



Leukemia – Acute Lymphocytic (Adults)

What is cancer?

The body is made up of trillions of living cells. Normal body cells grow, divide to make new cells, and die in an orderly fashion. During the early years of a person's life, normal cells divide faster to allow the person to grow. After the person becomes an adult, most cells divide only to replace worn-out or dying cells or to repair injuries.

Cancer begins when cells in a part of the body start to grow out of control. There are many kinds of cancer, but they all start because of out-of-control growth of abnormal cells.

Cancer cell growth is different from normal cell growth. Instead of dying, cancer cells continue to grow and form new, abnormal cells. Cancer cells can also invade (grow into) other tissues, something that normal cells cannot do. Growing out of control and invading other tissues are what makes a cell a cancer cell.

Cells become cancer cells because of damage to DNA. DNA is in every cell and directs all its actions. In a normal cell, when DNA gets damaged the cell either repairs the damage or the cell dies. In cancer cells, the damaged DNA is not repaired, but the cell doesn't die like it should. Instead, this cell goes on making new cells that the body does not need. These new cells will all have the same damaged DNA as the first cell does.

People can inherit damaged DNA, but most DNA damage is caused by mistakes that happen while the normal cell is reproducing or by something in our environment. Sometimes the cause of the DNA damage is something obvious, like cigarette smoking. But often no clear cause is found.

In most cases the cancer cells form a tumor. Some cancers, like leukemia, rarely form tumors. Instead, these cancer cells involve the blood and blood-forming organs and circulate through other tissues where they grow.

Cancer cells often travel to other parts of the body, where they begin to grow and form new tumors that replace normal tissue. This process is called *metastasis*. It happens when the cancer cells get into the bloodstream or lymph vessels of our body.

No matter where a cancer may spread, it is always named for the place where it started. For example, breast cancer that has spread to the liver is still called breast cancer, not liver cancer. Likewise, prostate cancer that has spread to the bone is metastatic prostate cancer, not bone cancer.

Different types of cancer can behave very differently. For example, lung cancer and breast cancer are very different diseases. They grow at different rates and respond to different treatments. That is why people with cancer need treatment that is aimed at their particular kind of cancer.

Not all tumors are cancerous. Tumors that aren't cancer are called *benign*. Benign tumors can cause problems – they can grow very large and press on healthy organs and tissues. But they cannot grow into (invade) other tissues. Because they can't invade, they also can't spread to other parts of the body (metastasize). These tumors are almost never life threatening.

What is acute lymphocytic leukemia?

Acute lymphocytic leukemia (ALL), also called *acute lymphoblastic leukemia*, is a cancer that starts from the early version of white blood cells called *lymphocytes* in the bone marrow (the soft inner part of the bones, where new blood cells are made).

Leukemia cells usually invade the blood fairly quickly. They can then spread to other parts of the body, including the lymph nodes, liver, spleen, central nervous system (brain and spinal cord), and testicles (in males). Other types of cancer also can start in these organs and then spread to the bone marrow, but these cancers are not leukemia.

The term “acute” means that the leukemia can progress quickly, and if not treated, would probably be fatal within a few months. *Lymphocytic* means it develops from early (immature) forms of lymphocytes, a type of white blood cell. This is different from acute myeloid leukemia (AML), which develops in other blood cell types found in the bone marrow. For more information on AML, see our document *Leukemia--Acute Myeloid*.

Other types of cancer that start in lymphocytes are known as *lymphomas* (non-Hodgkin lymphoma or Hodgkin disease). The main difference between these types of cancers is that leukemias like ALL mainly affects the bone marrow and the blood, and may spread to other places, while lymphomas mainly affect the lymph nodes or other organs but may involve the bone marrow. Sometimes cancerous lymphocytes are found in both the bone marrow and lymph nodes when the cancer is first diagnosed, which can make it hard to tell if the cancer is leukemia or lymphoma. If more than 25% of the bone marrow is replaced by cancerous lymphocytes, the disease is usually considered leukemia. The size

of lymph nodes is also important. The bigger they are, the more likely the disease will be considered a lymphoma. For more information on lymphomas, see our documents *Non-Hodgkin Lymphoma* and *Hodgkin Disease*.

There are actually many types of leukemia. They differ based on what types of cells they start in, how quickly they grow, which people they affect, and how they are treated. To understand leukemia, it helps to know about the blood and lymph systems.

Normal bone marrow, blood, and lymphoid tissue

Bone marrow

Bone marrow is the soft inner part of some bones, such as the skull, shoulder blades, ribs, pelvis, and bones in the spine. The bone marrow is made up of a small number of blood stem cells, more mature blood-forming cells, fat cells, and supporting tissues that help cells grow.

Blood stem cells go through a series of changes to make new blood cells. During this process, the cells develop into 1 of the 3 main types of blood cell components:

- Red blood cells
- Platelets
- White blood cells (which include lymphocytes, granulocytes, and monocytes)

Red blood cells

Red blood cells carry oxygen from the lungs to all other tissues in the body, and take carbon dioxide back to the lungs to be removed.

Platelets

Platelets are actually cell fragments made by a type of bone marrow cell called a *megakaryocyte*. Platelets are important in plugging up holes in blood vessels caused by cuts or bruises.

White blood cells

White blood cells help the body fight infections.

Lymphocytes

These are the main cells that make up lymphoid tissue, a major part of the immune system. Lymphoid tissue is found in lymph nodes, the thymus, the spleen, the tonsils and

adenoids, and is scattered throughout the digestive and respiratory systems and the bone marrow.

Lymphocytes develop from cells called *lymphoblasts* to become mature, infection-fighting cells. The 2 main types of lymphocytes are B lymphocytes (B cells) and T lymphocytes (T cells).

- **B lymphocytes:** B lymphocytes protect the body from invading germs by maturing into plasma cells, which make proteins called antibodies. The antibodies attach to the germs (bacteria, viruses, and fungi), which helps the immune system destroy them.
- **T lymphocytes:** There are several types of T cells, each with a special job. Some T cells can destroy germs directly, while others play a role in either boosting or slowing the activity of other immune system cells.

Acute lymphocytic leukemia develops from early forms of lymphocytes. It can start in either early B cells or T cells at different stages of maturity. This is discussed in the section “How is acute lymphocytic leukemia classified?”

Granulocytes

These are white blood cells that have granules in them, which are spots that can be seen under the microscope. These granules contain enzymes and other substances that can destroy germs, such as bacteria. The 3 types of granulocytes – *neutrophils*, *basophils*, and *eosinophils* – are distinguished by the size and color of their granules.

Monocytes

These white blood cells, which are related to granulocytes, also help protect the body against bacteria. After circulating in the bloodstream for about a day, monocytes enter body tissues to become *macrophages*, which can destroy some germs by surrounding and digesting them.

Development of leukemia

Any type of early blood-forming cell of the bone marrow can turn into a leukemia cell. Once this change happens, the leukemia cells will not mature normally. The leukemia cells could reproduce quickly, and might not die when they should. Instead they survive and build up in the bone marrow. Over time, these cells spill into the bloodstream and spread to other organs, where they can keep other cells from functioning normally.

Types of leukemia

There are 4 main types of leukemia:

- Acute myeloid (or myelogenous) leukemia (AML)

- Chronic myeloid (or myelogenous) leukemia (CML)
- Acute lymphocytic (or lymphoblastic) leukemia (ALL)
- Chronic lymphocytic leukemia (CLL)

Acute leukemia versus chronic leukemia

The first factor in classifying leukemia is whether most of the abnormal cells are mature (look like normal white blood cells) or immature (look more like stem cells).

Acute leukemia: In acute leukemia, the bone marrow cells cannot mature properly. Immature leukemia cells continue to reproduce and build up. Without treatment, most people with acute leukemia would live only a few months. Some types of acute leukemia respond well to treatment, and many patients can be cured. Other types of acute leukemia have a less favorable outlook.

Chronic leukemia: In chronic leukemia, the cells can mature partly but not completely. These cells may look fairly normal, but they generally do not fight infection as well as normal white blood cells do. They also live longer, build up, and crowd out normal cells. Chronic leukemias tend to progress over a longer period of time, and most people can live for many years. But chronic leukemias are generally harder to cure than acute leukemias.

Myeloid leukemia versus lymphocytic leukemia

The second factor in classifying leukemia is the type of bone marrow cells that are affected.

Myeloid leukemia: Leukemias that start in early forms of myeloid cells – the cells that make white blood cells (other than lymphocytes), red blood cells, or platelet-making cells (megakaryocytes) – are *myeloid* leukemias (also known as *myelocytic*, *myelogenous*, or *non-lymphocytic* leukemias).

Lymphocytic leukemia: Leukemias that start in immature forms of lymphocytes are called *lymphocytic* leukemias (also known as *lymphoid* or *lymphoblastic* leukemias).

The rest of this document focuses on acute lymphocytic leukemia (ALL) in adults. For information on ALL in children, please see our document *Childhood Leukemia*. Chronic leukemias and acute myeloid leukemia of adults are discussed in other American Cancer Society documents.

What are the key statistics about acute lymphocytic leukemia?

The American Cancer Society's estimates for acute lymphocytic leukemia (ALL) in the United States for 2015 (including both children and adults) are:

- About 6,250 new cases of ALL (3,100 in males and 3,150 in females)
- About 1,450 deaths from ALL (800 in males and 650 in females)

The risk for developing ALL is highest in children younger than 5 years of age. The risk then declines slowly until the mid-20s, and begins to rise again slowly after age 50. Overall, about 4 of every 10 cases of ALL are in adults.

The average person's lifetime risk of getting ALL is less than 1 in 750. The risk is slightly higher in males than in females, and higher in whites than in African Americans.

Most cases of ALL occur in children, but most deaths from ALL (about 4 out of 5) occur in adults. Children may do better because of differences in childhood and adult ALL in the disease itself, differences in treatment (children's bodies can often handle aggressive treatment better than adult's), or some combination of these. Some information on treatment success rates for adult ALL can be found in the section "Response rates to treatment for acute lymphocytic leukemia."

What are the risk factors for acute lymphocytic leukemia?

A risk factor is something that affects your chance of getting a disease such as cancer. Some risk factors, like smoking, can be controlled. Others, like a person's age or family history, can't be changed.

But risk factors don't tell us everything. Having a risk factor, or even several risk factors, does not mean that you will definitely get the disease. And many people who get the disease may have few or no known risk factors. Even if a person has one or more risk factors and develops cancer, it is often very hard to know how much they might have contributed to the cancer.

There are only a few known risk factors for acute lymphocytic leukemia (ALL).

Radiation exposure

Being exposed to high levels of radiation is a risk factor for both ALL and acute myeloid leukemia (AML). Japanese atomic bomb survivors had a greatly increased risk of developing acute leukemia, usually within 6 to 8 years after exposure.

Treating cancer with radiation therapy also increases the risk of leukemia, although AML is more often seen than ALL. The risk seems to be higher if chemotherapy and radiation are both used in treatment.

The possible risks of leukemia from being exposed to lower levels of radiation, such as from medical imaging tests (such as x-rays) are not well-known. Exposure of a fetus to radiation within the first months of development may carry an increased risk of leukemia, but the extent of the risk is not clear.

