma
Mitomycin (mye toe MYE sin)		Antibiotic	Injection powder for reconstitution	IV	20 mg/m^2 every 6–8 weeks	Adenocarcinoma of the stomach or pancreas
Mitomycin ureteral gel (mye toe MYE sin)	Jelmyto	Antibiotic	Solution, reconstituted	Ureteral instillation	Up to 15 mL (60 mg) weekly × 6 weeks	Urothelial cancer
Mitotane (MYE toe tane)	Lysodren	Adrenal cytotoxic agent	Tablet	Oral	Varies widely depending on indication	Adrenocortical carcinoma
Mitoxantrone (mye toe ZAN trone)		Antibiotic	Injection solution	IV	12 mg/m^2 once daily for 3 days in 3- to 4-week cycles	Acute nonlymphocytic leukemias (ANLL), prostate cancer, multiple sclerosis
Nelarabine (nel AY re been)	Arranon	Antimetabolite (purine analog)	Injection solution	IV	1,500 mg/m^2/dose on days 1, 3, and 5; repeat every 21 days	ALL, lymphoblastic lymphoma
Nilutamide (nye LOO ta mide)	Nilandron	Hormone (antiandrogen)	Tablet	Oral	300 mg once daily	Prostate cancer
Oxaliplatin (ox AL i pla tin)		Alkylating agent (platinum complex)	Injection solution	IV	85 mg/m^2 every 2 weeks until disease progression or unacceptable toxicity	Colon cancer, colorectal cancer
Paclitaxel (pak li TAX el)	Formerly Taxol	Antimitotic (taxane)	Injection solution	IV	135–175 mg/m^2 over 3 hours every 3 weeks	Breast, NSCLC and ovarian cancers; AIDS-related Kaposi's sarcoma

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MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Paclitaxel protein-bound particles (pak li TAX el)	Abraxane	Antimitotic (taxane)	Suspension for reconstitution	IV	260 mg/m^2 IV over 30 minutes every 3 weeks	Breast cancer
Pegaspargase (peg AS par jase)	Oncaspar	Enzyme	Injection solution	IM, IV	2,500 units/m^2 (as part of a chemotherapy regimen), not to be administered more frequently than every 14 days	ALL
Pemetrexed (pem e TREX ed)	Alimta, Pemfexy	Antimetabolite (antifolate)	Injection powder for reconstitution	IV	500 mg/m^2 on day 1 of each 21-day cycle (in combination with cisplatin)	Malignant pleural mesothelioma, nonsquamous NSCLC
Pentostatin (pen toe STAT in)	Nipent	Antimetabolite (purine analog)	Injection powder for reconstitution	IV	4 mg/m^2 every 2 weeks	Hairy cell leukemia
Pralatrexate (pral a TREX ate)	Folotyn	Antimetabolite (antifolate)	Injection solution	IV	30 mg/m^2 once weekly for 6 weeks of a 7-week treatment cycle	Peripheral T-cell lymphoma (PTCL)
Procarbazine (proe KAR ba zeen)	Matulane	Alkylating agent	Capsule	Oral	2–4 mg/kg/day for 7 days then increase to 4–6 mg/kg/day until response is obtained	Hodgkin's disease
Streptozocin (step toe ZOE sin)	Zanosar	Alkylating agent	Injection powder for reconstitution	IV	1–1.4 g/m^2 weekly for 6 weeks followed by a 4-week rest period	Pancreatic cancer
Tamoxifen (ta MOKS i fen)	Soltamox (formerly Nolvadex)	Hormone (antiestrogen)	Tablet, solution	Oral	20–40 mg/day	Breast cancer
Temozolomide (te moe ZOE loe mide)	Temodar	Alkylating agent	Capsule, injection powder for reconstitution	Oral, IV	100–200 mg/m^2/day for 5 days per treatment cycle	Central nervous system (CNS) cancers
Teniposide (ten i POE side)		Antimitotic (podophyllotoxin)	Injection solution	IV	165 mg/m^2/dose days 1, 4, 8, and 11 of alternating consolidation cycles	Childhood ALL

