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PATIENTS & CAREGIVERS

Non-Hodgkin Lymphoma



Revised **2024**

A six-word narrative about living with blood cancer from patients in our LLS Community

Stay strong and keep moving forward. Find the positive in every day. Be your own best patient advocate. Changed my life for the better. Accept, learn and focus on present. Learning to live a different life. Sudden and life changing—be positive. Waiting, worrying, anxiousness/happy I'm alive! Embrace a new normal each day. 5 years, 41 infusions, constant fatigue. Patience, positive attitude, hope and faith. Test to test, I will survive! Treatment, fatigue, treatment, fatigue and survival. Love life, live better every day. I don't look back only forward. So far, so good, live life. Meditation, mindfulness, wellness, faith, nutrition and optimism. Finding the joy while living with uncertainty. Watch, wait, treat, regroup, rest, re-energize. Blessed to be doing so well! Eye opening needed learning and healing. Feel great: uncertain travel plans annoying. Renewed faith, meditation, diet, mindfulness, gratitude. Watchful waiting can be watchful worrying. Scary, expensive, grateful, blessings, hope, faith. Thank god for stem cell transplants! Do not know what to expect. Extraordinarily grateful, I love my life. Diagnosed; frightened; tested; treating; waiting; hoping. I'm more generous, impatient less often. Embrace your treatment day after day. Live today, accept tomorrow, forget yesterday. Strength you never realized you had. Challenging to our hearts and minds. Life is what we make it. Live life in a beautiful way.



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Join our online social network for people who are living with or supporting someone who has a blood cancer. Members will find

- Thousands of patients and caregivers sharing experiences and information, with support from knowledgeable staff
- Accurate and cutting-edge disease updates
- The opportunity to participate in surveys that will help improve care.

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Introduction

“Lymphoma” is a general term for a group of blood cancers that originate in the lymphatic system. This booklet provides detailed information about the diagnosis, staging and treatment of non-Hodgkin lymphoma (NHL) for patients and their families.

You can find information about some NHL subtypes in this book. Other NHL subtypes are covered in separate LLS booklets. Use the table below to find the specific subtype and where to find that information.

Subtype Information in This Booklet	Subtype Information in Other LLS Materials
Aggressive Subtypes	
Diffuse large B-cell lymphoma (DLBCL)—page 20	Mantle cell lymphoma (MCL)
High-grade B-cell lymphoma with double or triple hits (HBL)—page 21	
Acquired immunodeficiency syndrome (AIDS)-associated lymphoma—page 23	
Burkitt lymphoma (BL)—page 23	
Primary central nervous system (CNS) lymphoma—page 24	
Primary mediastinal large B-cell lymphoma (PMBCL)—page 25	Peripheral T-cell lymphoma (PTCL), including systemic anaplastic large-cell lymphoma (ALCL)
T-cell lymphoblastic lymphoma (T-LBL)—page 25	
Indolent Subtypes	
Follicular lymphoma (FL) —page 26	Marginal zone lymphoma (MZL), including gastric mucosa-associated lymphoid tissue (MALT) lymphoma, nodal marginal zone lymphoma (NMZL) and splenic marginal zone lymphoma (SMZL)
	Chronic lymphocytic leukemia/small-cell lymphocytic lymphoma (CLL/SLL)
	Lymphoplasmacytic lymphoma/Waldenström macroglobulinemia (WM)
	Cutaneous T-cell lymphoma (CTCL), including information about mycosis fungoides (MF) and Sézary syndrome (SS)

Visit www.LLS.org/booklets to find all of the LLS materials listed in this introduction.

This booklet also includes brief descriptions of normal blood, bone marrow and the lymphatic system, as well as a glossary of health terms to help readers understand information that may be new to them.

An estimated 722,631 people in the United States are either living with or are in remission from NHL. About 80,550 people were expected to be diagnosed with NHL in 2023 (see *Incidence, Causes and Risk Factors* on page 36). Advances in the treatment of NHL are resulting in improved remission and cure rates. New treatment approaches are being studied in clinical trials for patients of all ages and for all stages of the disease.

All LLS publications mentioned in this booklet are free and can be viewed, downloaded or ordered online at www.LLS.org/booklets.

Source: FACTS: Updated Data on Blood Cancers 2022-2023. The Leukemia & Lymphoma Society. August 2023.

