Chemotherapy is the use of any drug (such as aspirin or penicillin) to treat any disease. But to most people, chemotherapy refers to drugs used for cancer treatment. It’s often shortened to “chemo.”

Chemotherapy is used to treat many cancers. More than 100 chemotherapy drugs are used today – either alone or in combination with other drugs or treatments. These drugs vary widely in their chemical composition, how they are taken, their usefulness in treating specific forms of cancer, and their side effects.

**Understanding the life cycle of a cell**

All living tissue is made up of cells. Cells grow and reproduce to replace cells lost through injury or normal “wear and tear.” The *cell cycle* is the normal life cycle of a cell. It’s a series of steps that both normal cells and cancer cells go through in order to form new cells.

Understanding the cell cycle helps doctors predict which drugs are likely to work well together and decide how often doses of each drug should be given.

**Phases of the cell cycle**

The cell cycle has 5 phases. Since cell reproduction happens over and over, the cell cycle is shown as a circle. All the phases lead back to the resting phase (G0), which is the starting point.

When a cell goes through the cell cycle, it reproduces 2 new identical cells. Each of the 2 cells made from the first cell can go through this cell cycle again when new cells are needed.
• **G0 phase (resting stage):** The cell has not yet started to divide. Cells spend much of their lives in this phase. Depending on the type of cell, G0 can last from a few hours to a few years. When the cell gets a signal to reproduce, it moves into the G1 phase.

• **G1 phase:** The cell starts making more proteins and growing larger, so the new cells will be of normal size. This phase lasts about 18 to 30 hours.

• **S phase:** The chromosomes containing the genetic code (DNA) are copied so that both of the new cells formed will have matching strands of DNA. This phase lasts about 18 to 20 hours.

• **G2 phase:** The cell checks the DNA and gets ready to start splitting into 2 cells. This phase lasts from 2 to 10 hours.

• **M phase (mitosis):** The cell actually splits into 2 new cells. This phase lasts only 30 to 60 minutes.

### Why the cell cycle matters

The cell cycle is important because many chemotherapy drugs work only on cells that are actively reproducing (not cells that are in the resting phase, G0). Some drugs specifically attack cells in a particular phase of the cell cycle (the M or S phases, for example). Understanding how these drugs work helps oncologists predict which drugs are likely to work well together. Doctors can also plan how often doses of each drug should be given based on the timing of the cell phases.

Chemotherapy drugs can’t tell the difference between reproducing cells of normal tissues (like those that are replacing worn-out normal cells) and cancer cells. This means normal cells are damaged along with the cancer cells, and this causes side effects. Each time chemotherapy is given, it involves trying to find a balance between destroying the cancer
cells (in order to cure or control the disease) and sparing the normal cells (to lessen unwanted side effects).

Types of chemotherapy drugs

Chemotherapy drugs can be divided into several groups based on factors such as how they work, their chemical structure, and their relationship to another drug. Some drugs act in more than one way, and may belong to more than one group.

Knowing how the drug works is important in predicting side effects. This helps doctors decide which drugs are likely to work well together. If more than one drug will be used, this information also helps them plan exactly when each of the drugs should be given (in which order and how often).

Alkylating agents

Alkylating agents directly damage DNA (the genetic material in each cell) to keep the cell from reproducing. These drugs work in all phases of the cell cycle and are used to treat many different cancers, including leukemia, lymphoma, Hodgkin disease, multiple myeloma, and sarcoma, as well as cancers of the lung, breast, and ovary.

Because these drugs damage DNA, they can cause long-term damage to the bone marrow. In rare cases, this can lead to acute leukemia. The risk of leukemia from alkylating agents is “dose-dependent,” meaning that the risk is small with lower doses, but goes up as the total amount of the drug used gets higher. The risk of leukemia after getting alkylating agents is highest about 5 to 10 years after treatment.

