



Treating Childhood Leukemia

Making treatment decisions

Children and teens with leukemia and their families have special needs. These needs can be met best by cancer centers for children and teens, working closely with the child's primary care doctor. These centers offer the advantage of being treated by teams of specialists who know the differences between cancers in adults and those in children and teens, as well as the unique needs of younger people with cancer.

For childhood leukemias, this team is typically led by a pediatric oncologist, a doctor who treats children's cancers. Many other specialists may be involved in your child's care as well, including other doctors, nurses, nurse practitioners (NPs), physician assistants (PAs), psychologists, social workers, rehabilitation specialists, and other health professionals.

Going through cancer treatment with a child often means meeting lots of specialists and learning about parts of the medical system you probably haven't had contact with before. You can find out more about this in [Children Diagnosed With Cancer: Understanding the Health Care System](#).

After leukemia is diagnosed and tests have been done to determine its type, your child's cancer care team will discuss the treatment options with you. The most important factor in choosing a treatment is the type of leukemia, but other factors also play a role.

The main treatment for childhood leukemia is [chemotherapy](#). For some children with higher risk leukemias, high-dose chemotherapy may be given along with a [stem cell transplant](#). Other treatments such as [targeted drugs](#), [immunotherapy](#), [surgery](#), and [radiation therapy](#) may be used in special circumstances.

Treatment of acute forms of childhood leukemia (lymphocytic and myeloid) is usually very intensive, so it is important that it takes place in a center that specializes in treating childhood cancers. Your child's doctor should make sure that treatment reflects your

child's risk group (based on certain prognostic factors) and that he or she will be treated according to a protocol or guidelines of the National Cancer Institute or a cooperative study group. This will ensure the most up-to-date treatment.

It's important to discuss your child's treatment options as well as their possible side effects with the treatment team to help make the decision that's the best fit for your child. If there is anything you don't understand, ask to have it explained. (See [What should you ask your child's doctor about childhood leukemia?](#) for some questions to ask.)

It's also important that you tell your child's doctors about any drugs, herbal remedies, or other alternative medicines you might be giving your child so that the doctors can determine if they might affect standard treatments.

For more on how a specific type of childhood leukemia is treated, see the following sections:

- [Treatment of acute lymphocytic \(lymphoblastic\) leukemia \(ALL\)](#)
- [Treatment of acute myelogenous leukemia \(AML\)](#)
- [Treatment of acute promyelocytic leukemia \(APL\)](#)
- [Treatment of juvenile myelomonocytic leukemia \(JMML\)](#)
- [Treatment of chronic myelogenous leukemia \(CML\)](#)

Thinking about taking part in a clinical trial

Clinical trials are carefully controlled research studies that are done to get a closer look at promising new treatments or procedures. Clinical trials are one way to get state-of-the-art cancer treatment. In some cases they may be the only way to get access to newer treatments. They are also the best way for doctors to learn better methods to treat cancer. Still, they are not right for everyone.

If you would like to learn more about clinical trials that might be right for your child, start by asking your doctor if your clinic or hospital conducts clinical trials. See [Clinical Trials](#) to learn more.

Considering complementary and alternative methods

You may hear about alternative or complementary methods that your doctor hasn't mentioned to treat your child's cancer or relieve symptoms. These methods can include vitamins, herbs, and special diets, or other methods such as acupuncture or massage,

to name a few.

Complementary methods refer to treatments that are used along with regular medical care. Alternative treatments are used instead of a doctor's medical treatment. Although some of these methods might be helpful in relieving symptoms or helping your child feel better, many have not been proven to work. Some might even be dangerous.

Be sure to talk to your child's cancer care team about any method you are thinking about using. They can help you learn what is known (or not known) about the method, which can help you make an informed decision. See [Complementary and Alternative Medicine](#) to learn more.

Help getting through cancer treatment

Your child's cancer care team will be your first source of information and support, but there are other resources for help when you need it. Hospital- or clinic-based support services are an important part of your child's care. These might include nursing or social work services, financial aid, nutritional advice, rehab, or spiritual help.

The American Cancer Society also [has programs and services](#) – including rides to treatment, lodging, and more – to help your child get through treatment. Call our National Cancer Information Center at 1-800-227-2345 and speak with one of our trained specialists.

The treatment information given here is not official policy of the American Cancer Society and is not intended as medical advice to replace the expertise and judgment of your cancer care team. It is intended to help you and your family make informed decisions, together with your doctor. Your doctor may have reasons for suggesting a treatment plan different from these general treatment options. Don't hesitate to ask him or her questions about your treatment options.

Immediate Treatment for Childhood Leukemia

Some children with leukemia are critically ill when they are first diagnosed with leukemia. For example:

- A shortage of normal white blood cells might lead to very serious [infections](#).
- Low levels of platelets or clotting factors in the blood can cause severe bleeding.

- Not having enough red blood cells can lower the amount of oxygen getting to body tissues and put a tremendous strain on the heart.