If there is an increased risk from lower levels of radiation it is likely to be small, but to be safe, most doctors try to limit a person's exposure to radiation as much as possible.

Certain chemical exposures

The risk of ALL may be increased by exposure to certain chemotherapy drugs and certain chemicals, including benzene. Benzene is a solvent used in the rubber industry, oil refineries, chemical plants, shoe manufacturing, and gasoline-related industries, and is also present in cigarette smoke, as well as some glues, cleaning products, detergents, art supplies, and paint strippers. Chemical exposure is more strongly linked to an increased risk of AML than to ALL.

Certain viral infections

Infection with the human T-cell lymphoma/leukemia virus-1 (HTLV-1) can cause a rare type of T-cell acute lymphocytic leukemia. Most cases occur in Japan and the Caribbean area. This disease is not common in the United States.

In Africa, the Epstein-Barr virus (EBV) has been linked to Burkitt lymphoma, as well as to a form of acute lymphocytic leukemia. In the United States, EBV most often causes infectious mononucleosis ("mono").

Inherited syndromes

Acute lymphocytic leukemia does not appear to be an inherited disease. It does not seem to run in families, so a person's risk is not increased if a family member has the disease. But there are some inherited syndromes with genetic changes that seem to raise the risk of ALL. These include:

- Down syndrome
- Klinefelter syndrome
- Fanconi anemia
- Bloom syndrome

- Ataxia-telangiectasia
- Neurofibromatosis

Race/ethnicity

Acute lymphocytic leukemia is more common in whites than in African Americans, but the reasons for this are not clear.

Gender

Acute lymphocytic leukemia is slightly more common in males than in females. The reason for this is unknown.

Having an identical twin with ALL

Someone who has an identical twin who develops ALL in the first year of life has an increased risk of getting ALL.

Uncertain, unproven or controversial risk factors

Other factors that have been studied for a possible link to ALL include:

- Exposure to electromagnetic fields (such as living near power lines or using cell phones)
- Workplace exposure to diesel, gasoline, pesticides, and certain other chemicals
- Smoking
- Exposure to hair dyes

So far, none of these factors has been linked conclusively to ALL. Research in these areas continues.

Do we know what causes acute lymphocytic leukemia?

Some people with acute lymphocytic leukemia (ALL) have one or more of the known risk factors (see the section “What are the risk factors for acute lymphocytic leukemia?”), but most do not. The cause of their cancer remains unknown at this time. Even when a person has one or more risk factors, there is no way to tell whether it actually caused the cancer.

During the past few years, scientists have made great progress in understanding how certain changes in DNA can cause normal bone marrow cells to become leukemia cells. Normal human cells grow and function based mainly on the information contained in each cell's chromosomes. Chromosomes are like bundles of long molecules of DNA in each cell. DNA is the chemical that makes up our genes – the instructions for how our cells function. We look like our parents because they are the source of our DNA. But our genes affect more than the way we look.

Some genes contain instructions for controlling when our cells grow and divide. Certain genes that help cells grow and divide are called *oncogenes*. Others that slow down cell growth and division or cause them to die at the right time are called *tumor suppressor genes*.

Each time a cell prepares to divide into 2 new cells, it must make a new copy of the DNA in its chromosomes. This process is not perfect, and errors can occur that may affect genes within the DNA. Cancers can be caused by DNA mutations (changes) that turn on oncogenes or turn off tumor suppressor genes.

Translocations are the most common type of DNA change that can lead to leukemia. Human DNA is packaged in 23 pairs of chromosomes. A translocation means that DNA from one chromosome breaks off and becomes attached to a different chromosome. The point on the chromosome where the break occurs can affect genes – for example, it can turn on oncogenes or turn off genes that would normally help a cell mature.

The most common translocation in ALL in adults is known as the *Philadelphia chromosome*, which is a swap of DNA between chromosomes 9 and 22, abbreviated as t(9;22). It occurs in about 1 out of 4 adult ALL cases. Other, less common translocations are those between chromosomes 4 and 11, t(4;11), or 8 and 14, t(8;14).

Other chromosome changes such as *deletions* (the loss of part of a chromosome) and *inversions* (the rearrangement of the DNA within part of a chromosome) can also affect the development of ALL, although they are less common. In many cases of ALL, the gene changes that lead to the leukemia are not known.

Doctors are trying to figure out why these changes occur and how each of them might lead to leukemia. Not all cases of ALL have the same chromosome changes. Some changes are more common than others, and some seem to have more of an effect on a person's prognosis (outlook) than others.

Some people with certain types of cancer have inherited DNA mutations from a parent. These changes increase their risk for the disease. But ALL is very rarely caused by one of these inherited mutations.

Usually DNA mutations related to ALL occur during the person's lifetime rather than having been inherited before birth. They may result from exposure to radiation or cancer-causing chemicals, but in most cases the reason they occur is not known.

Can acute lymphocytic leukemia be prevented?

The risk of many types of cancer can be reduced with lifestyle changes to avoid certain risk factors, but there is no known way to prevent most cases of leukemia at this time.

Most people who get acute lymphocytic leukemia have no known risk factors, so there is no way to prevent these leukemias from developing

Can acute lymphocytic leukemia be found early?

For many types of cancers, diagnosis at the earliest possible stage makes treatment much more effective. The American Cancer Society recommends screening tests for early detection of certain cancers in people without any symptoms.

But at this time there are no special tests recommended to detect acute lymphocytic leukemia (ALL) early. The best way to find leukemia early is to report any possible signs or symptoms of leukemia (see the section “Signs and symptoms of acute lymphoblastic leukemia”) to the doctor right away.

Some people are known to have a higher risk of ALL (or other leukemias) because of an inherited disorder such as Down syndrome. Most doctors recommend that these people have careful, regular medical checkups. The risk of leukemia, although greater than in the general population, is still very low for most of these syndromes.

Signs and symptoms of acute lymphocytic leukemia

Acute lymphocytic leukemia (ALL) can cause many different signs and symptoms. Most of these occur in all kinds of ALL, but some are more common with certain subtypes.

Problems caused by low blood cell counts

Most signs and symptoms of ALL result from shortages of normal blood cells, which happen when the leukemia cells crowd out the normal blood-making cells in the bone marrow. These shortages show up on blood tests, but they can also cause symptoms, including:

- Feeling tired
- Feeling weak

- Feeling dizzy or lightheaded
- Shortness of breath
- Fever
- Infections that don't go away or keep coming back
- Bruising easily
- Bleeding, such as frequent or severe nosebleeds and bleeding gums

General symptoms

Patients with ALL also often have several non-specific symptoms. These can include:

- Weight loss
- Fever
- Night sweats
- Fatigue
- Loss of appetite

Of course, these are not just symptoms of ALL and are more often caused by something other than leukemia.

Swelling in the abdomen

Leukemia cells may build up in the liver and spleen, causing them to enlarge. This might be noticed as a fullness or swelling of the belly or feeling full after eating only a small amount. The lower ribs usually cover these organs, but when they are enlarged the doctor can feel them.

Enlarged lymph nodes

ALL that has spread to lymph nodes close to the surface of the body (such as on the sides of the neck, in the groin, or in underarm areas), might be noticed as lumps under the skin. Lymph nodes inside the chest or abdomen may also swell, but these can be detected only by imaging tests such as CT or MRI scans.

Bone or joint pain

Sometimes leukemia cells build up near the surface of the bone or inside the joint and cause bone or joint pain.

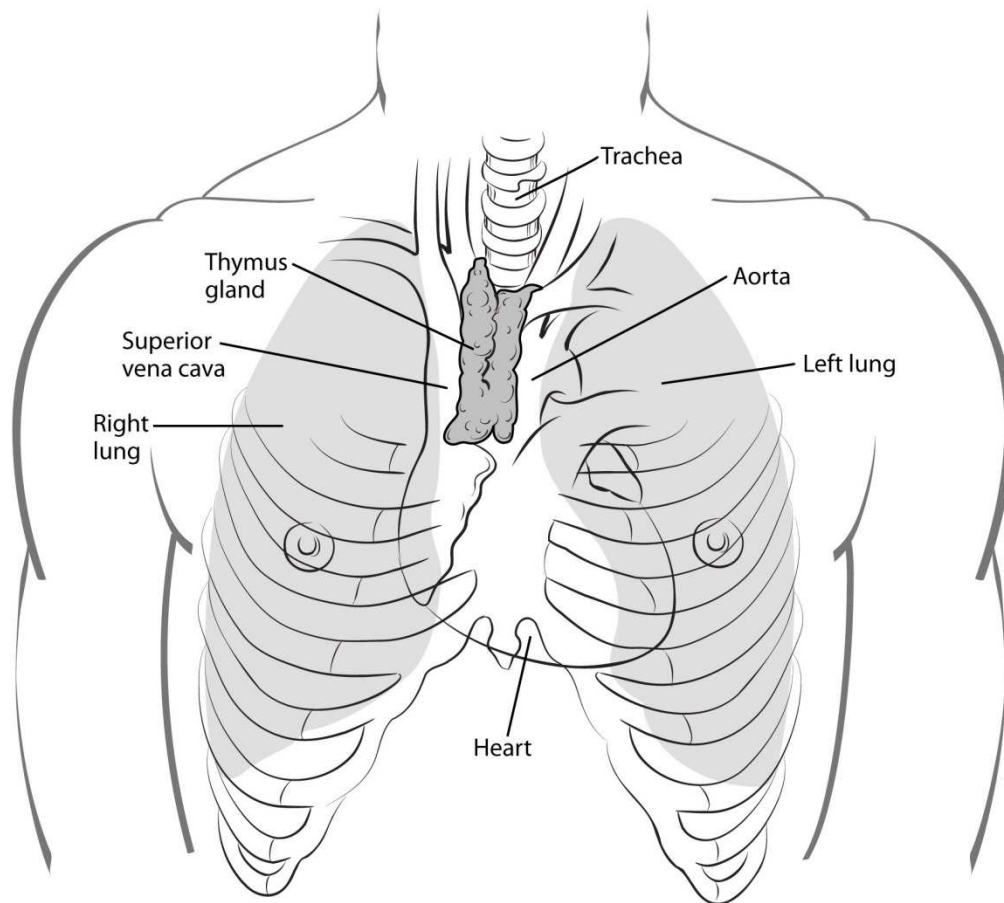
Spread to other organs

Less often, ALL spreads to other organs:

- If ALL spreads to the brain and spinal cord it can cause headaches, weakness, seizures, vomiting, trouble with balance, facial numbness, or blurred vision.
- ALL may spread to the chest cavity, where it can cause fluid buildup and trouble breathing.
- Rarely, ALL may spread to the skin, eyes, testicles, kidneys, or other organs.

Symptoms from an enlarged thymus

The T-cell subtype of ALL often affects the thymus, which is a small organ in the middle of the chest behind the sternum (breastbone) and in front of the trachea (windpipe). An enlarged thymus can press on the trachea, causing coughing or trouble breathing.