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MEDICATION TABLE 31-1. Cytotoxic and Hormonal Antineoplastic Agents[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Thioguanine (thye oh GWAH neen)	Tabloid	Antimetabolite (purine analog)	Tablet	Oral	60 mg/m^2/day for 14 days	AML
Thiotepa (thye oh TEP a)	Tepadina	Alkylating agent	Injection powder for reconstitution	Intravesical, IV, intracavitary, intrathecal	Dose and route of administration various depending on indication	Bladder, breast, ovarian cancers
Topotecan (toe poe TEE kan)	Hycamtin	Antimitotic (camptothecin)	Capsule, injection powder for reconstitution, injection solution	IV, oral	1.5 mg/m^2/day repeated every 21 days	Ovarian or cervical cancer, small cell lung cancer
Toremifene (tore EM i feen)	Fareston	Hormonal agent (estrogen receptor antagonist)	Tablet	Oral	60 mg once daily	Metastatic breast cancer in postmenopausal women
Triptorelin (trip toe REL in)	Trelstar, Triptodur	Hormonal agent (GnRH agonist)	Injection powder for reconstitution	IM	3.75 mg once every 4 weeks	Prostate cancer
Valrubicin (val ROO bi sin)	Valstar	Antibiotic (anthracycline)	Injection solution	Intravesical	800 mg once weekly (retain for 2 hours) for 6 weeks	Bladder cancer
Vinblastine (vin BLAS teen)	Formerly Velban	Antimitotic (vinca alkaloid)	Injection powder for reconstitution, injection solution	IV	5.5–7.4 mg/m^2 every 7 days	Hodgkin's and non-Hodgkin's lymphoma, testicular cancer, breast cancer, mycosis fungoides, Kaposi's sarcoma, histiocytosis, choriocarcinoma
Vincristine (vin KRIS teen)	Vincasar PFS (formerly Oncovin)	Antimitotic (vinca alkaloid)	Injection solution	IV	1.4 mg/m^2/dose, doses capped at 2 mg/dose according to individual protocol	ALL, lymphomas, Wilms' tumor, neuroblastoma, rhabdomyosarcoma
Vinorelbine (vi NOR el been)		Antimitotic (vinca alkaloid)	Injection solution	IV	30 mg/m^2/dose every 7 days	NSCLC

GnRH = gonadotropin-releasing hormone; IM = intramuscular; IV = intravenous; SUBQ = subcutaneous.

MEDICATION TABLE 31-2. Biologic Therapies Used to Treat Cancer[11]

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Abemaciclib (a bem a SYE klib)	Verzenio	Enzyme inhibitor	Tablet	Oral	150 mg or 200 mg twice daily	Breast cancer
Acalabrutinib (a KAL a broo ti nib)	Calquence	Enzyme inhibitor	Capsule	Oral	100 mg every 12 hours	CLL, mantle cell lymphoma
Ado-trastuzumab emtansine (a do tras TU zoo mab em TAN seen)	Kadcyla	Monoclonal antibody-antineoplastic complex	Solution reconstituted	IV	3.6 mg/kg every 3 weeks	Breast cancer
Afatanib (a FA ti nib)	Gilotrif	Enzyme inhibitor	Tablet	Oral	40 mg once daily	NSCLC
Aldesleukin (IL-2) (al des LOO kin)	Proleukin	Biological response modifier	Powder for reconstitution	IV	600,000 International Units/kg every 8 hours	Renal cell carcinoma (RCC), melanoma
Alectinib (al EK ti nib)	Alecensa	Enzyme inhibitor (2nd generation)	Tablet	Oral	600 mg twice daily	NSCLC
Alemtuzumab (al em TOOZ oo mab)	Campath, Lemtrada	Monoclonal antibody	Solution (preservative free)	IV, SUBQ	3 mg/day increased to 30 mg/dose	Lymphomas, prolymphocytic leukemia
Alpelisib (AL pe LIS ib)	Piqray	Enzyme inhibitor	Tablet	Oral	300 mg once daily	Breast cancer
Atezolizumab (ah TEZ oh liz U mab)	Tecentriq	Monclonal antibody	Solution	IV	Flat dose of 840 mg every 2 weeks OR 1,200 mg every 3 weeks OR 1,680 mg every 4 weeks	Breast, lung, or urothelial cancer
Axitinib (ax I ti nib)	Inlyta	Enzyme inhibitor	Tablet	Oral	5–10 mg twice daily	RCC, thyroid cancer
Belinostat (be LIN oh stat)	Beleodaq	Enzyme inhibitor	Solution (preservative free)	IV	1,000 mg/m^2 once daily on days 1–5 every 21 days	Peripheral T-cell lymphoma
Bevacizumab (be va SIZ yoo mab)	Avastin, Mvasi, Zirabev, Alymsys	Monoclonal antibody	Solution (preservative free)	IV	5 or 10 mg/kg every 2 weeks	Colorectal cancer, NSCLC, glioblastoma, RCC
Bexarotene (bex AIR oh teen)	Targretin	Retinoid	Capsule	Oral	300–400 mg/m^2/day	Cutaneous T-cell lymphoma