These problems must often be addressed before treatment of the leukemia can begin. Antibiotics, blood growth factors, and [transfusions of platelets and red blood cells](#) may be given to treat or help prevent some of these conditions.

- [References](#)

[See all references for Leukemia in Children](#)

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Surgery for Childhood Leukemia

Surgery has a very limited role in treating childhood leukemia. Because leukemia cells spread throughout the bone marrow and to many other organs through the blood, it's not possible to cure this type of cancer by surgery. Aside from a possible [lymph node biopsy](#), surgery rarely has any role even in the diagnosis, since a bone marrow aspirate and biopsy can usually diagnose leukemia.

Often before [chemotherapy](#) is about to start, surgery is needed to insert a small plastic tube, called a [central venous catheter or venous access device \(VAD\)](#), into a large blood vessel. The end of the tube stays just under the skin or sticks out in the chest area or upper arm. The VAD is left in place during treatment to give intravenous (IV) drugs such as chemotherapy and to take blood samples. This lowers the number of needle sticks needed during treatment. It's very important for parents to learn how to care for the catheter to keep it from getting infected.

In cases where a boy with leukemia has a relapse of the disease in a testicle, surgery may sometimes be done to remove the testicle (along with giving [chemotherapy](#) to treat the rest of the body).

For more information on surgery as a treatment for cancer, see [Cancer Surgery](#).

- [References](#)

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Radiation Therapy for Childhood Leukemia

Radiation therapy uses high-energy radiation to kill cancer cells. It is not always needed to treat leukemia, but it can be used in different situations:

- It is sometimes used to try to prevent or treat the spread of leukemia to the brain or treat the testicles if they are involved by leukemia cells.
- It can be used (rarely) to treat a tumor that is pressing on the trachea (windpipe). But chemotherapy is often used instead, as it may work more quickly.
- Radiation to the whole body is often an important part of treatment before a bone marrow or peripheral blood stem cell transplant (see [High-Dose Chemotherapy and Stem Cell Transplant](#)).

External beam radiation therapy, in which a machine delivers a beam of radiation to a specific part of the body, is the type of radiation used most often for childhood leukemia. Before treatment starts, the radiation team will take careful body measurements to determine the correct angles for aiming the radiation beams and the proper dose of radiation.

The treatment itself is much like getting an x-ray, but the radiation is more intense. It is painless, but some younger children may need to be sedated to make sure they don't move during the treatment. Each treatment lasts only a few minutes, although the setup time – getting your child into place for treatment – usually takes longer.

Possible side effects of radiation

The possible short-term sideeffects depend on where the radiation is aimed. Sunburn-like skin changes and hair loss in the treated area are possible. Radiation to the abdomen can sometimes cause nausea, vomiting, or diarrhea. For radiation that includes large parts of the body, the effects may include fatigue and an increased risk of infection.

Longer-term side effects are also possible and are described in [What Happens After Treatment for Childhood Leukemia?](#)

More information on radiation therapy can be found in the [Radiation Therapy](#) section of our website.

- [References](#)

[See all references for Leukemia in Children](#)

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Chemotherapy for Childhood Leukemia

Chemotherapy (chemo) is the main treatment for nearly all childhood leukemias. This is treatment with anti-cancer drugs that are given into a vein, into a muscle, into the cerebrospinal fluid (CSF), or taken as pills. Except when given into the CSF, chemo drugs enter the bloodstream and reach all areas of the body, making this treatment very useful for cancers such as leukemia.

The treatment of leukemia uses combinations of several chemo drugs. Doctors give chemo in cycles, with each period of treatment followed by a rest period to give the body time to recover. In general, treatment for acute myeloid leukemia (AML) uses higher doses of chemo over a shorter period of time (usually less than a year), and acute lymphocytic leukemia (ALL) treatment uses lower doses of chemo over a longer period of time (usually 2 to 3 years).

Some of the drugs used to treat childhood leukemia include:

- Vincristine (Oncovin)
- Daunorubicin, also known as daunomycin (Cerubidine)
- Doxorubicin (Adriamycin)
- Cytarabine, also known as cytosine arabinoside or ara-C (Cytosar)
- L-asparaginase (Elspar), PEG-L-asparaginase (pegaspargase, Oncaspar)
- Etoposide (VePesid, others)

- Teniposide (Vumon)
- 6-mercaptopurine (Purinethol)
- 6-thioguanine
- Methotrexate
- Mitoxantrone
- Cyclophosphamide (Cytosan)
- Prednisone
- Dexamethasone (Decadron, others)

Children will probably get several of these drugs at different times during the course of treatment, but they do not get all of them.

Possible side effects of chemotherapy

Chemo drugs attack cells that are dividing quickly, which is why they work against cancer cells. But other cells in the body, such as those in the bone marrow (where new blood cells are made), the lining of the mouth and intestines, and the hair follicles, also divide quickly. These cells can also be affected by chemotherapy, which can lead to side effects.