The superior vena cava (SVC), a large vein that carries blood from the head and arms back to the heart, passes next to the thymus. If the thymus is enlarged, it may press on the SVC, causing the blood to “back up” in the veins. This is known as *SVC syndrome*. It can cause swelling in the face, neck, arms, and upper chest (sometimes with a bluish-red color). It can also cause headaches, dizziness, and a change in consciousness if it affects the brain. The SVC syndrome can be life-threatening, and needs to be treated right away.

How is acute lymphocytic leukemia diagnosed?

Certain signs and symptoms can suggest that a person might have acute lymphocytic leukemia, but tests are needed to confirm the diagnosis.

Medical history and physical exam

If you have signs and symptoms that suggest you might have leukemia, the doctor will want to get a thorough medical history, including how long you have had symptoms and if you have any history of exposure to risk factors.

During the physical exam, the doctor will probably focus on any enlarged lymph nodes, areas of bleeding or bruising, or possible signs of infection. The eyes, mouth, and skin will be looked at carefully, and a thorough nervous system exam may be done. Your abdomen will be felt for signs of an enlarged spleen or liver.

Your doctor may also order tests of your blood cell counts. If the results suggest leukemia, the doctor may refer you to a *hematologist*, a doctor who specializes in treating blood disorders (including blood cancers like leukemia). This doctor may run one or more of the tests described below.

Tests used to diagnose and classify ALL

If your doctor thinks you have leukemia, he or she will need to check samples of cells from your blood and bone marrow to be sure of the diagnosis. Other tissue and cell samples may also be taken to help guide treatment.

Blood tests

Blood samples for ALL tests are generally taken from a vein in the arm.

Complete blood count (CBC) and blood cell exam (peripheral blood smear): The complete blood count (CBC) measures the numbers of red blood cells, white blood cells, and platelets. This test is often done along with a differential (or diff) which looks at the numbers of the different types of white blood cells. These tests are often the first ones done on patients with a suspected blood problem.

For the *peripheral blood smear* (sometimes just called a smear), a drop of blood is smeared across a slide and then looked at under a microscope to see how the cells look. Changes in the numbers and the appearance of the cells often help diagnose leukemia.

Most patients with ALL have too many immature white cells in their blood, and not enough red blood cells or platelets. Many of the white blood cells will be lymphoblasts (blasts), which are immature lymphocytes not normally found in the bloodstream. Lymphoblasts do not function like normal, mature white blood cells.

Even though these findings may suggest leukemia, the disease usually is not diagnosed without looking at a sample of bone marrow cells.

Blood chemistry and coagulation tests: Blood chemistry tests measure the amounts of certain chemicals in the blood, but they are not used to diagnose leukemia. In patients

already known to have ALL, these tests can help detect liver or kidney problems caused by spreading leukemia cells or the side effects of certain chemotherapy drugs. These tests also help determine if treatment is needed to correct low or high blood levels of certain minerals.

Blood coagulation tests may also be done to make sure the blood is clotting properly.

Bone marrow tests

Bone marrow aspiration and biopsy: Bone marrow samples are obtained by bone marrow aspiration and biopsy – tests usually done at the same time. The samples are usually taken from the back of the pelvic (hip) bone, although in some cases they may be taken from the sternum (breastbone) or other bones.

In bone marrow *aspiration*, you lie on a table (either on your side or on your belly). After cleaning the skin over the hip, the doctor numbs the skin and the surface of the bone by injecting a local anesthetic, which may cause a brief stinging or burning sensation. A thin, hollow needle is then inserted into the bone and a syringe is used to suck out a small amount of liquid bone marrow. Even with the anesthetic, most patients still have some brief pain when the marrow is removed.

A bone marrow *biopsy* is usually done just after the aspiration. A small piece of bone and marrow is removed with a slightly larger needle that is twisted as it is pushed down into the bone. With local anesthetic, most patients just feel some pressure and tugging from the biopsy, but a few may feel a brief pain. Once the biopsy is done, pressure will be applied to the site to help prevent bleeding.

These bone marrow tests are used to help diagnose leukemia. They may also be done again later to tell if the leukemia is responding to treatment.

Routine exams under a microscope: The bone marrow is looked at under a microscope by a pathologist (a doctor specializing in lab tests) and may be reviewed by the patient's hematologist/oncologist (a doctor specializing in cancer and blood diseases).

The doctors will look at the size, shape, and other traits of the white blood cells in the samples to classify them into specific types.

A key factor is whether the cells appear mature (look like normal blood cells), or immature (lacking features of normal blood cells). The most immature cells are called lymphoblasts (or blasts for short).

Determining what percentage of cells in the bone marrow are blasts is particularly important. A diagnosis of ALL generally requires that at least 20% to 30% of the cells in the bone marrow are blasts. Under normal circumstances, blasts are never more than 5% of bone marrow cells.

Sometimes just counting and looking at the cells doesn't provide a definite diagnosis, and other lab tests are needed.

Cytochemistry: In cytochemistry tests, cells are put on a slide and exposed to chemical stains (dyes) that react only with certain substances found in or on different kinds of cells. These stains cause color changes that can be seen under a microscope, which can help the doctor determine what types of cells are present. For instance, one stain will turn parts of acute myeloid leukemia (AML) cells black, but has no effect on ALL cells.

Flow cytometry and immunohistochemistry: These tests are used for *immunophenotyping* – classifying cells according to proteins on or in the cells. This kind of testing is very helpful in determining the exact type of leukemia present. For diagnosing leukemia, it is most often done on cells from bone marrow, but it can also be done on cells from the blood, lymph nodes, and other body fluids.

For both flow cytometry and immunohistochemistry, samples of cells are treated with antibodies that stick to certain proteins. For immunohistochemistry, the cells are examined under a microscope to see if the antibodies stuck to them and so they have those proteins, while for flow cytometry a special machine is used.

These tests are helpful in diagnosing leukemia and lymphoma. For ALL, they are most often used to help determine the exact subtype of ALL in someone already thought to have the disease based on looking at the blood and bone marrow under a microscope.

Chromosome testing

Normal human cells contain 23 pairs of chromosomes (bundles of DNA). In some cases of leukemia, the cells have chromosome changes. Sometimes a piece of a chromosome is missing – called a deletion.

More often in ALL, 2 chromosomes swap some of their DNA, so that part of one chromosome becomes attached to part of a different chromosome. This is called a *translocation*. The most common chromosome change in adult ALL is a translocation between chromosomes 9 and 22 [often written t(9;22)], which results in a shortened chromosome 22 (called the *Philadelphia chromosome*). About 1 out of 4 adults with ALL have this abnormality in their leukemia cells. This change is especially important because it can be targeted with certain drugs.

Information chromosome changes can be useful in predicting a person's outlook and response to treatment. For this reason, chromosome testing is a standard part of the work-up of ALL patients.

Cytogenetics: For this test, the cells are grown in lab dishes until they start dividing and the chromosomes can be seen under a microscope. Then the chromosomes are looked at under a microscope to detect any changes.

Because it takes time for the cells to start dividing, cytogenetic testing often takes about 2 to 3 weeks. It is often used to look at cells in the bone marrow, but it can also be used to look at cells from the blood. An advantage of cytogenetic testing is that it looks at all of the chromosomes, and the doctor doesn't have to know in advance what changes to test for.

Not all chromosome changes can be seen under a microscope. Other lab tests can often help find these changes.

Fluorescent in situ hybridization (FISH): This is another way to look at chromosomes and genes. It uses special fluorescent dyes that only attach to specific genes or parts of particular chromosomes. FISH can find most chromosome changes (such as translocations) that are visible under a microscope in standard cytogenetic tests, as well as some changes too small to be seen with usual cytogenetic testing.

FISH can be used on regular blood or bone marrow samples. Because the cells don't have to be able to divide for this test, it can also be used to look at cells from other tissues, like lymph node samples. It is very accurate and can usually provide results within a couple of days. But because FISH only tests for certain gene changes (and doesn't look at the chromosomes overall), it is best for looking for the changes that are important based on the kind of leukemia a person has.

Polymerase chain reaction (PCR): This is a very sensitive DNA test that can also find certain gene changes too small to be seen with a microscope, even if very few leukemia cells are present in a sample. Like FISH, it is used to find particular gene changes and not to look at the chromosomes overall. For ALL, it is often used to look for the gene made by the Philadelphia chromosome.

If the leukemia cells have a particular gene (or chromosome) change, PCR can be used after treatment to try to find small numbers of leukemia cells that may not be visible with a microscope.

Lumbar puncture (spinal tap)

ALL can spread to the area around the brain and spinal cord. To check for this spread, doctors remove a sample of the fluid from that area (cerebrospinal fluid or CSF) for testing.

You may lay on your side or sit up for this test. The doctor first numbs an area in the lower part of the back over the spine. A small, hollow needle is then placed between the bones of the spine and into the area around the spinal cord to collect some fluid.

A lumbar puncture can also be used to put chemotherapy drugs into the CSF to try to prevent or treat the spread of leukemia to the spinal cord and brain.

Lymph node biopsy

Removing a lymph node or part of a lymph node is often done to help diagnose lymphomas, but is only rarely needed with leukemia because the diagnosis is usually made looking at blood and bone marrow.

In this procedure, a surgeon cuts through the skin to remove all or part of a lymph node. If the node is near the skin surface, this is a simple operation that can often be done with local anesthesia, but if the node is inside the chest or abdomen, general anesthesia is used to keep you asleep during the biopsy.

When the entire lymph node is removed, it is called an *excisional lymph node biopsy*. If only part of the lymph node is removed, it is called an *incisional lymph node biopsy*.

Imaging tests

Imaging tests use x-rays, sound waves, magnetic fields, or radioactive particles to produce pictures of the inside of the body. Because leukemia does not usually form tumors, imaging tests aren't as useful as they are for other types of cancer.

Imaging tests might be done in people with ALL, but they are done more often to look for infections or other problems, rather than for the leukemia itself. In some cases they may be done to help determine the extent of the disease, if it is thought it may have spread beyond the bone marrow and blood.

X-rays

Chest x-rays may be done if the doctor suspects a lung infection. They may also be done to look for enlarged lymph nodes in the chest.

Computed tomography (CT) scan

The CT scan is a type of x-ray test that produces detailed, cross-sectional images of your body. Unlike a regular x-ray, CT scans can show the detail in soft tissues (such as internal organs).

This test can help tell if any lymph nodes or organs in your body are enlarged. It isn't usually needed to diagnose ALL, but it may be done if your doctor suspects leukemia cells are growing in an organ, like your spleen.

Instead of taking one picture, like a regular x-ray, a CT scanner takes many pictures as it rotates around you. A computer then combines these pictures into detailed images of the part of your body being studied.

Before the scan, you may be asked to drink a contrast solution and/or get an intravenous (IV) injection of a contrast dye that helps better outline abnormal areas in the body. You

may need an IV line for injecting the contrast dye. The IV injection of contrast dye can cause a feeling of flushing or warmth in the face or elsewhere. Some people are allergic and get hives or, rarely, more serious reactions like trouble breathing and low blood pressure. Be sure to tell the doctor if you have any allergies or have ever had a reaction to any contrast material used for x-rays.

A CT scanner has been described as a large donut, with a narrow table in the middle opening. You will need to lie still on the table while the scan is being done. CT scans take longer than regular x-rays, and you might feel a bit confined by the ring while the pictures are being taken.