New treatments may have been approved since this book was printed. Check www.LLS.org/DrugUpdates or call (800) 955-4572.

Lymphoma

“Lymphoma” is a general term for a group of blood cancers that originate in the lymphatic system, part of the body’s immune system. The two major types of lymphoma are Hodgkin lymphoma (HL) and non-Hodgkin lymphoma (NHL).

Both HL and NHL are further classified into subtypes. Knowing the subtype of your disease is very important because the treatment approach is based on the subtype. Information about treatments for specific NHL subtypes begins on page 19.

For more information about Hodgkin lymphoma, see the free LLS booklet *Hodgkin Lymphoma*.

Non-Hodgkin Lymphoma Basics

Non-Hodgkin lymphoma (NHL) is the term for a diverse group of blood cancers that share a single characteristic—they all arise from lymphocytes. Lymphocytes are white blood cells that are part of the body’s immune system. There are three main types of lymphocytes: B cells, T cells and natural killer (NK) cells. In lymphoma, a lymphocyte undergoes a cancerous (malignant) change and then multiplies, eventually crowding out healthy cells and creating tumors.

These tumors generally develop in the lymph nodes or in lymphatic tissue found in organs such as the stomach, intestines or skin. In some cases, NHL involves the blood and the bone marrow (the spongy tissue in the hollow, central cavity of

bones, where blood cell formation occurs). Lymphoma cells may develop in just one place or in many sites in the body (see **Figure 1** on page 7).

Although some types of leukemia are closely related to NHL, leukemia and lymphoma are different. Leukemias begin when a cell in the bone marrow undergoes a genetic change (mutation). Lymphomas begin when a cell, either in a lymph node or in some other lymphatic structure, undergoes a mutation. Lymphomas can develop in the skin, gastrointestinal tract, or other sites in the body, including the bone marrow. It is important to recognize that leukemias, which originate in the bone marrow, often involve lymph nodes or other organs. Lymphomas, which originate in lymphatic tissue outside the bone marrow, often involve the bone marrow.

More than 90 specific NHL subtypes have been identified and assigned names, called “diagnostic designations,” by the World Health Organization (WHO). The Revised European American Lymphoma and World Health Organization (REAL/WHO) classification of non-Hodgkin lymphoma categorizes NHL subtypes by the characteristics of the lymphoma cells, including their appearance, the presence of proteins on the surface of the cells, and their genetic features. The prognosis and treatment approaches for different NHL subtypes are influenced by findings from studying the diseased cells and tissues under a microscope. Biopsy samples are examined by a hematopathologist (a doctor who specializes in the diagnosis of blood disorders and blood cancers).

One way that NHL subtypes are classified is by cell type. Some NHL subtypes, such as diffuse large B-cell lymphoma (DLBCL) and follicular lymphoma (FL), involve lymphocytes called B cells. Other subtypes, such as peripheral T-cell lymphoma (PTCL) and cutaneous T-cell lymphoma (CTCL), involve lymphocytes called T cells or natural killer (NK) cells.

Specialists further classify NHL subtypes according to the rate of disease progression, that is, either fast growing (aggressive) or slow growing (indolent). Aggressive lymphoma subtypes (also called high-grade NHL) account for about 60 percent of all NHL cases. Diffuse large B-cell lymphoma is the most common aggressive NHL subtype. Slow growing (indolent) subtypes account for about 40 percent of all NHL cases. Follicular lymphoma is the most common subtype of indolent NHL. When indolent lymphoma is first diagnosed, patients typically have fewer signs and/or symptoms than patients with aggressive lymphoma subtypes. Whether the diagnosed subtype is aggressive or indolent determines the appropriate treatment, so getting an accurate diagnosis is especially important. In some cases, indolent forms of NHL later transform into an aggressive form of the disease.

Table 1, on page 5 provides a list of some of the diagnostic designations for NHL subtypes based on the World Health Organization (WHO) classification and categorized by cell type (B cell, T cell or NK cell). The percentages listed reflect the frequency of diagnosed cases of the most common NHL subtypes.