Alkylating agents are divided into different classes, including:

- Nitrogen mustards: such as mechlorethamine (nitrogen mustard), chlorambucil, cyclophosphamide (Cytoxan®), ifosfamide, and melphalan
- Nitrosoureas: such as streptozocin, carmustine (BCNU), and lomustine
- Alkyl sulfonates: busulfan
- Triazines: dacarbazine (DTIC) and temozolomide (Temodar®)
- Ethylenimines: thiotepa and altretamine (hexamethylmelamine)

The platinum drugs (such as cisplatin, carboplatin, and oxalaplatin) are sometimes grouped with alkylating agents because they kill cells in a similar way. These drugs are less likely than the alkylating agents to cause leukemia later.
Antimetabolites

*Antimetabolites* interfere with DNA and RNA growth by substituting for the normal building blocks of RNA and DNA. These agents damage cells during the S phase, when the cell’s chromosomes are being copied. They are commonly used to treat leukemias, cancers of the breast, ovary, and the intestinal tract, as well as other types of cancer.

Examples of antimetabolites include:

- 5-fluorouracil (5-FU)
- 6-mercaptopurine (6-MP)
- Capecitabine (Xeloda®)
- Cytarabine (Ara-C®)
- Floxuridine
- Fludarabine
- Gemcitabine (Gemzar®)
- Hydroxyurea
- Methotrexate
- Pemetrexed (Alimta®)

Anti-tumor antibiotics

These drugs are not like the antibiotics used to treat infections. They work by altering the DNA inside cancer cells to keep them from growing and multiplying.

Anthracyclines

*Anthracyclines* are anti-tumor antibiotics that interfere with enzymes involved in DNA replication. These drugs work in all phases of the cell cycle. They are widely used for a variety of cancers.

Examples of anthracyclines include:

- Daunorubicin
- Doxorubicin (Adriamycin®)
- Epirubicin
• Idarubicin

A major concern when giving these drugs is that they can permanently damage the heart if given in high doses. For this reason, lifetime dose limits are often placed on these drugs.

**Other anti-tumor antibiotics**

Anti-tumor antibiotics that are not anthracyclines include:

• Actinomycin-D
• Bleomycin
• Mitomycin-C
• Mitoxantrone (also acts as a topoisomerase II inhibitor)

**Topoisomerase inhibitors**

These drugs interfere with enzymes called topoisomerases, which help separate the strands of DNA so they can be copied during the S phase. (Enzymes are proteins that cause chemical reactions in living cells.) Topoisomerase inhibitors are used to treat certain leukemias, as well as lung, ovarian, gastrointestinal, and other cancers.

Topoisomerase inhibitors are grouped according to which type of enzyme they affect:

*Topoisomerase I inhibitors* include:

• Topotecan
• Irinotecan (CPT-11).

*Topoisomerase II inhibitors* include:

• Etoposide (VP-16)
• Teniposide.
• Mitoxantrone (also acts as an anti-tumor antibiotic)

Topoisomerase II inhibitors can increase the risk of a second cancer – acute myelogenous leukemia (AML) – as early as 2 to 3 years after the drug is given.

**Mitotic inhibitors**

*Mitotic inhibitors* are often plant alkaloids and other compounds derived from natural products. They work by stopping mitosis in the M phase of the cell cycle but can damage
cells in all phases by keeping enzymes from making proteins needed for cell reproduction.

Examples of mitotic inhibitors include:

- **Taxanes**: paclitaxel (Taxol®) and docetaxel (Taxotere®)
- **Epothilones**: ixabepilone (Ixempra®)
- **Vinca alkaloids**: vinblastine (Velban®), vincristine (Oncovin®), and vinorelbine (Navelbine®)
- **Estramustine** (Emcyt®)

They are used to treat many different types of cancer including breast, lung, myelomas, lymphomas, and leukemias. These drugs may cause nerve damage, which can limit the amount that can be given.

### Corticosteroids

Corticosteroids, often simply called steroids, are natural hormones and hormone-like drugs that are useful in the treatment of many types of cancer, as well as other illnesses. When these drugs are used as part of cancer treatment, they are considered chemotherapy drugs.

Examples of corticosteroids include:

- Prednisone
- Methylprednisolone (Solumedrol®)
- Dexamethasone (Decadron®).

Steroids are also commonly used to help prevent nausea and vomiting caused by chemotherapy. They are used before chemotherapy to help prevent severe allergic reactions, too.