In some cases, a CT can be used to guide a biopsy needle precisely into a suspected abnormality, such as an abscess. For this procedure, called a *CT-guided needle biopsy*, you stay on the CT scanning table while a radiologist moves a biopsy needle through the skin and toward the mass. CT scans are repeated until the needle is within the mass. A biopsy sample is then removed to be looked at under a microscope.

Sometimes a test that combines the CT scan with a PET (positron emission tomography) scan (PET/CT scan) is done. For a PET scan, a form of radioactive sugar (known as *fluorodeoxyglucose* or *FDG*) is injected into the blood. The amount of radioactivity used is low. Because cancer cells in the body grow rapidly, they absorb large amounts of the sugar. A special camera can then create a picture of areas of radioactivity in the body. The PET/CT scan lets the doctor compare areas of higher radioactivity on the PET scan with the more detailed appearance of that area on the CT. This is not often needed for patients with ALL.

Magnetic resonance imaging (MRI) scan

Like CT scans, MRI scans provide detailed images of soft tissues in the body. But MRI scans use radio waves and strong magnets instead of x-rays. The energy from the radio waves is absorbed by the body and then released in a pattern formed by the type of body tissue and by certain diseases. A computer translates the pattern into a very detailed image of parts of the body. A contrast material called *gadolinium* is often injected into a vein before the scan to better see details. This contrast material is different from the one used for CT scans.

MRI scans are very helpful in looking at the brain and spinal cord.

MRI scans take longer than CT scans – often up to an hour. You may have to lie inside a narrow tube, which is confining and can be distressing to some people. Newer, more open MRI machines may be another option. The MRI machine makes loud buzzing and clicking noises that you may find disturbing. Some places provide headphones or earplugs to help block this noise out.

Ultrasound

Ultrasound uses sound waves and their echoes to produce a picture of internal organs or masses. Usually for this test, a small, microphone-like instrument called a *transducer* is placed on the skin (which is first lubricated with gel). The transducer emits sound waves and picks up the echoes as they bounce off the organs. A computer converts the echoes into an image that is displayed on a computer screen.

Ultrasound can be used to look at lymph nodes near the surface of the body or to look for enlarged organs inside your abdomen such as the kidneys, liver, and spleen.

This is an easy test to have, and it uses no radiation. For most ultrasounds, you simply lie on a table, and a technician moves the transducer over the part of your body being looked at.

Gallium scan and bone scan

These tests are not often done for ALL, but they may be useful if you have bone pain that might be caused by either an infection or cancer in the bones.

For these tests, the doctor or nurse injects a slightly radioactive chemical into the bloodstream. The chemical collects in areas of cancer or infection, which can then be seen with a special type of camera. The images from these scans are seen as “hot spots” in the body, but they don’t provide much detail. If an area lights up on the scan, other imaging tests such as x-rays, CTs, or MRIs may be done to get a more detailed look at the area. If leukemia is a possibility, a biopsy of the area may be needed to confirm this.

How is acute lymphocytic leukemia classified?

Most types of cancers are assigned numbered stages to describe their extent in the body, based on the size of the tumor and how far the cancer has spread.

Acute lymphocytic leukemia (ALL), on the other hand, does not usually form tumor masses. It generally affects all of the bone marrow in the body and, in many cases, might have spread to other organs, such as the liver, spleen, and lymph nodes. Therefore the outlook for the patient with ALL depends on other information, such as the subtype of ALL (determined by lab tests), the age of the patient, and other lab test results.

Different systems have been used to classify ALL into subtypes.

The French-American-British (FAB) classification

In the 1970s, a group of French, American, and British (FAB) leukemia experts divided ALL into 3 subtypes (L1, L2, and L3), based on the way the leukemia cells looked under the microscope after routine staining. This system has largely been replaced, as newer lab tests now allow doctors to classify ALL more accurately.

Classification based on immunophenotype

Doctors have found that cytogenetic tests, flow cytometry, and other lab tests provide more detailed information about the subtype of ALL and the patient's prognosis. These tests help divide ALL into groups based on the *immunophenotype* of the leukemia, which takes into account:

- The type of lymphocyte (B cell or T cell) the leukemia cells come from
- How mature these leukemia cells are

These groups have largely replaced the FAB classification. The subtypes of ALL are now named as follows:

B-cell ALL

- Early pre-B ALL (also called pro-B ALL) – about 10% of cases
- Common ALL – about 50% of cases
- Pre-B ALL – about 10% of cases
- Mature B-cell ALL (Burkitt leukemia) – about 4% of cases

T-cell ALL

- Pre-T ALL – about 5% to 10% of cases
- Mature T-cell ALL – about 15% to 20% of cases

The subtypes of ALL each carry a slightly different outlook (prognosis), but other factors (like gene changes in the leukemia cells) may also have an impact. Some of these prognostic factors are listed in the next section.

Mixed lineage acute leukemias

In recent years, newer lab tests have shown that a small number of acute leukemias actually have both lymphocytic and myeloid features. Sometimes the leukemia cells have both myeloid and lymphocytic traits in the same cells. In other cases, a person may have

some leukemia cells with myeloid features and others with lymphocytic features. These types of leukemias may be called *mixed lineage leukemia*, *ALL with myeloid markers* (My+ ALL), *AML with lymphoid markers*, or *biphenotypic acute leukemia* (BAL).

Most studies suggest these leukemias tend to have a poorer outlook than standard subtypes of ALL or AML. Not all doctors agree on the best way to treat them. Intensive treatment (such as a stem cell transplant) is often used when possible, as there is a high risk of recurrence after treatment.

Prognostic factors

As leukemia treatment has improved over the years, research has focused on why some people have a better chance for cure than others. Differences in patients that affect response to treatment are called *prognostic factors*. They help doctors decide if people with a certain type of leukemia should get more or less treatment.

Age

Younger patients tend to have a better prognosis than older patients. There is no set cutoff for this, but generally those younger than 50 do better than those in their 50s, while people in their 50s do better than those in their 60s or older.

Initial white blood cell count

People with a lower WBC count (less than 30,000 for B-cell ALL and less than 100,000 for T-cell ALL) at the time of diagnosis tend to have a better prognosis.

ALL subtype

In general, T-cell ALL has a better prognosis, while mature B-cell ALL (Burkitt leukemia) has a poorer prognosis. Other subtypes of B-cell ALL fall somewhere in between. It's important to note that this doesn't apply to all cases. For instance, some subtypes of T-cell ALL have a better outlook than others.

Chromosome abnormalities

The presence of a translocation between chromosomes 4 and 11 in the leukemia cells predicts a poorer outlook, so does extra chromosome 8 or a missing chromosome 7. The presence of Philadelphia chromosome (a translocation between chromosomes 9 and 22) used to predict a poorer outlook, but not if modern targeted therapy drugs are used.

Response to chemotherapy

Patients who go into a complete remission (no visible leukemia in the bone marrow – see below) within 4 to 5 weeks of starting treatment tend to have a better prognosis than those for whom this takes longer. Patients who don't achieve a complete remission at all have a poorer outlook. The prognostic value of minimal residual disease (described below) is still being studied.

Status of acute lymphocytic leukemia after treatment

How well leukemia responds to treatment affects the patient's long-term chance for recovery.

Remission

A remission (*complete remission*) is usually defined as having no evidence of leukemia after treatment. This means the bone marrow contains fewer than 5% blast cells, the blood cell counts are within normal limits, and there are no signs or symptoms of the disease. A *molecular complete remission* means no evidence of leukemia cells in the bone marrow is found, even when using very sensitive lab tests, such as polymerase chain reaction (PCR). Even when leukemia is in remission, this does not always mean that it has been cured.

Minimal residual disease

Minimal residual disease (MRD) is a term used after treatment when leukemia cells can't be found in the bone marrow using standard lab tests (such as looking at cells under a microscope), but they can still be detected with more sensitive tests (such as flow cytometry or PCR). Patients with MRD after treatment are more likely to have the leukemia relapse (come back after treatment) and overall have a poorer outlook than those who achieve a complete remission. Doctors are looking to see if these patients could benefit from further or more intensive treatment.

Active disease

Active disease means that either there is evidence that the leukemia is still present during treatment or that the disease has relapsed (come back) after treatment. For a patient to be in relapse, more than 5% of the bone marrow must be made up of blast cells.

How is acute lymphocytic leukemia treated?

This information represents the views of the doctors and nurses serving on the American Cancer Society's Cancer Information Database Editorial Board. These views are based on their interpretation of studies published in medical journals, as well as their own professional experience.

The treatment information in this document is not official policy of the 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.

General treatment information

Adult acute lymphocytic leukemia (ALL) is not a single disease. It is really a group of related diseases, and patients with different subtypes of ALL may have different outlooks and responses to treatment.

After your cancer is diagnosed and staged, your cancer care team will discuss your treatment options with you. Choosing a treatment plan is an important decision, so it is important to take time and think about your choices. Treatment options for each patient are based on the leukemia subtype as well as certain prognostic features (described in “How is acute lymphocytic leukemia classified?”).

The main types of treatment used for ALL are:

- Chemotherapy
- Targeted therapy
- Stem cell transplant

Other treatments such as surgery, radiation therapy, or monoclonal antibodies, may be used in special circumstances.

Treatment of ALL typically lasts for about 2 years. It is often intense, especially in the first few months of treatment, so it is important that you are treated in a center that has experience with this disease.

You may have different types of doctors on your treatment team. The doctor in charge or your team will most likely be a hematologist, a doctor who specializes in treating blood diseases, including leukemia. Many other specialists may be involved in your care as well, including nurse practitioners, nurses, nutrition specialists, social workers, and other health professionals.

It is important to discuss all of your treatment options, including their goals and possible side effects, with your doctors to help make the decision that best fits your needs. It's also very important to ask questions if there is anything you're not sure about. You can find some good questions to ask in the section “What should you ask your doctor about acute lymphocytic leukemia?”

Treatment for ALL usually needs to start very soon after it is diagnosed, but if time permits, it is often a good idea to seek a second opinion. A second opinion might give you more information and help you feel confident about your chosen treatment plan.

The next few sections describe the types of treatments used for ALL. This is followed by a discussion of the typical treatment approach for ALL in adults.

Chemotherapy for acute lymphocytic leukemia

Chemotherapy (chemo) is the use of drugs to treat cancer. Most often, these drugs are injected into a vein, into a muscle, under the skin, or taken by mouth. The drugs travel through the bloodstream to reach cancer cells all over the body. This makes chemo useful for cancers such as leukemia that has spread throughout the body. Most chemo doesn't reach the area around the brain and spinal cord well, so it may need to be injected into the cerebrospinal fluid to kill cancer cells in that area. This is called *intrathecal chemo*.

Doctors give chemo in cycles, with each period of treatment followed by a rest period to allow the body time to recover. Because of its potential side effects, chemo is sometimes not recommended if you are in poor health, but older age by itself should not stop someone from getting chemo if they need it and are healthy.

Chemo for acute lymphocytic leukemia (ALL) uses a combination of anti-cancer drugs. They are given in 3 phases, usually over the course of about 2 years (see "Typical treatment of acute lymphocytic leukemia").