Table 1. Diagnostic Designations for Non-Hodgkin Lymphoma (NHL)

Mature B-cell lymphomas (about 85% to 90% of NHL cases)

Aggressive

- Diffuse large B-cell lymphoma (DLBCL) (30%)
- Mantle cell lymphoma (MCL) (3%)—has features of both indolent and aggressive NHL
- Lymphoblastic lymphoma (2%)
- Burkitt lymphoma (BL) (2%)
- Primary mediastinal (thymic) large B-cell lymphoma (PMBCL)
- Transformed follicular and transformed mucosa-associated lymphoid tissue (MALT) lymphomas
- High-grade B-cell lymphoma with double or triple hits (HBL)
- Primary cutaneous DLBCL, leg type
- Primary DLBCL of the central nervous system
- Primary central nervous system (CNS) lymphoma
- Acquired immunodeficiency syndrome (AIDS)-associated lymphoma

Indolent

- Follicular lymphoma (FL) (22%)
- Marginal zone lymphoma (MZL) (7%)
- Chronic lymphocytic leukemia/small-cell lymphocytic lymphoma (CLL/SLL) (7%)
- Gastric mucosa-associated lymphoid tissue (MALT) lymphoma (8%)
- Lymphoplasmacytic lymphoma (1%)
- Waldenström macroglobulinemia (WM)
- Nodal marginal zone lymphoma (NMZL) (1%)
- Splenic marginal zone lymphoma (SMZL)

Mature T-cell and natural killer (NK)-cell lymphomas (about 10% to 15% of NHL cases)

Systemic

- Peripheral T-cell lymphoma, not otherwise specified (PTCL-NOS) (6%)
- Systemic anaplastic large-cell lymphoma (ALCL) (2%)
 - Breast implant-associated anaplastic large-cell lymphoma (BIA-ALCL)
- Lymphoblastic lymphoma (2%)
- Hepatosplenic T-cell lymphoma
- Enteropathy-associated intestinal T-cell lymphoma
 - Monomorphic epitheliotropic intestinal T-cell lymphoma
- Angioimmunoblastic T-cell lymphoma (AITL)
- Adult T-cell leukemia/lymphoma
- Extranodal natural killer (NK)/T-cell lymphoma (ENK/TCL), nasal type

Primary cutaneous

- Cutaneous T-cell lymphoma (CTCL) (4%)
 - Mycosis fungoides (MF)
 - Sézary syndrome (SS)
- Primary cutaneous anaplastic large-cell lymphoma (pcALCL)
- Subcutaneous panniculitis-like T-cell lymphoma (SPTCL)
 - Primary cutaneous gamma delta T-cell lymphoma

This table is based on information presented in The World Health Organization (WHO) Classification of Haematolymphoid Tumours, 5th edition. The descriptive parts of the names (eg, follicular, mantle cell or marginal zone) refer to the specific areas of lymph nodes where the lymphoma originated.

Sources: Alaggio R, et al. *Leukemia*, 2022; NCCN Guidelines version 5, 2023; NCCN Guidelines, version 1, 2023. See complete References section in this booklet.

Signs and Symptoms

Signs and symptoms are changes in the body that may indicate the presence of disease. A sign is a change that the doctor sees during an examination or in a laboratory test result. A symptom is a change that a patient can see and/or feel.

A person who has signs and/or symptoms that suggest the possibility of non-Hodgkin lymphoma (NHL) is usually referred to a blood cancer specialist called a hematologist-oncologist. This doctor will order additional tests and a lymph node biopsy to make a diagnosis (see *Diagnosis* on page 8). Because the signs and/or symptoms of NHL are also associated with a number of other, less serious diseases, these test results can also be used to rule out a diagnosis of NHL.

There are about 600 lymph nodes in the body. The most common early sign of NHL is painless swelling of one or more lymph node(s). For example:

- Most patients with NHL have one or more enlarged lymph node(s) in the neck, armpit or groin (see **Figure 1** on page 7).
- In fewer patients, a swollen node appears near the ears, the elbow or in the throat near the tonsils.

Occasionally, the disease starts in a site other than in a lymph node, such as a bone, a lung, the gastrointestinal tract or the skin. In these circumstances, patients may experience symptoms that are associated with that specific site.