The [side effects of chemo](#) depend on the type and dose of drugs given and the length of treatment. These side effects can include:

- Hair loss
- Mouth sores
- Loss of appetite
- Diarrhea
- Nausea and vomiting
- Increased risk of infections (because of low white blood cell counts)
- Bruising and bleeding easily (from low platelet counts)
- Fatigue (caused by low red blood cell counts)

The problems with blood cell counts are often caused by the leukemia itself at first. They might get worse during the first part of treatment because of the chemotherapy, but they will probably improve as the leukemia cells are killed off and the normal cells in the bone marrow recover.

The side effects above usually go away when treatment is finished. There are often ways to reduce these side effects. For instance, drugs can be given to help prevent or reduce nausea and vomiting. Other drugs known as *growth factors* can be given to help keep the blood cell counts higher.

Tumor lysis syndrome is another possible side effect of chemotherapy. It can happen in patients who had large numbers of leukemia cells in the body before treatment. When chemo kills these cells, they break open and release their contents into the bloodstream. This can overwhelm the kidneys, which aren't able to get rid of all of these substances at once. Too much of certain minerals can also affect the heart and nervous system. This problem can be prevented by making sure the child gets lots of fluids during treatment and by giving certain drugs, such as bicarbonate, allopurinol, and rasburicase, which help the body get rid of these substances.

Some chemo drugs can also have specific side effects that are not listed above. Be sure to ask your child's doctor or nurse about any specific side effects you should watch for and about what you can do to help reduce these side effects.

Chemotherapy given directly into the cerebrospinal fluid (CSF) around the brain and spinal cord (known as *intrathecal chemotherapy*) can have its own side effects, although these are not common. Intrathecal chemo may cause trouble thinking or even seizures in some children.

Chemo can also cause some long-term side effects. These are discussed in [What Happens After Treatment for Childhood Leukemia?](#)

For more information on chemotherapy, see the [Chemotherapy](#) section of our website.

- [References](#)

[See all references for Leukemia in Children](#)

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Targeted Therapy for Childhood Leukemia

In recent years, new drugs that target specific parts of cancer cells have been developed. These targeted drugs work differently from standard [chemotherapy](#) drugs. They can be used instead of or along with chemo in some situations, and they have

side effects that are different (and often less severe) than chemo. Some targeted drugs can be useful in certain childhood leukemias.

BCR-ABL inhibitors for CML (and some cases of ALL)

Nearly all children with [chronic myeloid leukemia \(CML\)](#) have an abnormal chromosome in their leukemia cells known as the [Philadelphia chromosome](#). These chromosomes have a specific gene mutation known as *BCR-ABL*, which helps the leukemia cells grow.

Targeted drugs such as **imatinib (Gleevec)**, **dasatinib (Sprycel)**, and **nilotinib (Tasigna)** specifically attack cells that have this gene mutation. These drugs are very effective at controlling the leukemia for long periods of time in most children, although it's not yet clear if the drugs can help cure CML.

A small number of children with [acute lymphocytic leukemia \(ALL\)](#) also have the Philadelphia chromosome in their leukemia cells. Studies have shown that their outcome is improved when these drugs are given along with chemotherapy drugs.

These drugs are taken daily as pills. Possible side effects include diarrhea, nausea, muscle pain, fatigue, and skin rashes. These are generally mild. A common side effect is swelling around the eyes or in the hands or feet. Some studies suggest this fluid buildup may be caused by the drugs' effects on the heart. Other possible side effects include lower red blood cell and platelet counts at the start of treatment. These drugs might also slow a child's growth, especially if used before puberty.

Gemtuzumab ozogamicin (Mylotarg) for AML

This is a targeted therapy that consists of a monoclonal antibody (a manmade immune protein) linked to a chemotherapy drug. The antibody acts like a homing signal, bringing the chemo drug to the leukemia cells, where it enters the cells and kills them when they try to divide into new cells.

This drug can be used to treat some children with [acute myeloid leukemia \(AML\)](#) that has come back after treatment or is no longer responding to treatment. It is given as an infusion into a vein (IV), typically for 3 doses, with 2 days in between each dose.

The most common side effects are fever, nausea and vomiting, low levels of blood cells (with increased risks of infection, bleeding, and fatigue), swelling and sores in the mouth, constipation, rash, and headaches. Less common but more serious side effects

can include:

- Severe liver damage, including veno-occlusive disease (blockage of veins in the liver)
- Reactions during the infusion (similar to an allergic reaction). Your child will likely be given medicines before each infusion to help prevent this.
- Serious or life-threatening infections, especially in people who have already had a stem cell transplant
- Changes in the rhythm of the heart

Other targeted drugs are now being tested in [clinical trials](#) as well.

For more general information on targeted drugs, see [Targeted Therapy](#).