The most commonly used drugs include:

- Vincristine (Oncovin[®]) or liposomal vincristine (Marqibo[®])
- Daunorubicin (daunomycin or Cerubidine[®]) or doxorubicin (Adriamycin[®])
- Cytarabine (cytosine arabinoside, ara-C, or Cytosar[®])
- L-asparaginase (Elspar[®]) or PEG-L-asparaginase (pegaspargase or Oncaspar[®])
- Etoposide (VP-16)
- Teniposide (Vumon[®])
- 6-mercaptopurine (6-MP or Purinethol[®])
- Methotrexate
- Cyclophosphamide (Cytosan[®])
- Prednisone
- Dexamethasone (Decadron[®])

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

Possible side effects

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 are also likely to be affected by chemo, which can lead to side effects.

The side effects of chemo depend on the type and dose of drugs given and the length of time they are taken. Common side effects may include:

- Hair loss
- Mouth sores
- Loss of appetite
- Nausea and vomiting
- Diarrhea
- Increased risk of infections (due to low white blood cell counts)
- Easy bruising or bleeding (due to low blood platelet counts)
- Fatigue (due to low red blood cell counts)
- Numbness, tingling, or weakness in hands or feet (from nerve damage)

These side effects are usually short-term and go away once treatment is finished. There are often ways to lessen these side effects. For example, drugs can be given to help prevent or reduce nausea and vomiting. Be sure to ask your doctor or nurse about medicines to help reduce side effects, and let him or her know when you do have side effects so they can be managed effectively.

Many of the side effects of chemo are caused by low white blood cell counts. Drugs known as growth factors (G-CSF and GM-CSF, for example) may be given to speed the recovery of white blood cell counts during chemo to reduce the chance for serious infections.

Antibiotics and drugs that help prevent fungal and viral infections may be given before there are signs of infection or at the earliest sign that an infection may be developing. There are also steps that you can take to lower your risk of infection. These are discussed in our document *Infections in People With Cancer*.

Because white blood cell counts are so important during treatment, some people find it helpful to keep track of them. If you are interested in this, ask your doctor or nurse about your blood cell counts and what these numbers mean.

If your platelet counts are low, you may be given drugs or platelet transfusions to help protect against bleeding. Likewise, shortness of breath and extreme fatigue caused by low red blood cell counts may be treated with drugs or with red blood cell transfusions.

Certain drugs might cause specific side effects. For example, cytarabine (ara-C) can cause certain problems, especially when used at high doses. These can include dryness in the eyes and effects on certain parts of the brain, which can lead to problems with coordination and balance.

Other organs that could be directly damaged by certain chemo drugs include the kidneys, liver, testicles, ovaries, brain, heart, and lungs. Doctors and nurses carefully monitor treatment to reduce the risk of these side effects as much as possible. If serious side effects occur, the chemo may have to be reduced or stopped, at least for a time.

One of the most serious side effects of ALL therapy is an increased risk of getting acute myelogenous leukemia (AML) at a later time. This occurs in a small portion of patients after they have received chemo drugs such as etoposide, teniposide, cyclophosphamide, or chlorambucil. Less often, people cured of leukemia may later develop non-Hodgkin lymphoma or other cancers. Of course, the risk of getting these second cancers must be balanced against the obvious benefit of treating a life-threatening disease such as leukemia with chemotherapy.

Tumor lysis syndrome is another possible side effect of chemo. It is most common in patients who have large numbers of leukemia cells, so it is seen most often in people getting chemo for the first time. 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. Excess amounts of certain minerals may also affect the heart and nervous system. This can often be prevented by giving extra fluids during treatment and by giving certain drugs, such as allopurinol and rasburicase, which help the body get rid of these substances.

Targeted therapy for acute lymphocytic leukemia

In recent years, new drugs that target specific parts of cancer cells have been developed. These drugs work differently than standard chemotherapy (chemo) drugs. They often have different (and less severe) side effects. These drugs are often referred to as targeted therapy. Some of these drugs can be useful in certain cases of acute lymphocytic leukemia (ALL).

About 1 out of 4 adult patients with ALL have leukemia cells with the *Philadelphia chromosome*. This is an abnormal chromosome formed by the swapping of material between chromosomes 9 and 22. This forms a new gene called *BCR-ABL*. The

Philadelphia chromosome and *BCR-ABL* gene are also found in the cells of a different leukemia – chronic myeloid leukemia (CML). Cells with the *BCR-ABL* gene make an abnormal protein that helps the cells grow. Drugs have been developed to attack this protein. These drugs are called *tyrosine kinase inhibitors* (or TKIs), and include imatinib (Gleevec[®]), dasatinib (Sprycel[®]), nilotinib (Tasigna[®]), bosutinib (Bosulif[®]), and ponatinib (Iclusig[®]). Although these drugs were originally aimed at treating CML, some of them have been found to be helpful in treating patients with ALL that has the Philadelphia chromosome.

In studies of patients whose ALL cells contain the Philadelphia chromosome, adding one of these drugs to chemo help more patients go into remission after treatment. Continuing on these drugs can also help keep the leukemia from coming back.

These drugs are taken daily as pills. Common 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. Other possible side effects include lower red blood cell and platelet counts at the start of treatment. All of these side effects get worse at higher than usual doses of the drug. Other more serious side effects can occur, as well, which differ depending on which drug is used.

More information about side effects of targeted therapy drugs can be found in our document *Targeted Therapy*.

Monoclonal antibodies to treat acute lymphocytic leukemia

Antibodies are proteins made by the body's immune system to help fight infections. Man-made versions, called monoclonal antibodies, can be designed to attack a specific target, such as a substance on the surface of lymphocytes.

Blinatumomab (Blinicyto[™]) is a special kind of monoclonal antibody because it can attach to 2 different proteins at the same time. One part of blinatumomab attaches to the CD19 protein, which is found on B-cells, including some leukemia and lymphoma cells. Another part attaches to CD3, a protein found on immune cells called T cells. By binding to both of these proteins, this drug brings the cancer cells and immune cells together, which is thought to cause the immune system to attack the cancer cells.

This drug is used to treat B-cell types of ALL. It is given into a vein (IV) as a continuous infusion over 28 days. It may be repeated again for more cycles with 2 weeks off in between. Because of certain serious side effects that occur more often during the first few times it is given, the patient usually needs to be treated in a hospital or clinic for the beginning of at least the first 2 cycles.

The most common side effects are fever, headache, swelling of the feet and hands, nausea, tremor, rash, constipation, and low blood potassium levels. It can also cause low white blood cell counts, which increase the risk of serious infection.

This drug can also cause neurologic problems, such as seizures, difficulty in speaking or slurred speech, passing out, confusion, and loss of balance.

Some patients have serious reactions during the infusion of this drug. Symptoms can include feeling lightheaded or dizzy (due to low blood pressure), headache, nausea, fever or chills, shortness of breath, and/or wheezing. Let your healthcare team know if you develop any of these symptoms, as this reaction can be life-threatening. If you do have a reaction, the drug will be stopped while the reaction is treated.

Surgery for acute lymphocytic leukemia

Surgery has a very limited role in the treatment of acute lymphocytic leukemia (ALL). Because leukemia cells spread widely throughout the bone marrow and to many other organs through the blood, it is 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 of ALL, since a bone marrow aspirate and biopsy can usually diagnose leukemia.

Often before chemotherapy (chemo) 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 vein. 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 chemo and to take blood samples. This lowers the number of needle sticks needed during treatment. It is very important to learn how to care for the device to keep it from getting infected.

Ommaya reservoir

Giving chemo directly into the fluid that surrounds the brain and spinal cord (cerebrospinal fluid or CSF) is often a part of the treatment of ALL. In this treatment, called *intrathecal chemo*, the medicines can be given through a lumbar puncture (spinal tap) or through an Ommaya reservoir. An Ommaya reservoir is a dome-like device attached to a catheter. The dome part sits under the skin of the scalp, with the catheter going through a hole in the skull and into one of the cavities of the brain (a ventricle). Intrathecal chemo can be given by placing a needle through the skin and into the dome. The chemo goes through the catheter and into the CSF in the ventricle. The CSF in the ventricle circulates through the other ventricles and into the area around the brain and spinal cord. An Ommaya reservoir allows you to get intrathecal chemo without having to get repeated spinal taps. CSF can also be withdrawn from the Ommaya reservoir to check for leukemia cells and signs of infection (instead of a spinal tap).

Radiation therapy for acute lymphocytic leukemia

Radiation therapy uses high-energy radiation to kill cancer cells. It is not usually part of the main treatment for people with acute lymphocytic leukemia (ALL), but it is used in certain situations:

- Radiation is sometimes used to treat leukemia that has spread to the brain and spinal fluid or to the testicles.
- Radiation to the whole body is often an important part of treatment before a bone marrow or peripheral blood stem cell transplant (see the section “High-dose chemotherapy and stem cell transplant for acute lymphocytic leukemia”).
- Radiation is used (rarely) to help shrink a tumor if it is pressing on the trachea (windpipe) and causing breathing problems. But chemotherapy is often used instead, as it may work more quickly.
- Radiation can also be used to reduce pain in an area of bone invaded by leukemia, if chemotherapy hasn’t helped.

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 ALL. Before your treatment starts, the radiation team will take careful measurements to determine the correct angles for aiming the radiation beams and the proper dose of radiation. Radiation therapy is much like getting an x-ray, but the radiation is more intense. The procedure itself is painless. Each treatment lasts only a few minutes, although the setup time – getting you into place for treatment – usually takes longer.

The possible side effects of radiation therapy depend on the dose given and where the radiation is aimed. They include:

- Fatigue (tiredness)
- Skin changes in the treated area, which can range from mild redness to burning and peeling
- Hair loss in the area being treated
- Nausea and vomiting (more common if the abdomen/belly is being treated)
- Diarrhea (more common if the belly or pelvis is being treated)
- Lowered blood cell counts, which can lead to fatigue and shortness of breath (from low red blood cell counts) and an increased risk of infection (from low white blood cell counts)

High-dose chemotherapy and stem cell transplant for acute lymphocytic leukemia

Standard doses of chemotherapy aren't always able to cure acute lymphocytic leukemia (ALL). Even though higher doses of chemo drugs might be more effective, they are not given because they could lead to long-term severe bone marrow damage. Because the bone marrow is where new blood cells are formed, this could lead to life-threatening infections, bleeding, and other problems due to low blood cell counts.

A stem cell transplant (SCT) allows doctors to use higher doses of chemo (sometimes along with radiation) to kill the cancer cells. After these treatments are finished, the patient receives a transplant of blood-forming stem cells to restore the bone marrow.

Blood-forming stem cells used for a transplant are obtained either from the blood (for a peripheral blood stem cell transplant, or PBSCT), from the bone marrow (for a bone marrow transplant, or BMT), or from umbilical cord blood. Most often, stem cells from the blood are used.