Common Signs and Symptoms. These include

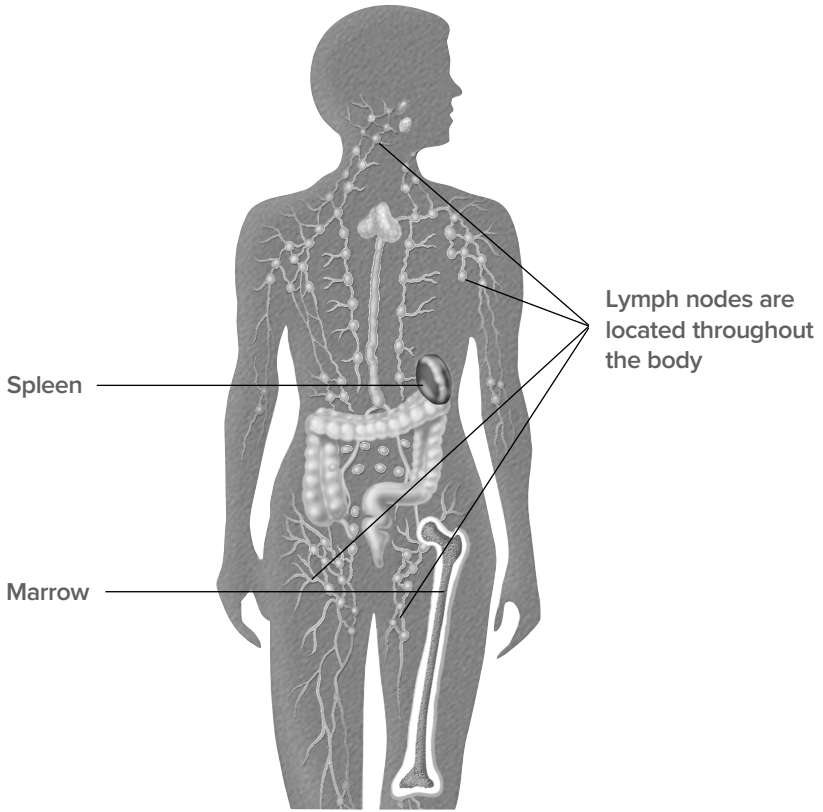
- Painless swelling in one or more lymph node(s)
- Unexplained fever
- Drenching night sweats
- Persistent fatigue
- Loss of appetite
- Unexplained weight loss
- Cough or chest pain
- Abdominal pain
- Sensation of bloating or fullness (due to an enlarged spleen)
- Itchy skin
- Enlargement of the spleen or liver
- Rashes or skin lumps

Some people have no signs and/or symptoms, and the disease may be discovered during a routine medical examination or while the patient is under their doctor's care for an unrelated condition.

B Symptoms. The term B symptoms is used to refer to fever, drenching night sweats and loss of more than 10 percent of body weight over 6 months.

B symptoms are significant to the prognosis and staging of the disease. Other NHL symptoms, such as itching and fatigue, do not have the same prognostic importance as B symptoms and are not considered B symptoms.

Figure 1. Non-Hodgkin Lymphoma (NHL) and the Lymphatic System



The lymphatic system is part of the immune system. The normal immune system helps to protect the body from infection. The marrow, lymph nodes and spleen are some of the parts of the immune system. There are about 600 lymph nodes located throughout the body.

Lymph nodes and other lymphatic tissues that are commonly involved in lymphoma include those around the ears and jaw, in the tonsils and adenoids, in the front and back of the neck, above and below the collar bone, in the armpit, near the elbow, in the chest, in the abdomen, in the pelvis and in the groin. The spleen contains many clusters of lymphocytes that can become malignant and multiply, leading to the enlargement of the spleen. The gut-associated (intestinal) lymph tissue may also be the site of lymphoma development.

Diagnosis

An accurate diagnosis includes determination of the specific subtype of non-Hodgkin lymphoma (NHL) and is one of the most important aspects of a person's care. A precise diagnosis will help the doctor to:

- Determine the appropriate treatment
- Communicate the goals of therapy and explain what to expect to the patient

A diagnosis of NHL is usually made based on the findings from microscopic examination of a lymph node biopsy specimen (a piece or sample of a lymph node obtained from a biopsy procedure). It is important to receive an accurate diagnosis and to know the NHL subtype. Patients may want to ask the doctor to write down the diagnosis for them, including their specific subtype.

Physical Evaluation. The doctor will take a comprehensive medical history and ask questions regarding either the absence or presence of B symptoms. Physical examination will include measurement of all accessible lymph node groups, as well as the size of organs, such as the spleen and liver.