- [References](#)

[See all references for Leukemia in Children](#)

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Immunotherapy for Childhood Leukemia

Immunotherapy is the use of medicines to help a patient's own immune system recognize and destroy cancer cells more effectively. Several types of immunotherapy are being studied for use against childhood leukemia, and some are now coming into use.

Chimeric antigen receptor (CAR) T-cell therapy

For this treatment, immune cells called *T cells* are removed from the child's blood and genetically altered in the lab to have specific receptors (called *chimeric antigen receptors*, or CARs) on their surface. These receptors can attach to proteins on leukemia cells. The T cells are then multiplied in the lab and given back into the child's

blood, where they can seek out the leukemia cells and attack them.

Tisagenlecleucel (Kymriah) is a type of CAR T-cell therapy that targets the CD19 protein on certain leukemia cells. It can be used to treat childhood acute lymphoblastic leukemia (ALL) that has come back after treatment or that is no longer responding to treatment.

To make this treatment, T cells are removed from the child's blood during a process called leukapheresis. Blood is removed through an IV line and goes into a machine that removes the T cells. The remaining blood then goes back into the body. This typically takes a few hours, and it might need to be repeated. The cells are then frozen and sent to a lab, where they are turned into CAR T cells and are multiplied. This process can take a few weeks.

For the treatment itself, the child typically gets chemotherapy for a few days to help prepare the body. Then they get the CAR T cells as an infusion into a vein. Because this treatment can have serious side effects (see below), it is only given in medical centers that have special training with this treatment.

In most children who have had this treatment, the leukemia could no longer be detected within a few months of treatment, although it's not yet clear if this means that they have been cured.

Possible side effects

This treatment can have serious or even life-threatening side effects, which is why it needs to be given in a medical center that has special training in its use.

Cytokine release syndrome (CRS): CRS happens when T cells release chemicals (cytokines) that ramp up the immune system. This can happen within a few days to weeks after treatment, and can be life-threatening. Symptoms can include:

- High fever and chills
- Trouble breathing
- Severe nausea, vomiting, and/or diarrhea
- Severe muscle or joint pain
- Feeling dizzy or lightheaded

Nervous system problems: This drug can have serious effects the nervous system, which can result in symptoms such as:

- Headaches

- Changes in consciousness
- Confusion or agitation
- Seizures
- Trouble speaking and understanding
- Loss of balance

Other serious side effects: Other possible side effects can include:

- Serious infections
- Low blood cell counts, which can increase the risk of infections, fatigue, and bruising or bleeding

It's very important to report any side effects to the health care team right away, as there are often medicines that can help treat them.

Other types of immunotherapy are also being studied for use against leukemia (some of which are described in [What's New in Childhood Leukemia Research and Treatment?](#)).

- [References](#)

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High-dose Chemotherapy and Stem Cell Transplant for Childhood Leukemia

A stem cell transplant (SCT) can sometimes be used for children whose chances of being cured are poor with standard or even intense [chemotherapy](#). SCT lets doctors use even higher doses of chemotherapy than a child could normally tolerate.

High-dose chemotherapy destroys the bone marrow, which is where new blood cells are formed. This could lead to life-threatening infections, bleeding, and other problems caused by low blood cell counts. A stem cell transplant is given after the chemo to restore the blood-forming stem cells in the bone marrow.

The blood-forming stem cells used for a transplant can come either from the blood or

from the bone marrow. Sometimes stem cells from a baby's umbilical cord blood are used.

Allogeneic stem cell transplant

For childhood leukemias, the type of transplant used is known as an *allogeneic stem cell transplant*. In this type of transplant, the blood-forming stem cells are donated from another person.

The donor's tissue type (also known as the *HLA type*) should match the patient's tissue type as closely as possible to help prevent the risk of major problems with the transplant. Tissue type is based on certain substances on the surface of cells in the body. The closer the tissue match between the donor and the recipient, the better the chance the transplanted cells will "take" and begin making new blood cells.

The donor is usually a brother or sister with the same tissue type as the patient. Rarely, it can be an HLA-matched, unrelated donor – a stranger who has volunteered to donate blood-forming stem cells. Sometimes umbilical cord stem cells are used. These stem cells come from blood drained from the umbilical cord and placenta after a baby is born and the umbilical cord is cut. (This blood is rich in stem cells.) Whatever their source, the stem cells are then frozen and stored until they are needed for the transplant.

To learn about how a stem cell transplant is done, see [Stem Cell Transplant \(Peripheral Blood, Bone Marrow, and Cord Blood Transplants\)](#).

When stem cell transplant (SCT) might be used

Acute lymphocytic leukemia (ALL): In ALL, SCT might be used for a child whose leukemia doesn't respond well to initial treatment or relapses (comes back) early after going into remission. It's less clear if SCT should be used for children whose ALL relapses more than 6 months after finishing the initial chemotherapy. These children will often do well with another round of standard dose chemotherapy.