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MEDICATION TABLE 31-2. Biologic Therapies Used to Treat Cancer[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Binimetinib (bin I ME ti nib)	Mektovi	Enzyme inhibitor	Tablet	Oral	45 mg twice daily	Colorectal cancer, melanoma
Blinatumomab (blin a TOOM oh mab)	Blincyto	Monoclonal antibody	Reconstituted solution	IV	Dose based on weight if ≥45 kg (fixed dose) = Minimal residual disease positive (MRD+): 28 mcg on days 1–28 of 6 week treatment cycle; Relapsed/refractory (RR): 9 mcg daily on days 1–7 followed by 28 mcg days 8–28 of 6 week treatment cycle. Dose based on BSA if <45 kg = Minimal residual disease positive (MRD+): 15 mcg/m^2/day (max 28 mcg/day) as a continuous infusion on days 1–28 of 6 week treatment cycle; Relapsed/refractory (RR): 5 mcg/m^2/day (max 9 mcg/day) days 1–7 followed by 15 mcg/m^2/day (max 28 mcg/day) days 8–28 of 6 week treatment cycle	ALL
Bortezomib (bor TEZ oh mib)	Velcade	Enzyme inhibitor	Powder for reconstitution	IV, SUBQ	1.3 mg/m^2	Multiple myeloma, lymphoma
Bosutinib (boe SUE ti nib)	Bosulif	Enzyme inhibitor	Tablet	Oral	400 mg or 500 mg once daily	CML
Brentuximab vedotin (bren TUX i mab ve DOE tin)	Adcetris	Antibody drug conjugate, monoclonal antibody	Powder for reconstitution	IV	1.2–1.8 mg/kg every 2 or 3 weeks	Hodgkins lymphoma, peripheral T-cell lymphoma
Brigatinib (bre GA ti nib	Alunbrig	Enzyme inhibitor (2nd generation)	Tablet	Oral	180 mg once daily	NSCLC
Cabozantinib (ka boe ZAN ti nib)	Cabometyx, Cometriq	Enzyme inhibitor	Tablet	Oral	60–140 mg once daily	Hepatocellular carcinoma, RCC, thyroid cancer
Carfilzomib (car FILLS oh mib)	Kyprolis	Enzyme inhibitor	Solution	IV	20 mg/m^2 days 1 and 2, if tolerated increased to 27 mg/m^2 OR 36 mg/m^2 OR 56 mg/m^2 OR 70 mg/m^2	Multiple myeloma, Waldenstrom macroglobulinemia

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MEDICATION TABLE 31-2. Biologic Therapies Used to Treat Cancer[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Ceritinib (Se RI ti nib)	Zykadia	Enzyme inhibitor (2nd generation)	Capsule, tablet	Oral	450 mg once daily	NSCLC
Cetuximab (se TUX i mab)	Erbitux	Monoclonal antibody	Injection solution	IV	Initial dose of 400 mg/m^2 followed by weekly maintenance dose of 250 mg/m^2	Colorectal cancer, squamous cell carcinoma
Copanlisib (koe pan LIS ib)	Aliqopa	Enzyme inhibitor	Tablet	Oral	60 mg on days 1, 8, and 15 of a 28-day treatment cycle	Follicular lymphoma
Crizotinib (kri ZO ti nib)	Xalkori	Enzyme inhibitor (1st generation)	Tablet	Oral	250 mg twice daily	NSCLC
Dabrafenib (da BRAF e nib)	Tafinlar	Enzyme inhibitor	Capsule	Oral	150 mg twice daily	Melanoma, NSCLC, thyroid cancer
Dacomitinib (DAK oh MI ti nib)	Vizimpro	Enzyme inhibitor	Tablet	Oral	45 mg once daily	NSCLC
Daratumumab (dar a TOOM ue mab)	Darzalex	Monoclonal antibody	Injection solution	IV	16 mg/kg once weekly initially	Multiple myeloma
Dasatinib (da SA ti nib)	Sprycel	Enzyme inhibitor	Tablet	Oral	100 mg once daily	Chronic myelogenous leukemia (CML)
Dinutuximab (din ue TUX i mab)	Unituxin	Monoclonal antibody	Injection solution	IV	17.5 mg/m^2 for 4 consecutive days for maximum 5 cycles	Neuroblastoma
Durvalumab (dur VAL ue mab)	Imfinzi	Monoclonal antibody	Injection solution	IV	10 mg/kg once every 2 weeks	NSCLC, urothelial cancer
Duvelisib (DOO ve LIS ib)	Coptiktra	Enzyme inhibitor	Capsules	Oral	25 mg twice daily	CLL, follicular lymphoma
Elotuzumab (el oh TOOZ ue mab)	Empliciti	Monoclonal antibody	Reconstituted solution	IV	10 mg/kg once weekly initially	Multiple myeloma
Enasidenib (en a SID a nib)	IDHIFA	Enzyme inhibitor	Tablet	Oral	100 mg once daily	Acute myeloid leukemia
Encorafenib (en koe RAF e nib)	Braftovi	Enzyme inhibitor	Capsule	Oral	300 mg or 450 mg once daily	Colorectal cancer, melanoma
Erdafitinib (er da FI ti nib)	Balversa	Enzyme inhibitor	Tablet	Oral	8 mg once daily and increase to dose to 9 mg based on tolerability	Urothelial carcinoma
Erlotinib (er LOE ti nib)	Tarceva	Enzyme inhibitor	Tablet	Oral	150 mg once daily	NSCLC, pancreatic cancer