### Other chemotherapy drugs

Some chemotherapy drugs act in slightly different ways and do not fit well into any of the other categories.

Examples include drugs like L-asparaginase, which is an enzyme, and the proteosome inhibitor bortezomib (Velcade®).
Other types of cancer drugs

Other drugs and biological treatments are used to treat cancer, but aren’t usually considered chemotherapy. While chemotherapy drugs take advantage of the fact that cancer cells divide quickly, these drugs target other properties that make cancer cells different from normal cells. They often have less serious side effects than those commonly caused by chemotherapy drugs because they are targeted to affect cancer cells, not normal, healthy cells. Many are used along with chemotherapy.

Targeted therapies

As researchers have learned more about the inner workings of cancer cells, they’ve created new drugs that attack cancer cells more specifically than traditional chemotherapy drugs. Most attack cells with mutant (altered) versions of certain genes, or cells that express too many copies of a certain gene. These drugs can be used as part of the main treatment, or they may be used after treatment to keep the cancer under control or keep it from coming back.

Examples of targeted therapies include:

- Imatinib (Gleevec®)
- Gefitinib (Iressa®)
- Sunitinib (Sutent®)
- Bortezomib (Velcade®).

Targeted therapies are a huge research focus and it’s likely that many more will be developed in the future. To learn more, see Targeted Cancer Therapy.

Differentiating agents

These drugs act on the cancer cells to make them mature into normal cells. Examples include the retinoids, tretinoin (ATRA or Atralin®) and bexarotene (Targretin®), as well as arsenic trioxide (Arsenox®).

Hormone therapy

Drugs in this category are sex hormones, or hormone-like drugs, that change the action or production of female or male hormones. They are used to slow the growth of breast, prostate, and endometrial (uterine) cancers, which normally grow in response to natural sex hormones in the body. These cancer treatment hormones do not work in the same
ways as standard chemotherapy drugs. They work by making the cancer cells unable to use the hormone they need to grow, or by preventing the body from making the hormone.

Examples of hormone therapy include:

- **Anti-estrogens**: fulvestrant (Faslodex®), tamoxifen, and toremifene (Fareston®)
- **Aromatase inhibitors**: anastrozole (Arimidex®), exemestane (Aromasin®), and letrozole (Femara®)
- **Progestins**: megestrol acetate (Megace®)
- **Estrogens**
- **Anti-androgens**: bicalutamide (Casodex®), flutamide (Eulexin®), and nilutamide (Nilandron®)
- **Gonadotropin-releasing hormone (GnRH)**, also known as luteinizing hormone-releasing hormone (LHRH) agonists or analogs: leuprolide (Lupron®) and goserelin (Zoladex®)

**Immunotherapy**

Some drugs are given to people with cancer to help their immune systems recognize and attack cancer cells. These drugs offer a unique method of treatment, and are often considered to be separate from chemotherapy.

There are different types of immunotherapy. *Active immunotherapies* stimulate the body’s own immune system to fight the disease. *Passive immunotherapies* do not rely on the body to attack the disease; they’re immune system components (such as antibodies) created outside the body and given to fight the cancer.

Examples of active immunotherapies include:

- **Monoclonal antibody therapy**, such as rituximab (Rituxan®) and alemtuzumab (Campath®)
- **Non-specific immunotherapies and adjuvants** (other substances or cells that boost the immune response), such as BCG, interleukin-2 (IL-2), and interferon-alfa
- **Immunomodulating drugs**, such as thalidomide and lenalidomide (Revlimid®)

Cancer vaccines are a type of active specific immunotherapy. In 2010, the FDA approved the first vaccine to treat cancer (the Provenge® vaccine for advanced prostate cancer); other vaccines for many different types of cancer are being studied.

For more specific information on these types of drugs see *Cancer Immunotherapy*. 
Deciding which chemotherapy drugs to use

In some cases, the best choice of doses and schedules for giving each chemotherapy (chemo) drug are clear, and most doctors would recommend the same treatment. In other cases, less may be known about the single best way to treat people with certain types and stages of cancer. In these cases, different doctors might choose different drug combinations with different schedules.