SCT may also be recommended for children with some less common forms of ALL, such as those whose leukemias have the Philadelphia chromosome or those with T-cell ALL that doesn't respond well to initial treatment.

Acute myelogenous leukemia (AML): Because AML relapses more often than ALL, many doctors recommend SCT for children with AML right after they have gone into remission, if the child has a brother or sister with the same tissue type who can donate stem cells for the transplant. This is especially true if there is a very high risk of relapse

(as with some subtypes of AML or when there are certain chromosome changes in the cells). There is still some debate about which children with AML need this type of intensive treatment.

If a child with AML relapses after his or her first round of standard chemotherapy, most doctors will recommend SCT as soon as the child goes into remission again.

In either case, it is important that the leukemia is in remission before getting a stem cell transplant. Otherwise, the leukemia is more likely to return.

Other leukemias: SCT might also offer the best chance to cure some less common types of childhood leukemia, such as juvenile myelomonocytic leukemia (JMML) and chronic myelogenous leukemia (CML). For CML, newer targeted therapies are likely to be used first for most children, but a transplant might still be needed at some point.

Practical points

A stem cell transplant is a complex treatment that can cause life-threatening side effects. If the doctors think your child can benefit from a transplant, the best place to have this done is at a nationally recognized cancer center where the staff has experience with the procedure and with managing the recovery period.

A stem cell transplant often requires a long hospital stay and can be very expensive (often costing well over \$100,000). Be sure to get a written approval from your insurer before treatment if it is recommended for your child. Even if the transplant is covered by your insurance, your co-pays or other costs could easily amount to many thousands of dollars. It's important to find out what your insurer will cover before the transplant to get an idea of what you might have to pay.

Possible side effects of stem cell transplant

The possible side effects from SCT are generally divided into short and long-term effects.

Short-term side effects

The early complications and side effects are basically those caused by high-dose chemotherapy (see [Chemotherapy](#)), but they can be more severe. They can include:

- Low blood cell counts (with fatigue and an increased risk of infection and bleeding)
- Nausea and vomiting

- Loss of appetite
- Mouth sores
- Diarrhea
- Hair loss

One of the most common and serious short-term effects is the increased risk of serious infections. Antibiotics are often given to try to prevent this from happening. Other side effects, like low red blood cell and platelet counts, may require blood product transfusions or other treatments.

Long-term and late side effects

Some complications and side effects can last for a long time or might not occur until months or years after the transplant. These can include:

- Graft-versus-host disease (see below)
- Radiation damage to the lungs
- Problems with the thyroid or other hormone-making glands
- Problems with fertility
- Damage to bones or problems with bone growth
- Development of another cancer (including leukemia) years later

Graft-versus-host disease (GVHD) is one of the most serious complications of allogeneic stem cell transplants. This happens when the donor immune system cells attack the patient's own cells. GVHD can be acute or chronic, based on how soon after the transplant it begins.

The parts of the body most often affected by GVHD include the skin, liver, and digestive tract. The most common symptoms are severe skin rashes and severe diarrhea. If the liver is affected, the damage can lead to jaundice (yellowing of the skin and eyes) or even liver failure. GVHD can also cause lung damage, leading to problems breathing. The patient may feel weak, become tired easily, and have nausea, dry mouth, and muscle aches.

In severe cases, GVHD can be life-threatening. Drugs that weaken the immune system are often given as a part of the transplant to try to prevent GVHD, although they can have their own side effects.

On the good side, GVHD can lead to graft-versus-leukemia activity, in which any remaining leukemia cells are killed by the donor immune cells.

Be sure to talk to your child's doctor before the transplant to learn about possible long-term effects your child might have. More information on long-term effects can be found

in the section [What Happens After Treatment for Childhood Leukemia?](#)

To learn more about stem cell transplants, see [Stem Cell Transplant \(Peripheral Blood, Bone Marrow, and Cord Blood Transplants\)](#).

- [References](#)

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Treatment of Children With Acute Lymphocytic Leukemia (ALL)

The main treatment for children with acute lymphocytic leukemia (ALL) is [chemotherapy](#), usually in 3 main phases:

- Induction
- Consolidation (also called *intensification*)
- Maintenance

When leukemia is diagnosed, there are usually about 100 billion leukemia cells in the body. Killing 99.9% of these leukemia cells during the 1-month induction treatment is enough to achieve a remission, but it still leaves about 100 million leukemia cells in the body. These also must be destroyed. An intensive 1- to 2-month program of consolidation treatment and about 2 years of maintenance chemotherapy helps destroy the remaining cancer cells.

As mentioned earlier, children with ALL are typically divided into [standard-risk, high-risk, or very high-risk groups](#) to make sure that the correct types and doses of drugs are given. Treatment may be more or less intense, depending on the risk group.

Induction

The goal of induction chemotherapy is to achieve a *remission*. This means that

leukemia cells are no longer found in bone marrow samples, the normal marrow cells return, and the blood counts become normal. (A remission is not necessarily a cure.)