Lymph Node Biopsy. Making an accurate diagnosis of the patient's specific subtype of NHL can be challenging. It requires an experienced hematopathologist (a doctor who specializes in diagnosing diseases of the blood and marrow) to prepare the tissue samples from a biopsy, which is the procedure used to obtain a sample of lymph node tissue. Then the hematopathologist examines the tissue under the microscope and analyzes the findings. If there is either any doubt about the diagnosis, or to confirm it (in the case of a rarer type of lymphoma, for instance), it may be necessary to get a second opinion from another hematopathologist.

A biopsy of an involved lymph node or other tumor site is needed to confirm the NHL diagnosis and subtype. Several different types of biopsies are used to detect cancer in cells and tissues.

- Fine needle aspiration/fine needle biopsy—a thin, hollow needle is inserted through the skin into the lymph node or other suspicious area, then a small sample of cells and fluid (aspirate) is suctioned out
- Core needle biopsy—similar to a fine needle biopsy, but using a larger needle to remove a small core of tissue
- Incisional biopsy—a surgeon cuts into the skin to remove a small area of tissue
- Excisional biopsy—a surgeon cuts through the skin to remove an entire lymph node

The lymph node tissue sample that can be obtained through a fine needle aspiration is usually not sufficient for the hematopathologist to make a conclusive diagnosis. The preferred and most common type of biopsy is

the excisional biopsy, in which the whole lymph node is typically removed (excised). If the lymph node is just under the skin, the biopsy procedure is usually simple and can sometimes be done with a numbing medication (local anesthetic). If the lymph node is inside the chest or abdomen (stomach area), the patient may be sedated or receive general anesthesia.

The tissue sample is placed on a slide along with a preservative, then stained with dyes. The sample is examined under a microscope, and the doctor studies the size and shape of the cells and how they are arranged.

The examination findings may confirm that the person has lymphoma, and will identify the type of lymphoma. Sometimes, hematopathologists can determine a person's NHL subtype by looking at the cells of the tissue sample. They will note the distinctive patterns of changed cells and use that information to identify the NHL subtype. Other types of tests are usually also needed to confirm the diagnosis.

Non-Hodgkin lymphoma can develop in parts of the body that do not have lymph nodes, such as the lungs or bones. When lymphoma is detected exclusively outside of the lymph nodes, it is called "primary extranodal lymphoma," and the biopsy sample is taken from the body part that is involved.

Biomarker Tests. A biomarker test is a laboratory method that uses a sample of tissue, blood, or other body fluid to check for certain genes, proteins, or other molecules that may be a sign of a disease or condition such as cancer. Biomarker testing can also be used to check for certain changes in a gene or chromosome that may increase a person's risk of developing cancer or other diseases. Biomarker testing may be done with other procedures, such as biopsies, to help diagnose some types of cancer. It may also be used to help plan treatment, find out how well treatment is working, make a prognosis, or predict whether cancer will come back or spread to other parts of the body. Biomarker testing is also called molecular profiling and molecular testing. These types of tests include:

- **Flow cytometry**—In this technique, cells are taken from the blood or tissue biopsy sample and placed in a machine that detects which proteins (also called "markers" or "antigens") are expressed in the lymphoma cells.
- **Immunophenotyping**—A technique used to distinguish NHL from other types of lymphoma or other cancerous or noncancerous conditions. The hematopathologist looks for the presence of certain antigens (or markers) on the surface of the cells in a blood or bone marrow sample, to identify NHL cells and confirm the diagnosis. Immunophenotyping can further help determine whether the lymphoma cells are B cells, T cells or natural killer (NK) cells.
- **Epstein-Barr virus *in situ* hybridization**—A test used to detect the presence of the Epstein-Barr virus (EBV) in a sample of tissue. EBV can sometimes be found in people who have diffuse large B-cell lymphoma (DLBCL). This test can help determine a person's subtype of DLBCL.

- **Cytogenetic analysis**—Chromosomes are structures in cells that contain genetic information that carries instructions for the cell’s functions. This test is used to see if any chromosomal abnormalities are present in the dividing cells of a blood or bone marrow sample. One of the main methods of cytogenetic analysis is fluorescent in situ hybridization (FISH), a laboratory test that uses special dyes to identify abnormalities in chromosomes, such as translocations (portions where the genes between two chromosomes have swapped places) and deletions (a type of genetic change that involves the absence of a segment of DNA). Chromosomal abnormalities are important considerations in identifying specific subtypes of NHL, which informs the most effective treatment approach.
- **Gene expression profiling and microarray analysis**—These tests are used to identify cancer subtypes and risk factors. The findings help doctors predict how patients will respond to treatment, as well as which patients may be at increased risk for disease relapse. Gene expression profiling and microarray analysis are primarily used as research tools and are not generally used in clinical practice.