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MEDICATION TABLE 31-2. Biologic Therapies Used to Treat Cancer[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Everolimus (e ver OH li mus)	Afinitor, Zortress	Enzyme inhibitor	Tablet	Oral	10 mg once daily	Advanced RCC, breast cancer, subependymal giant cell astrocytoma (SEGA), pancreatic neuroendocrine tumors, prophylaxis of organ rejection
Gefitinib (ge FI ti nib)	Iressa	Enzyme inhibitor	Tablet	Oral	250 mg once daily	NSCLC
Gilteritinib (GIL te RI ti nib)	Xospata	Enzyme inhibitor	Tablet	Oral	120 mg once daily	AML
Glasdegib (glas DEG ib)	Daurismo	Hedgehog Pathway inhibitor	Tablet	Oral	100 mg once daily	AML
Ibritumomab (eye bri TOOM oh mab)	Zevalin	Monoclonal antibody	Injection solution	IV	Two-step regimen with rituximab	NHL
Ibrutinib (eye BROO ti nib)	Imbruvica	Enzyme inhibitor	Capsule, tablet	Oral	420 mg or 560 mg once daily	CLL, chronic graft-versus-host disease, mantle cell lymphoma, marginal zone lymphoma, Waldenstrom macroglobulinemia
Idelasib (eye DEL as ib)		Enzyme inhibitor	Tablet	Oral	150 mg twice daily	CLL, follicular B-cell non-Hodgkin's lymphoma, small lymphocytic lymphoma
Ixazomib (ix AZ oh mib)	Ninlaro	Enzyme inhibitor	Capsule	Oral	4 mg once weekly on days 1, 8, and 15 of 28-day treatment	Multiple myeloma
Imatinib (i MAT in ib)	Gleevec	Enzyme inhibitor	Tablet	Oral	400 mg once daily	Gastrointestinal stromal tumors (GIST), chronic myeloid leukemia, acute lymphoblastic leukemia (ALL), aggressive systemic mastocytosis (ASM), dermatofibrosarcoma protuberans (DFSP), hypereosinophilic syndrome (HES), chronic eosinophilic leukemia (CEL), myelodysplastic/myeloproliferative disease (MDS/MPD)