Factors to consider in choosing which drugs to use include:

- The type of cancer
- The stage of the cancer (how far it has spread)
- The patient’s age
- The patient’s overall health
- Other serious health problems (such as heart, liver, or kidney diseases)
- Types of cancer treatments given in the past

Doctors take these factors into account, along with information published in medical journals and textbooks describing the outcomes of similar patients treated with chemo.

Chemotherapy regimens or treatment plans may use a single drug or a combination of drugs. Most people with cancer get more than one chemo drug. This is typically more effective than a single drug, because the cancer cells can be attacked in several different ways. Doctors must also consider side effects of each drug and potential interactions among the drugs.

Considering the side effects

Different drugs have different side effects. It’s often better to use moderate doses of 2 drugs that will cause bearable side effects instead of very high doses of one drug that might cause severe side effects and maybe permanently damage an organ. But there are exceptions to this rule, and a single chemotherapy drug may be the best option for some people with certain types of cancer.

 Doctors try to give chemo at levels high enough to cure or control the cancer, while keeping side effects at a minimum. They also try to avoid multiple drugs that have similar side effects.

For more on chemo side effects and how to deal with them, please visit the “Treatment and Side Effects” section of our website.
Avoiding drug interactions

When looking at how to best combine 2 or more chemo drugs, doctors must also consider potential interactions between the drugs. They have to look at interactions between chemo drugs and other medicines the person is taking, too, including vitamins and non-prescription medicines. In some patients, these interactions may make side effects worse. In others, they may interfere with how well the chemo works.

It’s important that you tell your doctor about all medicines you are taking, including vitamins, herbal or dietary supplements, and non-prescription medicines – even if you only take them “as needed.”

For instance, platelets are the blood cells that cause blood to clot and prevent bleeding. Many chemo drugs slow down the bone marrow’s production of platelets for a time. Taking aspirin or other related drugs can also weaken blood platelets. This isn’t a problem for healthy people with normal platelet counts. But if a person has low platelet counts from chemo, this combination may put them at risk of a serious bleeding problem.

How vitamins affect chemo drugs

Many people want to take an active role in improving their overall health. They want to help their body’s natural defenses fight the cancer and speed up their recovery from chemo.

Because most people think of vitamins as a safe way to improve health, it’s not surprising that many people with cancer take high doses of one or more vitamins. But few know that some vitamins might make their chemo less effective.

Certain vitamins, such as A, E, and C act as antioxidants. This means that they can prevent formation of ions (free radicals) that damage DNA. This damage is thought to have an important role in causing cancer. But some chemotherapy drugs (as well as radiation treatments) work by producing these same types of free radical ions. These ions severely damage the DNA of cancer cells so the cells are unable to grow and reproduce. Some scientists believe that taking high doses of antioxidants during treatment may make chemo or radiation less effective.

Few studies have been done to thoroughly test this theory. But until we know more about the effects of vitamins on chemo, many doctors recommend the following during chemo treatment:

• If your doctor has not told you to take vitamins, it’s best not to take any.

• A simple multivitamin is probably OK for people who want to take a vitamin supplement, but always check with your doctor first.
• It’s safest to avoid taking high doses of antioxidant vitamins or supplements during cancer treatment. Ask your doctors if and when it might be OK to start such vitamins after treatment.

• If you are concerned about nutrition, you can usually get plenty of vitamins by eating a well-balanced diet.

Visit “Nutrition for People With Cancer” on our website to learn more about the importance of good nutrition during and after cancer treatment.

Planning chemotherapy treatments

Most chemotherapy (chemo) drugs are strong medicines that have a fairly narrow dose range for safety and effectiveness. Taking too little of a drug will not treat the cancer well and taking too much may cause life-threatening side effects. For this reason, doctors must calculate chemo doses very precisely.

Determining chemo doses

Depending on the drug(s) to be given, there are different ways to determine chemo doses. Most chemo drugs are measured in milligrams (mg).

The overall dose may be based on a person’s **body weight in kilograms** (1 kilogram is 2.2 pounds). For instance, if the standard dose of a drug is 10 milligrams per kilogram (10 mg/kg), a person weighing 110 pounds (50 kilograms) would get 500 mg (10 mg/kg x 50 kg).