Staging

Doctors use findings from physical examinations, imaging and laboratory tests to evaluate the extent of the disease. The doctor needs this information to determine the “stage” of the disease (see **Table 2** and **Figure 2** on page 14). Staging is a very important part of treatment planning.

Imaging Tests. Imaging tests are done by machines that help doctors determine the presence of disease in the body. Common imaging tests include x-rays, CT scans, and MRIs. Both the physical examination and imaging tests help the doctor evaluate:

- The location and distribution of lymph node enlargement
- Whether organs other than the lymph nodes are involved
- If there are very large masses of tumors in one or more site(s)

Imaging is a very important part of the staging and management of lymphoma. A doctor may first order imaging tests when a patient’s medical history and physical examination suggest a possible diagnosis of lymphoma. The imaging test(s) may show enlarged lymph nodes in either the chest or abdomen, or both. Tumor masses may also occur outside the lymph nodes in lungs, bones, or body tissues.

The imaging tests may include:

- **Chest x-rays**
- **A computed tomography (CT) scan**—A CT scan (also known as a “CAT scan”) uses special x-ray equipment to take multiple images from different angles around the body. A computer then processes the information from the images and produces a composite image that shows a cross section of the area being examined. Patients undergo CT scans of the neck, chest, abdomen and pelvis—all the places where lymph nodes are present—so the doctor can identify areas of disease. A CT scan can also show whether there is involvement of the lungs, liver and/or other organs, which helps the doctor determine the “stage” of the disease. A CT scan shows where the lymphoma is located and can measure the size of the mass.
- **Magnetic resonance imaging (MRI)**—An MRI scan is done in select cases to determine the stage of the NHL and can supplement the information gathered from other imaging tests. It uses a powerful magnet and radio waves linked to a computer to create clear and detailed cross-sectional images (slices) of the body. The “slices” can then be displayed on a video monitor and are also saved on a disk for future analysis. An MRI scan is particularly useful for displaying soft tissues, including the brain, spinal cord, joints and internal organs.
- **Positron emission tomography-computed tomography (PET-CT) scan**—This procedure combines the techniques of both PET (an imaging technique that produces a 3D image of functional processes in the body) and CT images. Both tests are done at the same time and by the same machine. There are different types of PET scans; the one used in evaluating lymphoma is a fluorodeoxyglucose (FDG) PET. In this test, a small amount of a radioactive sugar called FDG is injected into the patient. This type of PET scan is used to show differences in metabolic activity in the body and can also be used to distinguish between healthy and unhealthy tissue. The PET scanner detects the radiation given off by the FDG and produces color-coded images of the body that show both normal and potentially cancerous tissue.

A PET-CT scan reveals information about both the structure and function of cells and tissues in the body during a single imaging session. It provides a more detailed picture of where the cancer is located in the body than either test does by itself. Use of PET scans is increasing, as it can help doctors determine the stage of the disease, and also find and mark radiotherapy margins on the body (when needed), to confirm the patient’s response to treatment, and to provide a baseline to assess future treatment response.

Blood Tests. Blood tests are used to determine whether lymphoma cells are present in the blood, check for indicators of disease severity by examining blood protein levels, assess kidney and liver function, and measure important biological markers that are helpful prognostic indicators for several NHL subtypes.

Examples of the blood tests used to determine the extent of disease and when treatment is needed include:

- **A complete blood count (CBC)**—This test measures different components of the blood. The results include counts of red blood cells, white blood cells and platelets. A CBC may show
 - Anemia (low numbers of red blood cells)
 - Neutropenia (low numbers of neutrophils, a type of white blood cell)
 - Thrombocytopenia (low numbers of platelets)
- **A comprehensive metabolic panel**—Chemicals in the blood come from the liver, bones and other organs. This panel often includes tests for up to 14 substances, including electrolytes, glucose, and liver and kidney function markers. Abnormal levels can be caused by cancer or other health problems.
- **A beta-2 microglobulin test**—Beta-2 microglobulin is a small (micro) protein made by many types of cells, including lymphoma cells. High levels of this protein may be an indication that treatment is needed right away.
- **A lactate dehydrogenase (LDH) test**—LDH is a protein found in most cells. When a cell is damaged, LDH is released into the bloodstream. If associated with a cancer, a high LDH level may be a sign that treatment is needed soon.
- **Hepatitis testing**—The presence of hepatitis B or hepatitis C can be important when treating certain types of lymphoma. If a patient has had hepatitis B in the past, it can become active again due to cancer or some of its treatments. The presence of hepatitis C may diminish the effectiveness of therapy.
- **HIV (human immunodeficiency virus) testing**—If HIV is present, treating it can be an important part of how NHL is managed, as HIV treatment can improve how well cancer treatment works.
- **A uric acid test**—This test measures the amount of uric acid in the body. When cancer cells break down and die, they release their contents into the blood. If the cancer cells break down too quickly, the kidneys cannot remove these substances from the blood. An increased level of uric acid can lead to tumor lysis syndrome (TLS). See *Side Effects of Treatment* on page 31.
- **Antibody testing**—Antibodies, also called “immunoglobulins,” are proteins made by B cells. B cells release antibodies into the blood to help the body fight bacteria and viruses. Depending on the type of NHL, people may have either low or very high levels of tumor-specific antibodies. The quantitative immunoglobulins test measures the amount of each type of antibody. The serum protein electrophoresis (SPEP) test measures specific proteins in the blood.

Bone Marrow Biopsy. Many patients diagnosed with NHL undergo a bone marrow biopsy to make sure the disease has not spread to the bone marrow and to evaluate the potential benefit of certain therapies, including radioimmunotherapy (a combination of radiation therapy and immunotherapy).

A bone marrow biopsy may not always be required for patients with early-stage NHL who have low-risk features (eg, no B symptoms and no large masses).

Heart Tests. Some cancer treatments can damage the heart. Members of the treatment team may want to do tests to determine how well a patient’s heart is functioning before starting certain treatments. These tests include:

- **An echocardiogram**—An imaging test that uses ultrasound technology to create a picture of the heart
- **A multigated acquisition (MUGA) scan**—This scan measures how well the heart pumps blood. A radiotracer substance is injected into a vein. Pictures of the heart are taken with a special camera that detects the radiation released by the tracer.

Other Tests. Some tests are only done for certain NHL subtypes and are not necessary for all patients. Specific examples include:

- A full evaluation of the gastrointestinal (GI) tract, including upper and lower endoscopies and colonoscopies for patients who have NHL subtypes involving the GI tract, such as mantle cell lymphoma (MCL) and gastric mucosa-associated lymphoid tissue (MALT) lymphoma. Note: routine colonoscopies are important for everyone beginning at age 45, or earlier if there is a family history of colon cancer
- Testicular ultrasound is indicated for patients who have a testicular mass
- Spinal tap (lumbar puncture) and/or MRI of the brain or spinal column may be required for patients with certain subtypes or symptoms that suggest central nervous system involvement

Staging System. The Lugano modification of the Ann Arbor staging system (see **Table 2** on page 14) includes guidelines for the evaluation, staging, and response assessment of patients with malignant lymphomas.

Keep in mind that the designation “stage IV” does not have the same implications in NHL as it does for many other types of cancer. Non-Hodgkin lymphoma does not necessarily start at stage I and then progress to stage II, and so forth. In lymphoma, the stage identifies the specific location of the disease. It also does not reflect how well or poorly the patient will respond to treatment. A disease diagnosed as stage IV NHL may be highly treatable, depending on the specific subtype. See **Figure 2** on page 14 for information on NHL stages.