Types of transplants

There are 2 main types of stem cell transplants:

- Allogeneic stem cell transplant – in which the stem cells come from someone else. This is the preferred type of transplant in treating ALL.
- Autologous stem cell transplant – in which the patient gets back his or her own cells

For an allogeneic transplant, the donor's tissue type (also known as the HLA type) needs to match the patient's tissue type as closely as possible to help prevent the risk of major problems with the transplant. Usually this donor is a brother or sister if they have the same tissue type as the patient. If there are no siblings with a good match, the cells may come from an HLA-matched, unrelated donor – a stranger who has volunteered to donate their cells. Some patients cannot have this kind of transplant because a matching donor isn't available. The use of allogeneic transplant is also limited by its side effects, which are often too severe for people who are older or who have other health problems.

One option that may help patients who can't have an allogeneic transplant because of age or health issues is to have a stem cell transplant that uses lower doses of chemo and radiation that don't completely destroy the cells in their bone marrow. This is known as a non-myeloablative or reduced-intensity transplant. This kind of stem cell transplant relies on the donor cells to kill the leukemia cells, instead of the chemo and radiation. This is not a standard treatment for ALL, and is being studied to determine how useful it may be.

An autologous transplant may be an option for patients who can't have an allogeneic transplant because they don't have a matched donor. The trouble with this is that

leukemia is a disease of the bone marrow and blood, so there is a danger of giving the patient back leukemia cells with the stem cells. A process called *purging* may be done in the lab to try to remove leukemia cells in the samples and lower this risk.

Practical points

Bone marrow or peripheral blood SCT is a complex treatment that can cause life-threatening side effects. If your doctor thinks you might benefit from a transplant, you should discuss what kind you will have, the possible side effects, and how long it may take for you to recover. Stem cell transplants should be done at a hospital where the staff has experience with the procedure and with managing the recovery phase. Some bone marrow transplant programs may not have experience in certain types of transplants, especially transplants from unrelated or mismatched donors.

For more information on stem cell transplants, see our document *Stem Cell Transplant (Peripheral Blood, Bone Marrow, and Cord Blood Transplants)*.

Clinical trials for acute lymphocytic leukemia

You may have had to make a lot of decisions since you've been told you have cancer. One of the most important decisions you will make is choosing which treatment is best for you. You may have heard about clinical trials being done for your type of cancer. Or maybe someone on your health care team has mentioned a clinical trial to you.

Clinical trials are carefully controlled research studies that are done with patients who volunteer for them. They are done to get a closer look at promising new treatments or procedures.

If you would like to take part in a clinical trial, you should start by asking your doctor if your clinic or hospital conducts clinical trials. You can also call our clinical trials matching service for a list of clinical trials that meet your medical needs. You can reach this service at 1-800-303-5691 or on our website at www.cancer.org/clinicaltrials. You can also get a list of current clinical trials by calling the National Cancer Institute's Cancer Information Service toll-free at 1-800-4-CANCER (1-800-422-6237) or by visiting the NCI clinical trials website at www.cancer.gov/clinicaltrials.

There are requirements you must meet to take part in any clinical trial. If you do qualify for a clinical trial, it is up to you whether or not to enter (enroll in) it.

Clinical trials are one way to get state-of-the-art cancer treatment. Sometimes they may be the only way to get access to some newer treatments. They are also the only way for doctors to find better treatments for cancer. Still, they are not right for everyone.

You can get a lot more information on clinical trials in our document called *Clinical Trials: What You Need to Know*.

Complementary and alternative therapies for acute lymphocytic leukemia

When you have cancer you are likely to hear about ways to treat your cancer or relieve symptoms that your doctor hasn't mentioned. Everyone – from friends and family to Internet groups and websites – might offer ideas for what might help you. These methods can include vitamins, herbs, and special diets, or other methods such as acupuncture or massage, to name a few.

What exactly are complementary and alternative therapies?

Not everyone uses these terms the same way, and they are used to refer to many different methods, so it can be confusing. We use complementary to refer to treatments that are used along with your regular medical care. Alternative treatments are used instead of a doctor's medical treatment.

Complementary methods: Most complementary treatment methods are not offered as cures for cancer. Mainly, they are used to help you feel better. Some methods that are used along with regular treatment are meditation to reduce stress, acupuncture to help relieve pain, or peppermint tea to relieve nausea. Some complementary methods are known to help, while others have not been tested. Some have been proven not to be helpful, and a few have even been found harmful.

Alternative treatments: Alternative treatments may be offered as cancer cures. These treatments have not been proven safe and effective in clinical trials. Some of these methods may pose danger, or have life-threatening side effects. But the biggest danger in most cases is that you may lose the chance to be helped by standard medical treatment. Delays or interruptions in your medical treatments may give the cancer more time to grow and make it less likely that treatment will help.

Finding out more

It is easy to see why people with cancer think about alternative methods. You want to do all you can to fight the cancer, and the idea of a treatment with few or no side effects sounds great. Sometimes medical treatments like chemotherapy can be hard to take, or they may no longer be working. But the truth is that most of these alternative methods have not been tested and proven to work in treating cancer.

As you consider your options, here are 3 important steps you can take:

- Look for “red flags” that may suggest fraud. Does the method promise to cure all or most cancers? Are you told not to have regular medical treatments? Is the treatment a “secret” that requires you to visit certain providers or travel to another country?
- Talk to your doctor or nurse about any method you are thinking about using.

- Contact us at 1-800-227-2345 or visit the “Complementary and Alternative Medicine” section of our website to learn more about complementary and alternative methods in general and to find out about the specific methods you are looking at.

The choice is yours

Decisions about how to treat or manage your cancer are always yours to make. If you want to use a non-standard treatment, learn all you can about the method and talk to your doctor about it. With good information and the support of your health care team, you may be able to safely use the methods that can help you while avoiding those that could be harmful.

Typical treatment of acute lymphocytic leukemia

The main treatment for acute lymphocytic leukemia (ALL) in adults involves the long-term use of chemotherapy (chemo). In the past several years, doctors have begun to use more intensive chemo regimens, which has led to more responses to treatment. But these regimens are also more likely to cause side effects, such as low white blood cell counts. Patients may need to take other drugs to help prevent or treat these side effects.

Treatment typically takes place in 3 phases:

- Induction (or remission induction)
- Consolidation (intensification)
- Maintenance

The total treatment usually takes about 2 years, with the maintenance phase taking up most of this time. Treatment may be more or less intense, depending on the subtype of ALL and other prognostic factors.

ALL can spread to the area around the brain and spinal cord. Sometimes this has already occurred at the time the ALL is first diagnosed. This spread is found when the doctor does a lumbar puncture (spinal tap) and leukemia cells are seen when the fluid is looked at under the microscope. The treatment of this is discussed below.

Even if leukemia cells are not found in the spinal fluid at diagnosis, it is possible that there were too few leukemia cells for these tests to recognize or that they could start growing on the surface of the brain and spinal cord later on. That’s why an important part of treatment for ALL is *central nervous system (CNS) prophylaxis* – treatment that is meant to ensure the leukemia does not spread to the area around the brain or spinal cord. This is also described in more detail below.

Induction

The goal of induction chemo is 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. But a remission is not necessarily a cure, as leukemia cells may still be hiding somewhere in the body.

This is a phase of intensive chemo that usually lasts for a month or so. Different combinations of chemo drugs may be used, but they typically include:

- Vincristine
- Dexamethasone or prednisone
- Doxorubicin (Adriamycin), daunorubicin, or a similar anthracycline drug

Based on the patient's prognostic factors, some regimens may also include cyclophosphamide (Cytosan), L-asparaginase, etoposide (VP-16), and/or high doses of methotrexate or cytarabine (ara-C) as part of the induction phase.

For ALL patients whose leukemia cells have the Philadelphia chromosome, a targeted drug such as imatinib (Gleevec) is often included as well.

This first month of treatment is quite intensive and requires frequent visits to the doctor. You 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 prescribed. Sometimes complications can be serious enough to be life-threatening, but with advances in supportive care (nursing care, nutrition, antibiotics, growth factors, red blood cell and platelet transfusions as needed, etc.) in recent years, these are much less common than in the past.

Most often, leukemia goes into remission with induction chemotherapy. But because leukemia cells may still be hiding somewhere in the body, further treatment is needed.

CNS treatment or prophylaxis: Treatment to keep the leukemia cells from spreading to the CNS (prophylaxis) is similar to what is used to treat leukemia that has spread to the CNS. This is often started during induction and continued through the other phases of treatment. It may include one or more of the following:

- Chemo injected directly into the spinal fluid (called *intrathecal chemotherapy*). The drug used most often is methotrexate, but sometimes cytarabine or a steroid such as prednisone may be used as well. Intrathecal chemo can be given during a lumbar puncture (spinal tap) or through an Ommaya reservoir (this was discussed in the surgery section).
- High-dose IV methotrexate or cytarabine
- Radiation therapy to the brain and spinal cord

Consolidation (intensification)

If the leukemia goes into remission, the next phase often consists of another fairly short course of chemo, using many of the same drugs that were used for induction therapy. This typically lasts for a few months. Usually the drugs are given in high doses so that the treatment is still fairly intense. CNS prophylaxis may be continued at this time. A targeted drug like imatinib is also continued for patients whose leukemia cells have the Philadelphia chromosome.

Some patients in remission, such as those who have certain subtypes of ALL or other poor prognostic factors, are still at high risk for relapse (the leukemia coming back). Doctors may suggest an allogeneic stem cell transplant (SCT) at this time, especially for those who have a brother or sister who would be a good donor match. An autologous SCT may be another option. The possible risks and benefits of a stem cell transplant need to be weighed carefully for each patient based on their own case, as it's not clear that they are helpful for every patient. Patients considering this procedure may best be served by having it done at a center that has done a lot of stem cell transplants, and should ask about having it done as a part of a clinical trial.

Maintenance

After consolidation, the patient is generally put on a maintenance chemotherapy program of methotrexate and 6-mercaptopurine (6-MP). In some cases, this may be combined with other drugs such as vincristine and prednisone.

For ALL patients whose leukemia cells have the Philadelphia chromosome, a targeted drug like imatinib is often included as well.

Maintenance usually lasts for about 2 years. CNS prophylaxis may be continued at this time.

Some doctors feel that maintenance therapy may not be needed for some leukemias such as T-cell ALL and mature B-cell ALL (Burkitt leukemia).

Response rates to treatment for acute lymphocytic leukemia

In general, about 80% to 90% of adults will have complete remissions at some point during these treatments. This means leukemia cells can no longer be seen in their bone marrow. Unfortunately, about half of these patients relapse, so the overall cure rate is around 40%. Again, these rates vary depending on the subtype of acute lymphocytic leukemia (ALL) and other prognostic factors. For example, cure rates tend to be higher in younger patients and lower in older patients.

What if the leukemia doesn't respond or comes back after treatment?

If the leukemia is refractory – that is, if it doesn't go away with the first treatment (which happens in about 10% to 20% of patients) – then newer or more intensive doses of drugs may be tried, although they are less likely to work. Blinatumomab (Blinocyt) may be an option for patients with B-cell ALL. A stem cell transplant may be tried if the leukemia can be put into at least partial remission. Clinical trials of new treatment approaches may also be considered.

If leukemia goes into remission with the initial treatment but then comes back (recurs), it will most often do so in the bone marrow and blood. Occasionally, the brain or spinal fluid will be the first place it recurs.