Some chemo doses are determined based on **body surface area (BSA)**, which doctors calculate using height and weight. BSA is expressed in meters squared (m²).

Dosages for children and adults differ, even after BSA is taken into account. This is because children’s bodies process drugs differently. They may have different levels of sensitivity to the drugs, too. For the same reasons, dosages of some drugs may also be adjusted for people who:

- Are elderly
- Have poor nutritional status
- Are obese
- Have already taken or are currently taking other medicines
- Have already had or are currently getting radiation therapy
- Have low blood cell counts
• Have liver or kidney diseases

Setting a chemo schedule (cycles)

Chemo is commonly given at regular intervals called cycles. A cycle may involve a dose of one or more drugs followed by several days or weeks without treatment. This gives normal cells time to recover from drug side effects. Sometimes, doses may be given a certain number of days in a row, or every other day for several days, followed by a period of rest. Some drugs work best when given continuously over a set number of days.

Each drug is given on a schedule that’s carefully set up to make the most of its anti-cancer actions and minimize side effects. If more than one drug is used, the treatment plan will say how often and exactly when each drug should be given. The number of cycles given may be decided before treatment starts, based on the type and stage of cancer. In some cases, the number is flexible, and will take into account how the treatment affects the cancer and the person’s overall health.

Changes in doses and schedules

In most cases, the most effective doses and schedules of drugs to treat specific cancers have been found by testing them in clinical trials. It’s important, when possible, to get the full course of chemo, the full dose, and keep the cycles on schedule. This will give the best chance of getting the maximum benefit from treatment.

There may be times, though, when serious side effects require doctors to adjust the chemo plan (dose and/or schedule) to allow the body time to recover. In some cases, supportive medicines such as growth factors may be used to help the body recover more quickly. Again, the key is to give enough medicine to kill the cancer cells without causing other serious problems.

How chemo is given

In most cases, chemo drugs are put right into the bloodstream or taken as pills. They then travel throughout the body to kill cancer cells.

Sometimes there’s a need to get high doses of chemo to a specific area of the body. Regional chemotherapy directs the anti-cancer drugs into the part of the body where the cancer is. The purpose is to get more of the drug to the cancer, while trying to limit effects on the whole body. Side effects will often still happen because the drugs can be partly absorbed into the bloodstream and travel throughout the body.

Examples of regional chemo include drugs given into these parts of the body:

• Intra-arterial – injected into an artery that goes to a certain area of the body
Intravesical – put into the bladder

Intrapleural – put into the chest cavity between the lung and chest wall

Intraperitoneal – put into the belly (abdomen) around the intestines and other organs

Intrathecal – put into the central nervous system (brain and spinal cord)

Intralesional/intratumoral – injected right into the tumor

Topical – applied to the skin as a cream or lotion

**Intra-arterial chemo**

An intra-arterial infusion allows a chemo drug to be given right to the tumor through a small, flexible tube (catheter) that’s put in the main artery that supplies blood to the tumor. This method is used to treat disease in an organ such as the liver (this is called isolated hepatic perfusion), or to treat an extremity such as the leg (called isolated limb perfusion).

The goal is to concentrate the drug in the area of the tumor and decrease systemic side effects. The catheter is attached to an implanted or portable pump. Although this approach sounds like a good idea, most studies have not found it to be as useful as expected. This approach is being studied for many types of cancer in clinical trials. Except for clinical trials, it’s rarely available outside of specialized cancer centers.

**Intracavitary chemo**

_Intracavitary_ is a broad term used to describe chemo given right into a body cavity. The chemo drug is given through a catheter that’s put into one of the areas as described below.

**Intravesical chemotherapy** is often used for early stage bladder cancer. The chemo is usually given weekly for 4 to 12 weeks. For each treatment, a soft, flexible tube (called a urinary catheter) is put into the bladder to give the drug. The drug is kept in the bladder for about 2 hours and then drained. The catheter is taken out after each treatment.

**Intrapleural chemotherapy** is not used very often but may be helpful for some people with mesothelioma (cancer that develops in the lining of the lung), and those with lung or breast cancers that have spread to the pleura (the membrane around the lungs and lining the chest cavity). Intrapleural chemotherapy is given through soft, flexible tubes called chest catheters. These catheters can be used to give drugs and to drain fluid that can build up in the pleural space when cancer has spread to that area.