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MEDICATION TABLE 31-2. Biologic Therapies Used to Treat Cancer[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Interferon alfa-2b (in ter FEER on AL fa)	Intron A	Interferon	Injection powder for reconstitution, injection solution	IM, SUBQ	Dose varies, 6–18 month's duration	Leukemia, malignant melanoma, AIDS-related Kaposi's sarcoma, non-Hodgkin's lymphoma
Ipilimumab (ip i LIM ue mab)	Yervoy	Monoclonal antibody	Injection solution	IV	3 mg/kg every 3 weeks for 4 doses	Metastatic melanoma
Ivosidenib (EYE voe SID e nib)	Tibsovo	Enzyme inhibitor	Tablet	Oral	500 mg once daily	AML
Lapatinib (la PA ti nib)	Tykerb	Enzyme inhibitor	Tablet	Oral	1,250 mg once daily (used as part of a combination therapy)	Metastatic breast cancer
Lenalidomide (len a LID oh mide)	Revlimid	Immunomodulator	Capsule	Oral	10–25 mg once daily for 21 days of a 28-day treatment cycle	Myelodysplastic syndrome (MDS), multiple myeloma
Lenvatinib (len VA ti nib)	Lenvima	Enzyme inhibitor	Capsule	Oral	8–24 mg once daily	Endometrial carcinoma. hepatocellular carcinoma, renal cell carcinoma, thyroid cancer
Lorlatinib (lor LA ti nib)	Lorbrena	Enzyme inhibitor (3rd generation)	Tablet	Oral	100 mg once daily	NSCLC
Midostaurin (mye doe STAW rin)	Rydapt	Enzyme inhibitor	Capsule	Oral	50 mg or 100 mg twice daily	AML, mast cell leukemia, systemic mastocytosis
Mogamulizumab (moe GAM ue LIZ ue mab)	Poteligeo	Monoclonal antibody	Injection solution	IV	1 mg/kg days 1 and 15 of 28-day cycle	Mycosis fungoides, Sezary syndrome
Necitumumab (ne si TOOM oo mab)	Portrazza	Monoclonal antibody		IV	800 mg on days 1 and 8 of a 3-week cycle	Squamous NSCLC
Neratinib (ne RA ti nib)	Nerlynx	Enzyme inhibitor	Tablet	Oral	240 mg once daily	Breast cancer
Nilotinib (nil OT i nib)	Tasigna	Enzyme inhibitor	Capsule	Oral	300 mg twice daily	CML
Niraparib (nye RAP a rib)	Zejula	PARP inhibitor	Capsule	Oral	300 mg once daily	Ovarian, fallopian tube, or primary peritoneal cancer
Nivolumab (nye VOL ue mab)	Opdivo	Monoclonal antibody	Injection solution	IV	240 mg once every 2 weeks or 480 mg once every 4 weeks	Colorectal cancer, head and neck cancer, hepatocellular carcinoma, Hodgkin's lymphoma, melanoma, RCC, small cell lung cancer

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MEDICATION TABLE 31-2. Biologic Therapies Used to Treat Cancer[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Obinutuzumab (oh bi nue TOOZ ue mab)	Gazyva	Monoclonal antibody	Injection solution	IV	1,000 mg once daily	CLL, follicular lymphoma
Ofatumumab (o fa TOOM ue mab)	Arzerra	Monoclonal antibody	Injection solution	IV	Up to 2,000 mg once every 4 weeks for 4 doses	CLL
Osimertinib (oh si mer ti nib)	Tagrisso	Enzyme inhibitor	Tablet	Oral	80 mg once daily	NSCLC
Palbociclib (pal boe SYE klib)	Ibrance	Enzyme inhibitor	Capsule	Oral	125 mg once daily	Breast cancer
Panitumumab (pan i TOOM yoo mab)	Vectibix	Monoclonal antibody	Injection solution	IV	6 mg/kg every 2 weeks	Colorectal cancer
Panobinostat (pan oh BIN oh stat)	Farydak	Enzyme inhibitor	Capsule	Oral	20 mg once every other day for 3 doses every week on weeks 1 and 2 of 21-day cycle	Multiple myeloma
Pazopanib (paz OH pa nib)	Votrient	Enzyme inhibitor	Tablet	Oral	800 mg once daily until disease progression or unacceptable toxicity	RCC
Pembrolizumab (pem broe LIZ ue mab)	Keytruda	Monoclonal antibody	Injection solution	IV	200 mg once every 3 weeks	Cervical cancer, endometrial cancer, esophageal cancer, head and neck cancer, hepatocellualr carcinoma, Hodgkin's lymphoma, melanoma, Merkel cell carcinoma, NSCLC, small cell lung cancer, renal cell carcinoma, urothelial carcinoma
Ponatinib (poe NA ti nib)	Iclusig	Enzyme inhibitor	Tablet	Oral	45 mg once daily	ALL, CML
Ramucirumab (ra mue SIR ue mab)	Cyramza	Monoclonal antibody			8 mg/kg once every 2 weeks or 10 mg/kg on day 1 every 21 days (dose dependent on indication)	Colorectal cancer, gastric cancer, hepatocellular carcinoma, NSCLC
Regorafenib (re goe RAF e nib)	Stivarga	Enzyme inhibitor	Tablet	Oral	160 mg once daily for first 21 days of 28-day cycle	Colorectal cancer, gastrointestinal stromal tumor, hepatocellular carcinoma
Ribociclib (rye boe SYE klib)	Kisqali	Enzyme inhibitor	Tablet	Oral	600 mg once daily	Breast cancer
Rituximab (ri TUX i mab)	Rituxan, Truxima, Riabni	Monoclonal antibody	Injection solution	IV	375 mg/m^2 in cycle 1, then 500 mg/m^2 on day 1 (every 28 days) of cycles 2-6	NHL, CLL