More than 95% of children with ALL enter remission after 1 month of induction treatment. This first month is intense and requires prolonged hospital stays for treatment and frequent visits to the doctor. Your child may spend some or much of this time in the hospital, because serious [infections](#) or other complications can occur. It is very important to take all medicines as prescribed. Sometimes complications can be serious enough to be life-threatening, but in recent years, advances in supportive care (nursing care, nutrition, antibiotics, red blood cell and platelet transfusions as needed, etc.) have made these much less common than in the past.

Children with standard-risk ALL often receive 3 drugs for the first month of treatment. These include the chemotherapy drugs L-asparaginase and vincristine, and a steroid drug (usually dexamethasone). For children in high-risk groups, a fourth drug in the anthracycline class (daunorubicin is the one most often used) is typically added. Other drugs that may be given early are methotrexate and/or 6-mercaptopurine.

Intrathecal chemotherapy: All children also need chemotherapy into the cerebrospinal fluid (CSF) to kill any leukemia cells that might have spread to the brain and spinal cord. This treatment, known as *intrathecal* chemotherapy, is given through a [lumbar puncture \(spinal tap\)](#). It is usually given twice (or more if the leukemia is high risk or leukemia cells have been found in the CSF) during the first month and 4 to 6 times during the next 1 or 2 months. It is then repeated less often during the rest of treatment. Usually, methotrexate is the drug used for intrathecal chemotherapy. Hydrocortisone (a steroid) and cytarabine (ara-C) may be added, particularly in high-risk children.

Along with intrathecal therapy, some high-risk patients (for example, those with T-cell ALL) and those with many leukemia cells in their CSF when the leukemia is diagnosed may be given radiation therapy to the brain. This was more common in the past, but recent studies have found that many children even with high-risk ALL may not need radiation therapy if they are given more intensive chemotherapy. Doctors try to avoid giving radiation to the brain if possible, especially in younger children, because no matter how low the dose is kept, it can cause problems with thinking, growth, and development.

A possible side effect of intrathecal chemotherapy is seizures during treatment, which happen in a small percentage of children. Children who develop seizures are treated with drugs to prevent them.

Consolidation (intensification)

The next, and usually more intense, consolidation phase of chemotherapy typically lasts about 1 to 2 months. This phase reduces the number of leukemia cells still in the body. Several chemo drugs are combined to help prevent the remaining leukemia cells from developing resistance. Intrathecal therapy (as described above) is continued at this time.

Children with standard-risk ALL are usually treated with drugs such as methotrexate and 6-mercaptopurine or 6-thioguanine, but regimens differ among cancer centers. Vincristine, L-asparaginase, and/or prednisone may also be added.

Children with high-risk leukemia generally receive more intense chemotherapy. Extra drugs such as L-asparaginase, doxorubicin (Adriamycin), etoposide, cyclophosphamide, and cytarabine (ara-C) are often used, and dexamethasone is substituted for prednisone. There may be a second round of intense chemotherapy with the same drugs.

Children with Philadelphia chromosome-positive ALL may benefit from the addition of a [targeted drug](#) such as imatinib (Gleevec) or from a [stem cell transplant](#) at this time.

Maintenance

If the leukemia remains in remission after induction and consolidation, maintenance therapy can begin. Most treatment plans use daily 6-mercaptopurine and weekly methotrexate, given as pills, often along with vincristine, which is given intravenously, and a steroid (prednisone or dexamethasone). These latter 2 drugs are given for brief periods every 4 to 8 weeks. Other drugs may be added depending on the type of ALL and the risk of recurrence.

During the first few months of maintenance, most treatment plans include 1 or 2 repeat intensified treatments similar to the initial induction. These 4-week intensifications are called *re-induction* or *delayed intensification*.

Some children at higher risk may receive more intense maintenance chemotherapy and intrathecal therapy.

The total length of therapy (induction, consolidation, and maintenance) for most ALL treatment plans is 2 to 3 years. Because boys are at higher risk for relapse than girls, many doctors favor giving them several more months of treatment.

Treatment of residual disease

These treatment plans may change if the leukemia doesn't go into remission during induction or consolidation. The doctor will probably check the child's bone marrow soon after treatment starts to see if the leukemia is going away. If not, treatment may be more intense or prolonged.

If the leukemia seems to have gone away by standard lab tests, the doctor may do more [sensitive tests](#) to look for even small numbers of remaining leukemia cells. If any are found, then chemotherapy again may be intensified or prolonged.

Treatment of recurrent ALL

If the ALL recurs (comes back) at some point during or after treatment, the child will most likely be treated again with [chemotherapy](#). Much of the treatment strategy depends on how soon the leukemia returns after the first treatment. If the relapse occurs after a long time, the same drugs might still be effective, so the same or similar treatment may be used to try to get the leukemia into a second remission.