**Intraperitoneal chemotherapy** has become one of the standard treatments for certain stages of ovarian cancer. It may also be used to treat some colon cancers that come back after treatment, as well as mesotheliomas and cancers of the appendix, liver, or stomach.
that have spread throughout the belly (abdomen). Intraperitoneal chemo is given through a Tenckhoff catheter (a soft tube specially designed for removing or adding large amounts of fluid from or into the abdominal cavity) or through an implanted port (a small drum-like device) attached to a catheter. Chemo injected into the port travels through the catheter into the abdominal cavity where it’s absorbed into the affected area before entering the bloodstream. This approach can work very well, but it can also have more severe side effects than chemo put into the bloodstream (IV chemo). The higher doses that are used, along with more gradual absorption of the drug into the body, may be part of why the side effects may be worse.

**Intrathecal chemotherapy** is given right into the fluid surrounding and cushioning the brain and spinal cord (called the cerebrospinal fluid or CSF) to reach cancer cells in the fluid and the central nervous system (brain and spinal cord). Most chemo drugs that are put into the bloodstream are unable to cross the barrier between the bloodstream and the central nervous system, called the *blood-brain barrier*. Intrathecal chemotherapy gets the drug directly to the central nervous system.

Intrathecal chemotherapy is given in 1 of 2 ways:

- The chemo can be given by a *lumbar puncture* (spinal tap) done daily or weekly. This is when a thin needle is placed between the bones of the lower spine and into the space through which the CSF flows around the spinal cord.

- A special device called an *Ommaya reservoir* can be used. It’s a small, drum-like port that’s placed under the skin of the skull. An attached catheter goes through the skull into a ventricle (a space inside the brain filled with CSF). A special needle is put through the skin and into the port to give the chemo.

Chemo is given this way when it’s needed to treat cancer cells that have entered the central nervous system. This is seen most commonly in leukemias, but also may happen with some lymphomas and advanced solid tumors like breast and lung cancers. Intrathecal chemotherapy does not help when tumors have already started growing in the brain or spinal cord.

**Intralesional chemo**

Intralesional chemo refers to the drug being injected directly into the cancerous tumor. It may be used for tumors that are in or under the skin, and rarely for tumors that are on an organ inside the body. It’s only possible when the tumor can be safely reached by a needle, and is most often used when surgery isn’t an option.

**Topical chemo**

In this use, chemo is put on the skin in the form of a cream or lotion. Most often, it’s used to treat basal cell or squamous cell skin cancers. It’s also used to treat pre-cancerous
growths on the skin. The patient or a family member usually puts on the chemo cream. It’s important to understand the schedule, know exactly how to use these potent drugs, and know what kinds of precautions to use.

To learn more

More information from your American Cancer Society

Here is more information you might find helpful. You can read them online or order free copies of our documents from our toll-free number, 1-800-227-2345.

More on chemotherapy

Chemo – What It Is, How It Helps (also in Spanish)

Oral Chemotherapy: What You Need to Know

A Guide to Chemotherapy (also in Spanish)

We also have a lot of information on chemo side effects and what can be done to help manage them.

More on certain types of chemotherapy

Cancer Immunotherapy

Targeted Cancer Therapy

National organizations and websites*

Along with the American Cancer Society, other sources of information and support include:

CancerCare
Toll-free number: 1-800-813-4673
Website: www.cancercare.org

Provides free information, counseling, and support services to anyone affected by cancer.

National Cancer Institute (NCI)
Toll-free number: 1-800-4-CANCER (1-800-422-6237)
TTY: 1-800-332-8615
Website: www.cancer.gov
Provides accurate, up-to-date information about cancer to patients, their families, and the general public. Offers a clinical trials matching service. The website is also available in Spanish.

*Inclusion on this list does not imply endorsement by the American Cancer Society.

No matter who you are, we can help. Contact us anytime, day or night, for information and support. Call us at **1-800-227-2345** or visit www.cancer.org.

**References**


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1-800-227-2345 or www.cancer.org