In these cases, it is sometimes possible to put the leukemia into remission again with more chemotherapy (chemo), although this remission is not likely to last. The approach to treatment may depend on how soon the leukemia returns after the first treatment. If the relapse occurs after a long interval, the same or similar treatment may be used to try for a second remission. If the time interval is shorter, more aggressive chemo with other drugs may be needed. Blinatumomab (Blinocyt) may be an option for patients with B-cell ALL.

ALL patients with the Philadelphia chromosome who were taking a targeted drug like imatinib (Gleevec) are often switched to another targeted drug.

For patients with T cell leukemia, the chemo drug nelarabine (Arranon[®]) may be helpful.

If a second remission can be achieved, most doctors will advise some type of stem cell transplant if possible.

If the leukemia doesn't go away or keeps coming back, eventually chemo treatment will not be very helpful. If a stem cell transplant is not an option, a patient may want to consider taking part in a clinical trial of newer treatments.

Palliative treatment

At some point, it may become clear that further treatment, even in clinical trials, is extremely unlikely to cure the leukemia. At that time, the focus of treatment may shift to controlling symptoms caused by the leukemia, rather than attempting to cure the leukemia. This may be called *palliative treatment* or *supportive care*. For example, the doctor may advise less intensive chemo to try to slow the leukemia growth instead of trying to cure it.

As the leukemia grows in the bone marrow it may cause pain. It is important that you be as comfortable as possible. Treatments that may be helpful include radiation and appropriate pain-relieving medicines. If medicines such as aspirin and ibuprofen don't help with the pain, stronger opioid medicines such as morphine are likely to be helpful.

Other common symptoms from leukemia are low blood counts and fatigue. Medicines or blood transfusions may be needed to help correct these problems. Nausea and loss of appetite can be treated with medicines and high-calorie food supplements. Infections that occur may be treated with antibiotics.

For more information on palliative treatment, please see the section “If treatment for acute lymphocytic leukemia stops working.”

More acute lymphocytic leukemia treatment information

For more details on treatment options – including some that might not be addressed in this document – the National Cancer Institute (NCI) is a good source of information.

The NCI provides treatment guidelines via its telephone information center (1-800-4-CANCER) and its website (www.cancer.gov). Detailed guidelines intended for use by cancer care professionals are also available on this website.

What should you ask your doctor about acute lymphocytic leukemia?

It is important to have frank, honest discussions with your doctor. You should feel free to ask any question that’s on your mind, no matter how small it might seem. Here are some questions you might want to ask. Nurses, social workers, and other members of the treatment team may also be able to answer many of your questions.

- What kind of acute lymphocytic leukemia (ALL) do I have?
- Do I have any specific factors that might affect my prognosis?
- Do I need to have other tests before we can decide on treatment?
- Are there other doctors I need to see?
- How much experience do you have treating this type of leukemia?
- Should I get a second opinion before starting treatment? Can you suggest someone?
- How soon do we need to start treatment?
- What are my treatment choices?
- Which treatment do you recommend, and why?
- Should we consider a stem cell transplant? When?
- What are the risks and side effects to the treatments that you recommend?

- What should I do to be ready for treatment?
- How long will treatment last? What will it be like? Where will it be done?
- How will treatment affect my daily activities?
- What is my prognosis?
- What will we do if the treatment doesn't work or if the leukemia comes back?
- What type of follow-up will I need after treatment?

Be sure to write down any questions you have that are not on this list. For instance, you might want specific information about recovery times so that you can plan your work or activity schedule. Or you might want to ask about clinical trials for which you may qualify. Taking another person and/or a tape recorder to the appointment can be helpful.

What happens after treatment for acute lymphocytic leukemia?

For some people with acute lymphocytic leukemia (ALL), treatment may get rid of the cancer. Completing treatment can be both stressful and exciting. You may be relieved to finish treatment, but find it hard not to worry about the leukemia coming back. (When cancer comes back after treatment, it is called *recurrence*.) This is a very common concern in people who have had cancer.

It may take a while before your fears lessen. But it may help to know that many cancer survivors have learned to live with this uncertainty and are living full lives. Our document *Living With Uncertainty: The Fear of Cancer Recurrence*, gives more detailed information on this.

For some people, the leukemia may not go away completely. These people may get regular treatments with chemotherapy, radiation therapy, or other therapies to help keep the leukemia in check for as long as possible. Learning to live with cancer that does not go away can be difficult and very stressful. It has its own type of uncertainty. Our document *When Cancer Doesn't Go Away*, talks more about this.

Follow-up care

Treatment for ALL typically lasts for years. If you have completed treatment, your doctors will still want to watch you closely. It's very important to go to all of your follow-up appointments. During these visits, your doctors will ask questions about any problems you may have and might do exams and lab tests or imaging tests to look for signs of leukemia or treatment side effects. Almost any cancer treatment can have side effects. Some may last for a few weeks to months, but others can last the rest of your life.

This is the time for you to talk to your cancer care team about any changes or problems you notice and any questions or concerns you have.

It's also important to keep health insurance. Tests and doctor visits cost a lot, and even though no one wants to think of their cancer coming back, this could happen.

If a relapse occurs, it is usually while the patient is being treated or shortly after they have finished chemotherapy. If this happens, treatment would be as described in the section "What if the leukemia doesn't respond or comes back after treatment?" It is unusual for ALL to return if there are still no signs of the disease within 5 years after treatment.

For more general information on dealing with a recurrence, you may also want to see the American Cancer Society document *When Your Cancer Comes Back: Cancer Recurrence*.

Seeing a new doctor

At some point after your cancer diagnosis and treatment, you may find yourself seeing a new doctor who does not know all the details of your medical history. It is important that you be able to give your new doctor the details of your diagnosis and treatment. Gathering these details soon after treatment may be easier than trying to get them at some point in the future. Make sure you have this information handy:

- A copy of your pathology report(s) from any biopsies or surgeries
- If you had surgery, a copy of your operative report(s)
- If you stayed in the hospital, a copy of the discharge summary that doctors prepare when patients are sent home
- If you had radiation therapy, a copy of your treatment summary
- If you had chemotherapy or other medicines (like targeted therapy), a list of your drugs, drug doses, and when you took them

The doctor may want copies of this information for his records, but always keep copies for yourself.

Lifestyle changes after treatment for acute lymphocytic leukemia

You can't change the fact that you have had cancer. What you can change is how you live the rest of your life – making choices to help you stay healthy and feel as well as you can. This can be a time to look at your life in new ways. Maybe you are thinking about how to improve your health over the long term. Some people even start during cancer treatment.

Making healthier choices

For many people, a diagnosis of cancer helps them focus on their health in ways they may not have thought much about in the past. Are there things you could do that might make you healthier? Maybe you could try to eat better or get more exercise. Maybe you could cut down on alcohol, or give up tobacco. Even things like keeping your stress level under control may help. Now is a good time to think about making changes that can have positive effects for the rest of your life. You will feel better and you will also be healthier.

You can start by working on those things that worry you most. Get help with those that are harder for you. For instance, if you are thinking about quitting smoking and need help, call the American Cancer Society for information and support. This tobacco cessation and coaching service can help increase your chances of quitting for good.

Eating better

Eating right can be hard for anyone, but it can get even tougher during and after cancer treatment. Treatment may change your sense of taste. Nausea can be a problem. You may not feel like eating and lose weight when you don't want to. Or you may have gained weight that you can't seem to lose. All of these things can be very frustrating.

If treatment caused weight changes or eating or taste problems, do the best you can and keep in mind that these problems usually get better over time. You may find it helps to eat small portions every 2 to 3 hours until you feel better. You may also want to ask your cancer team about seeing a dietitian, an expert in nutrition who can give you ideas on how to deal with these treatment side effects.

One of the best things you can do after cancer treatment is put healthy eating habits into place. You may be surprised at the long-term benefits of some simple changes, like increasing the variety of healthy foods you eat. Getting to and staying at a healthy weight, eating a healthy diet, and limiting your alcohol intake may lower your risk for a number of types of cancer, as well as having many other health benefits.

Rest, fatigue, and exercise

Extreme tiredness, called *fatigue*, is very common in people treated for cancer. This is not a normal tiredness, but a "bone-weary" exhaustion that doesn't get better with rest. For some people, fatigue lasts a long time after treatment, and can make it hard for them to exercise and do other things they want to do. But exercise can help reduce fatigue. Studies have shown that patients who follow an exercise program tailored to their personal needs feel better physically and emotionally and can cope better, too.

If you were sick and not very active during treatment, it is normal for your fitness, endurance, and muscle strength to decline. Any plan for physical activity should fit your

own situation. If you haven't exercised in a few years, you will have to start slowly – maybe just by taking short walks.

Talk with your health care team before starting anything. Get their opinion about your exercise plans. Then, try to find an exercise buddy so you're not doing it alone. Having family or friends involved when starting a new exercise program can give you that extra boost of support to keep you going when the push just isn't there.

If you are very tired, you will need to balance activity with rest. It is OK to rest when you need to. Sometimes it's really hard for people to allow themselves to rest when they are used to working all day or taking care of a household, but this is not the time to push yourself too hard. Listen to your body and rest when you need to. (For more information on dealing with fatigue, please see *Fatigue in People With Cancer* and *Anemia in People With Cancer*.)

Keep in mind exercise can improve your physical and emotional health.

- It improves your cardiovascular (heart and circulation) fitness.
- Along with a good diet, it will help you get to and stay at a healthy weight.
- It makes your muscles stronger.
- It reduces fatigue and helps you have more energy.
- It can help lower anxiety and depression.
- It can make you feel happier.
- It helps you feel better about yourself.

And long term, we know that getting regular physical activity plays a role in helping to lower the risk of some cancers, as well as having other health benefits.

Can I lower my risk of the leukemia progressing or coming back?

Most people want to know if there are specific lifestyle changes they can make to reduce their risk of cancer progressing or coming back. Unfortunately, for most cancers, including ALL, there is little solid evidence to guide people. This doesn't mean that nothing will help – it's just that for the most part this is an area that hasn't been well studied. Most studies have looked at lifestyle changes as ways of preventing cancer in the first place, not slowing it down or preventing it from coming back.

Adopting healthy behaviors such as not smoking, eating well, and maintaining a healthy weight might help, but no one knows for sure. However, we do know that these types of changes can have positive effects on your health that can extend beyond your risk of leukemia or other cancers.

How does having acute lymphocytic leukemia affect your emotional health?

During and after treatment, you may find yourself overcome with many different emotions. This happens to a lot of people.

You may find yourself thinking about death and dying. Or maybe you're more aware of the effect the cancer has on your family, friends, and career. You may take a new look at your relationship with those around you. Unexpected issues may also cause concern. For instance, as you feel better and have fewer doctor visits, you will see your health care team less often and have more time on your hands. These changes can make some people anxious.

Almost everyone who has been through cancer can benefit from getting some type of support. You need people you can turn to for strength and comfort. Support can come in many forms: family, friends, cancer support groups, church or spiritual groups, online support communities, or one-on-one counselors. What's best for you depends on your situation and personality. Some people feel safe in peer-support groups or education groups. Others would rather talk in an informal setting, such as church. Others may feel more at ease talking one-on-one with a trusted friend or counselor. Whatever your source of strength or comfort, make sure you have a place to go with your concerns.