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MEDICATION TABLE 31-2. Biologic Therapies Used to Treat Cancer[11] *(Continued)*

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Rituximab and hyaluronidase (ri TUX i mab & hye al yoor ON i dase)	Rituxan Hycela	Monoclonal antibody	Subcutaneous depot injection	SUBQ	1,400 mg/23,400 units or 1,600 mg/26,800 units	CLL, diffuse large B-cell lymphoma, follicular lymphoma
Romidepsin (roe mi DEP sin)	Istodax	Enzyme inhibitor	Injection powder for reconstitution	IV	14 mg/m^2 days 1, 8, and 15 of a 28-day treatment cycle	Cutaneous T-cell lymphoma (CTCL) and peripheral T-cell lymphoma (PTCL)
Ruxolitinib (rux oh LI ti nib)	Jakafi	Enzyme inhibitor	Tablet	Oral	5–15 mg twice daily	Graft-versus-host disease, myelofibrosis, polycythemia vera
Sonidegib (soe ni DEG ib)	Odomzo	Hedgehog Pathway inhibitor	Capsule	Oral	200 mg once daily	Basal cell carcinoma
Sorafenib (soe RAF e nib)	NexAVAR	Enzyme inhibitor	Tablet	Oral	400 mg twice daily	RCC, hepatocellular cancer
Sunitinib (soo NI ti nib)	Sutent	Enzyme inhibitor	Capsule	Oral	50 mg once daily for 4 weeks of a 6-week treatment cycle	GIST, RCC, pancreatic neuroendocrine tumors
Talazoparib (tal a ZOE pa rib)	Talzenna	PARP inhibitor	Capsule	Oral	1 mg once daily	Breast cancer
Temsirolimus (tem sir OH li mus)	Torisel	Enzyme inhibitor	Injection solution	IV	25 mg once weekly	RCC
Trastuzumab (tras TOO zoo mab)	Herceptin, Kanjinti, Ogivri, Ontruzant, Herzuma	Monoclonal antibody	Injection powder for reconstitution	IV	4 mg/kg infused over 90 minutes	Breast cancer, gastric or gastroesophageal junction adenocarcinoma
Tretinoin (TRET i noe in)	Vesanoid	Retinoid	Capsule	Oral	45 mg/m^2/day in 2 equally divided doses (discontinue 30 days after complete remission or after 90 days of treatment)	APL
Vandetanib (van DET a nib)	Caprelsa	Enzyme inhibitor	Tablet	Oral	300 mg once daily	Thyroid cancer
Vemurafenib (vem ue RAF e nib)	Zelboraf	Enzyme inhibitor	Tablet	Oral	960 mg twice daily	Melanoma, NSCLC
Venetoclax (ven ET oh klax)	Venclexta	BLC-2 inhibitor	Tablet	Oral	400 mg once daily	AML, CLL
Vismodegib (vis moe DEG ib)	Erivedge	Hedgehog Pathway inhibitor	Capsule	Oral	150 mg once daily	Basal cell carcinoma
Vorinostat (vor IN oh stat)	Zolinza	Enzyme inhibitor	Capsule	Oral	400 mg once daily	Cutaneous T-cell lymphoma

IV = intravenous; SUBQ = subcutaneous.

MEDICATION TABLE 31-3. Chemoprotective Agents[11]

Generic Name (pronunciation)	Brand Name	Class	Dosage Forms	Route	Common Dose	Indication
Dexrazoxane (deks ray ZOKS ane)		Chemoprotective	Solution (reconstituted)	IV	10 × dose of doxorubicin	Prevention of doxorubicin cardiotoxicity
	Totect	Antidote	Solution (reconstituted)	IV	1,000 mg/m^2 daily × 2, then 500 mg/m^2 on day 3	Treatment for extravasation of anthracyclines during administration
Mesna (MES na)	Mesnex	Chemoprotective agent	Solution, tablet	IV, oral	IV: 60% of ifosfamide dose in 3 divided doses IV + PO: IV bolus 20% of ifosfamide dose followed by oral administration of 80% of ifosfamide dose in divided doses	Prevention of ifosfamide-induced hemorrhagic cystitis

IV = intravenous; PO = oral.