If the time interval is shorter, more aggressive chemotherapy with other drugs may be needed. The most commonly used chemo drugs are vincristine, L-asparaginase, anthracyclines (doxorubicin, daunorubicin, or mitoxantrone), cyclophosphamide, cytarabine (ara-C), and epipodophyllotoxins (etoposide or teniposide). The child will also receive a steroid (prednisone or dexamethasone). Intrathecal chemotherapy will also be given.

For children whose leukemia comes back within 6 months of starting treatment or for children with T-cell ALL who relapse, a [stem cell transplant](#) may be considered, especially if the child has a brother or sister who is a good tissue type match. Stem cell transplants may also be used for other children who relapse after a second course of chemotherapy.

Some children have an *extramedullary relapse*, meaning that leukemia cells are found in one part of the body (such as the cerebrospinal fluid [CSF] or the testicles) but are not detectable in the bone marrow. In addition to intensive chemotherapy as described above, children with spread to the CSF may get more intense intrathecal chemotherapy, sometimes with [radiation](#) to the brain and spinal cord (if that area had not been already treated with radiation). Boys with relapse in a testicle may get radiation to the area, and in some cases may have the affected testicle removed by surgery.

If ALL doesn't go away completely or if it comes back after a stem cell transplant, it can be very hard to treat. For some children, newer types of [immunotherapy](#), such as CAR T-cell therapy, might be helpful.

Philadelphia chromosome-type ALL

For children with certain types of ALL, such as those with the Philadelphia chromosome or other high-risk genetic changes, standard chemotherapy for ALL (as outlined above) might not be as effective. A [stem cell transplant](#) may be advised if induction treatment puts the leukemia in remission and a suitable stem cell donor is available.

Newer, [targeted drugs](#) such as imatinib (Gleevec) and dasatinib (Sprycel) are designed to kill leukemia cells that contain the Philadelphia chromosome. These drugs are taken as pills. Adding these drugs to chemotherapy seems to help improve outcomes, according to studies done so far.

- [References](#)

[See all references for Leukemia in Children](#)

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Treatment of Children With Acute Myelogenous Leukemia (AML)

Treatment of most children with acute myelogenous leukemia (AML) is divided into 2 main phases of [chemotherapy](#):

- Induction
- Consolidation (intensification)

Compared to treatment for ALL, the treatment for AML generally uses higher doses of chemotherapy but for a shorter time. Because of the intensity of treatment and the risk of serious complications, children with AML need to be treated in [cancer centers](#) or hospitals that have experience with this disease.

Induction

Treatment for AML uses different combinations of chemo drugs than those used for

ALL. The drugs most often used are daunorubicin (daunomycin) and cytarabine (ara-C), which are each given for several days in a row. The schedule of treatment may be repeated in 10 days or 2 weeks, depending on how intense doctors want the treatment to be. A shorter time between treatments can be more effective in killing leukemia cells, but it can also cause more severe side effects.

If the doctors think that the leukemia might not respond to just 2 drugs alone, they may add etoposide and/or 6-thioguanine. Children with very high numbers of white blood cells or whose leukemia has certain chromosome abnormalities may fall into this group.

Treatment with these drugs is repeated until the bone marrow shows no more leukemia. This usually occurs after 2 or 3 cycles of treatment.

Preventing relapse in the central nervous system: Most children with AML will also get intrathecal chemotherapy (given directly into the cerebrospinal fluid, or CSF) to help prevent leukemia from relapsing in the brain or spinal cord. Radiation therapy to the brain is used less often.

Consolidation (intensification)

About 85% to 90% of children with AML go into remission after induction therapy. This means no signs of leukemia are detected using standard lab tests, but it does not necessarily mean that the leukemia has been cured.

Consolidation (intensification) begins after the induction phase. The purpose is to kill any remaining leukemia cells by using more intensive treatment.

Some children have a brother or sister who would be a good stem cell donor. For these children, a [stem cell transplant](#) is often recommended once the leukemia is in remission, especially if the AML has some poorer [prognostic factors](#). Most studies have found this improves the chance for long-term survival over chemotherapy alone, but it is also more likely to cause serious complications. For children with good prognostic factors, some doctors may recommend just giving intensive [chemotherapy](#), and reserving the stem cell transplant in case the AML relapses.

For most children without a good stem cell donor, consolidation consists of the chemotherapy drug cytarabine (ara-C) in high doses. Daunorubicin may also be added. It is usually given for at least several months.

Intrathecal chemotherapy (into the cerebrospinal fluid) is usually given every 1 to 2 months for as long as intensification continues.

Maintenance chemotherapy is not needed for children with AML (other than those with APL).

An important part of treatment for AML is supportive care (proper nursing care, nutritional support, antibiotics, and blood transfusions). The intense treatment needed for AML usually destroys much of the bone marrow (causing severe shortages of blood cells) and can cause other serious complications. Without antibiotic treatment of [infections](#) or [transfusion support](#), the current high remission rates would not be possible.