The cancer journey can feel very lonely. It is not necessary or good for you to try to deal with everything on your own. And your friends and family may feel shut out if you do not include them. Let them in, and let in anyone else who you feel may help. If you aren't sure who can help, call your American Cancer Society at 1-800-227-2345 and we can put you in touch with a group or resource that may work for you.

If treatment for acute lymphocytic leukemia stops working

If the leukemia keeps growing or comes back after one kind of treatment, it is possible that another treatment plan might still cure it, or at least treat it enough to help you live longer and feel better. But when a person has tried many different treatments and the leukemia doesn't go away, it tends to become resistant to all treatment. If this happens, it's important to weigh the possible limited benefits of a new treatment against the possible downsides. Everyone has their own way of looking at this.

This is likely to be the hardest part of your battle with cancer – when you have been through many medical treatments and nothing's working anymore. Your doctor may offer you new options, but at some point you may need to consider that treatment is not likely to improve your health or change your outcome or survival.

If you want to continue to get treatment for as long as you can, you need to think about the odds of treatment having any benefit and how this compares to the possible risks and side effects. In many cases, your doctor can estimate how likely it is the leukemia will respond to treatment you are considering. For instance, the doctor may say that more chemo or radiation might have about a 1% chance of working. Some people are still tempted to try this. But it is important to think about and understand your reasons for choosing this plan.

No matter what you decide to do, you need to feel as good as you can. Make sure you are asking for and getting treatment for any symptoms you might have, such as nausea or pain. This type of treatment is called *palliative care*.

Palliative care helps relieve symptoms, but is not expected to cure the disease. It can be given along with cancer treatment, or can even be cancer treatment. The difference is its purpose – the main purpose of palliative care is to improve the quality of your life, or help you feel as good as you can for as long as you can. Sometimes this means using drugs to help with symptoms like pain or nausea. Often, in leukemia, palliative care includes transfusions of red blood cells to help you feel stronger. Sometimes, though, the treatments used to control symptoms are the same as those used to treat cancer. For instance, radiation might be used to help relieve bone pain caused by cancer that has spread to the bones. Or chemo might be used to help shrink a tumor and keep it from blocking the bowels. But this is not the same as treatment to try to cure the cancer.

At some point, you may benefit from hospice care. This is special care that treats the person rather than the disease; it focuses on quality rather than length of life. Most of the time, it is given at home. Your cancer may be causing problems that need to be managed, and hospice focuses on your comfort. You should know that while getting hospice care often means the end of treatments such as chemo and radiation, it doesn't mean you can't have treatment for the problems caused by the cancer or other health conditions. In hospice the focus of your care is on living life as fully as possible and feeling as well as you can at this difficult time. You can learn more about hospice in our documents called *Hospice Care* and *Nearing the End of Life*.

Staying hopeful is important, too. Your hope for a cure may not be as bright, but there is still hope for good times with family and friends – times that are filled with happiness and meaning. Pausing at this time in your cancer treatment gives you a chance to refocus on the most important things in your life. Now is the time to do some things you've always wanted to do and to stop doing the things you no longer want to do. Though the cancer may be beyond your control, there are still choices you can make.

What's new in acute lymphocytic leukemia research and treatment?

Researchers are now studying the causes, diagnosis, supportive care, and treatment of acute lymphocytic leukemia (ALL) at many medical centers, university hospitals, and other institutions.

Genetics of leukemia

Scientists are making great progress in understanding how changes in a person's DNA can cause normal bone marrow cells to develop into leukemia cells. A greater understanding of the genes (regions of the DNA) involved in certain translocations that often occur in ALL is providing insight into why these cells become abnormal. Doctors are now looking to learn how to use these changes to help them determine a person's outlook and whether they should receive more or less intensive treatment.

As this information unfolds, it may also be used to develop newer targeted therapies against ALL. Drugs such as imatinib (Gleevec) and dasatinib (Sprycel) are examples of such treatments. They are now used in treating ALL patients whose leukemia cells have the Philadelphia chromosome.

Gene expression profiling

This new lab technique is being studied to help identify and classify different cancers. Instead of looking at single genes, this test uses a special technology to look at the patterns of many different genes in the cancer cells at the same time. This may add to the information that comes from the current lab tests.

This information may eventually allow more personalized treatment by predicting which chemo drugs are likely to be most effective for each patient. These tests are also being used to find previously unknown changes inside ALL cells to help guide researchers in developing new drugs.

Detecting minimal residual disease

Progress in understanding DNA changes in ALL has already provided a highly sensitive test for detecting minimal residual disease after treatment – when so few leukemia cells are present that they cannot be found by routine bone marrow tests.

The polymerase chain reaction (PCR) test can identify ALL cells based on their gene translocations or rearrangements. This test can find one leukemia cell among many thousands of normal cells. A PCR test can be used in determining how completely chemotherapy has destroyed the ALL cells.

Doctors are now trying to determine if patients with minimal residual disease will benefit from further or more intensive treatment.

Improving chemotherapy

Studies are in progress to find the most effective combination of chemotherapy (chemo) drugs while limiting unwanted side effects. This is especially important in older patients, who often have a harder time tolerating current treatments.

New chemo drugs are also being developed and tested. For example, clofarabine (Clolar[®]) is approved to treat childhood ALL and shows promise in early studies of adults with this disease. Many other new drugs are also being studied.

Studies are also under way to determine whether patients with certain unfavorable prognostic features benefit from more intensive chemo, and whether some ALL patients with favorable prognostic factors might not need as much treatment.

The effectiveness of chemotherapy may be limited in some cases because the leukemia cells become resistant to it. Researchers are now looking at ways to prevent or reverse this resistance by using other drugs along with chemotherapy.

Stem cell transplants

Researchers continue to refine stem cell transplants to try to increase their effectiveness, reduce complications and determine which patients are likely to be helped by this treatment. Many studies are being done to try to help determine exactly when allogeneic, autologous, and mini-transplants might best be used.

Doctors are also studying *donor leukocyte infusion* in people who have already received an allogeneic transplant and who relapse. In this technique, the patient gets an infusion of white blood cells (leukocytes) from the same donor who contributed stem cells for the original transplant. The hope is that the cells will boost the new immune system and add to the graft-versus-leukemia effect. Early study results have been promising, but more research on this approach is needed.

Monoclonal antibodies

These drugs are man-made versions of immune system proteins (antibodies). They can be targeted to attach only to certain molecules, such as proteins on the surface of certain lymphocytes.

Some monoclonal antibodies, such as rituximab (Rituxan) and alemtuzumab (Campath), are already used to treat other blood disorders and are now being studied for use against ALL. Early results have been favorable, but it is still too early to know for sure.

Epratuzumab, a newer antibody, has also shown promise against ALL in early studies. Further studies are planned.

Another approach is to attach a chemo drug to a monoclonal antibody. The antibody serves as a homing device to bring the chemo drug to the cancer cell. One such drug, inotuzumab ozogamicin, has shown promise in treating ALL.

Studies of several other monoclonal antibodies to treat ALL are now under way as well.

Additional resources for acute lymphocytic leukemia

More information from your American Cancer Society

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

Dealing with diagnosis and treatment

Health Professionals Associated With Cancer Care

Talking With Your Doctor (also in Spanish)

After Diagnosis: A Guide for Patients and Families (also in Spanish)

Nutrition for the Person With Cancer During Treatment: A Guide for Patients and Families (also in Spanish)

A Message of Hope: Coping With Cancer in Everyday Life (also in Spanish)

Family and caregiver concerns

Talking With Friends and Relatives About Your Cancer (also in Spanish)

Helping Children When A Family Member Has Cancer: Dealing With Diagnosis (also in Spanish)

What It Takes to Be a Caregiver

Insurance and financial issues

In Treatment: Financial Guidance for Cancer Survivors and Their Families (also in Spanish)

Health Insurance and Financial Assistance for the Cancer Patient (also in Spanish)

More on cancer treatments

A Guide to Cancer Surgery (also in Spanish)

A Guide to Chemotherapy (also in Spanish)

Understanding Radiation Therapy: A Guide for Patients and Families (also in Spanish)

Targeted Therapy

Clinical Trials: What You Need to Know

Stem Cell Transplant (Peripheral Blood, Bone Marrow, and Cord Blood Transplants)

Cancer treatment side effects

Caring for the Patient With Cancer at Home: A Guide for Patients and Families (also in Spanish)

Distress in People With Cancer

Anxiety, Fear, and Depression

Nausea and Vomiting

Guide to Controlling Cancer Pain (also in Spanish)

Pain Diary

Anemia in People With Cancer

Fatigue in People With Cancer

Your American Cancer Society also has books that you might find helpful. Call us at 1-800-227-2345 or visit our bookstore online at cancer.org/bookstore to find out about costs or to place an order.

National organizations and Web sites*

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

Acute lymphocytic leukemia

Leukemia & Lymphoma Society

Toll-free number: 1-800-955-4572

Website: www.lls.org

Has a variety of service programs and resources available throughout the US and Canada including: the Information Resource Center, staffed by health care professionals, available via the toll-free number; free publications on all forms of leukemia and related topics; First Connection, a telephone-based peer support network for patients and survivors; family support groups; education teleconferences and web-casts – a schedule is on the website.

National Cancer Institute (NCI)

Toll-free number: 1-800-422-6237 (1-800-4-CANCER)

TTY: 1-800-332-8615

Website: www.cancer.gov

Their “Cancer Information Service” offers free, accurate, up-to-date information about cancer to patients, their families, and the general public; also can help people find clinical trials in their area.

National Coalition for Cancer Survivorship (NCCS)

Toll-free number: 1-888-650-9127

Website: www.canceradvocacy.org

Has publications on cancer-related topics; also offers the Cancer Survival Toolbox – a free program that teaches skills that can help people with cancer meet the challenges of their illness.

Bone marrow and peripheral blood stem cell transplants

National Bone Marrow Transplant Link (nbmtLINK)

Toll-free number: 1-800-546-5268 (1-800-LINK-BMT)

Website: www.nbmtlink.org

Programs and services include: information and referrals to meet a wide range of needs. Support through one-on-one conversations with trained peer support volunteers who are transplant survivors, caregivers, and donors. Telephone support groups facilitated by a clinical social worker, that link patients and families together to offer mutual support and coping strategies; and the nbmtLINK Online Resource Library – a comprehensive, searchable library giving access to the latest transplant information.

Be the Match (formerly the National Marrow Donor Program)

Toll-free number: 1-800-627-7692 (1-800-MARROW-2)

Website: www.bethematch.org

Provides a registry of volunteer bone marrow donors and cord blood units (the largest listing in the world), as well as a searchable listing of transplant centers that can be accessed directly at www.marrow.org/access. This listing contains information that may help a patient choose a transplant center. Also supports patients and their doctors throughout the transplant process, from diagnosis through survivorship; matches patients with the best donor or cord blood unit using innovative science and technology; has free educational materials; and offers financial assistance to eligible underinsured patients through the Patient Assistance Program.

**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.

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