Refractory or recurrent AML

Less than 15% of children have *refractory AML* (leukemia that does not respond to initial treatment). These leukemias are often very hard to cure, and doctors may recommend a [stem cell transplant](#) if it can be done.

Generally, the outlook for a child whose AML relapses (comes back) after treatment is slightly better than if the AML never went into remission, but this depends on how long the initial remission was. In more than half of cases of relapse, the leukemia can be put into a second remission with more chemotherapy. The chance of getting a second remission is better if the first remission lasted for at least a year, but long-term second remissions are rare without a stem cell transplant. Many different combinations of standard chemo drugs have been used in these situations, but the results have been mixed.

Another option for some children with refractory or recurrent AML is treatment with the [targeted drug](#) gemtuzumab ozogamicin (Mylotarg).

Most children whose leukemia has relapsed are good candidates for clinical trials testing new treatment regimens. The hope is that some sort of a remission can be attained so that a stem cell transplant can be considered. Some doctors may advise a stem cell transplant even if there is no remission. This can sometimes be successful.

- [References](#)

[See all references for Leukemia in Children](#)

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Treatment of Children With Acute Promyelocytic Leukemia (APL)

Treatment of acute promyelocytic leukemia (APL), the M3 subtype of acute myeloid leukemia (AML), differs from the usual AML treatment. This leukemia usually responds well to treatment, which is given in 3 phases:

- Induction
- Consolidation (also called *intensification*)
- Maintenance

Induction

Many children with APL have bleeding and blood-clotting issues at the time APL is diagnosed, which can cause serious problems during early treatment. Because of this, children with APL must be treated carefully and are often given an anticoagulant (“blood thinner”) to help prevent or treat these problems.

Children with APL get a non-chemotherapy drug similar to vitamin A called *all-trans retinoic acid* (ATRA). ATRA alone can often put APL into remission, but combining it with [chemotherapy](#) (usually daunorubicin and cytarabine) gives better long-term results. APL rarely spreads to the brain or spinal cord, so intrathecal chemotherapy is usually not needed.

Along with the possible side effects from the chemotherapy drugs, ATRA can cause a problem called *differentiation syndrome* (formerly known as *retinoic acid syndrome*). This can include breathing problems from fluid buildup in the lungs, low blood pressure, kidney damage, and severe fluid buildup elsewhere in the body. It can often be treated by stopping the ATRA for a while and giving a steroid such as dexamethasone.

Consolidation (intensification)

This is usually similar to induction, using both ATRA and chemotherapy (daunorubicin, sometimes along with cytarabine). Because of the success of this treatment, a stem cell transplant is not usually advised as long as the leukemia stays in remission.

Maintenance

Children with APL may get maintenance therapy with ATRA (often with the chemo drugs methotrexate and 6-mercaptopurine) for about a year.

Relapsed APL

If the leukemia comes back after treatment, most often it can be put into a second remission. Arsenic trioxide is a drug that is very effective in this setting, although it can sometimes cause problems with heart rhythms. Children getting this drug need to have their blood mineral levels watched closely. ATRA plus chemotherapy may be another option. A [stem cell transplant](#) may be considered once a second remission is achieved.

- [References](#)

[See all references for Leukemia in Children](#)

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Treatment of Children With Juvenile Myelomonocytic Leukemia (JMML)

JMML is fairly rare, so it has been hard to study, and there is no single best chemotherapy treatment for this leukemia. A [stem cell transplant](#) is the treatment of choice when possible, as it offers the best chance to cure JMML. About half of the children with JMML who get a stem cell transplant are still free of leukemia after several years. Sometimes, even if the leukemia recurs, a second stem cell transplant can be helpful.

Because JMML is hard to treat with current chemo drugs, taking part in a [clinical trial](#) looking at newer drugs may be a good option for children who can't get a stem cell transplant.

- [References](#)

[See all references for Leukemia in Children](#)

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Treatment of Children With Chronic Myelogenous Leukemia (CML)

This leukemia is rare in children, but it does occur. Treatment in children is similar to what is used for adults.

[Targeted drugs](#), such as imatinib (Gleevec), dasatinib (Sprycel), and nilotinib (Tasigna), attack cells with the Philadelphia chromosome, which is the key gene abnormality in CML cells. These drugs are usually very good at controlling CML, often for long periods of time and with less severe side effects than chemotherapy drugs. However, these drugs do not seem to cure CML when used alone, and they must be taken every day.

Imatinib is usually the drug tried first. If it doesn't work or if it becomes less effective over time, another drug may be tried. If targeted drugs are no longer helpful, high-dose chemotherapy with a [stem cell transplant](#) offers the best chance for a cure. Doctors are now studying whether adding targeted drugs to stem cell transplant regimens can help increase cure rates.

For more information on CML and its treatment, see [Chronic Myeloid Leukemia](#).

- [References](#)

[See all references for Leukemia in Children](#)

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