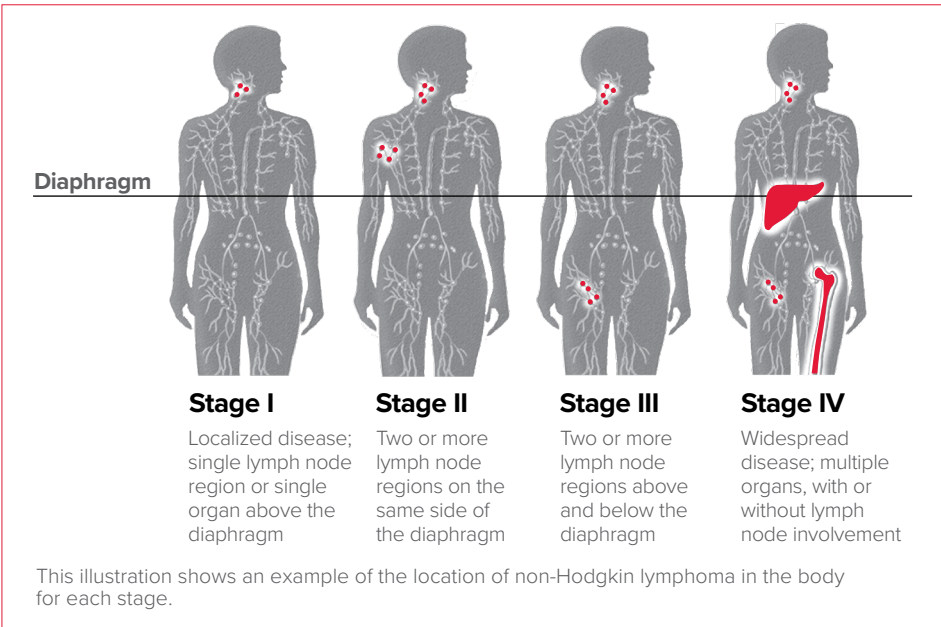
When all the diagnostic and staging tests are completed, the doctor will evaluate the information, identify the NHL subtype, determine which areas of the body are involved and begin to discuss treatment options with the patient.

Table 2. Lugano Modification of the Ann Arbor Staging System (for primary nodal lymphomas)

Stage	Involvement	Extranodal (E) Status
Limited		
Stage I	One node or a group of adjacent nodes	Single extranodal lesion without nodal involvement
Stage II	Two or more nodal groups on the same side of the diaphragm	Stage I or II, by nodal extent, with limited contiguous extranodal involvement
Stage II bulky	Stage II as above with “bulky” disease	Not applicable
Advanced		
Stage III	Nodes on both sides of the diaphragm Nodes above the diaphragm with spleen involvement	Not applicable
Stage IV	Additional non-contiguous extra lymphatic involvement	Not applicable

Source: Cheson BD, et al. *Journal of Clinical Oncology*, 2014. See complete References section in this booklet.

Figure 2. Non-Hodgkin Lymphoma (NHL) Stages



Treatment Overview

New treatments may have been approved since this book was printed.
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The initial therapy and intensity of treatment indicated for a patient are based on the subtype and stage of disease. In general, the goal of treatment is to destroy as many lymphoma cells as possible and to induce a complete remission. Complete remission means that all evidence of the disease is eliminated. Patients who achieve remission are sometimes cured. Even when imaging or other studies show remaining sites of disease involvement, treatment can keep the progression of non-Hodgkin lymphoma (NHL) in check for many years. This may be referred to as a “partial remission.”

The “watch and wait” approach (see page 26) may be used for patients who have indolent (slow-growing) subtypes of NHL without signs and/or symptoms. In this approach, treatment is either deferred or delayed until signs and/or symptoms of disease progression occur. Frequent and careful observation is required so that effective treatment can be started if the disease begins to advance. In some patients the disease progresses slowly over a long time, while in others it evolves (transforms) into a more aggressive type of NHL that requires immediate treatment.

In general, drug therapy (see **Table 4** on page 39 for *Drug Classes and Drug Functions* and **Table 5** starting on page 41 for *Some Drugs Used in the Treatment of Non-Hodgkin Lymphoma*) and radiation therapy are the two principal forms of treatment for NHL. Although radiation therapy is generally not the only or even the principal curative therapy, it is an important additional treatment in some cases. You may receive different drugs from those described in this booklet. This may still be considered proper treatment. Speak with your doctor to find out what treatment is best for you.

Table 6 on page 49 lists examples of drug combinations used to treat NHL. In clinical trials, researchers continue to study the most effective combinations of drugs for the treatment of all types of NHL, including newly diagnosed, refractory and relapsed disease.

You will have many concerns, questions and considerations if you are diagnosed with non-Hodgkin lymphoma. Before treatment begins, ask your doctor and other members of your healthcare team any questions you have about treatment planning and related issues, such as the possible long-term and late effects of treatment, including effects on fertility. Be sure you understand the doctor’s responses and discuss any concerns or issues that arise.

The Use of Biosimilars. A biosimilar is a biological product that is very similar to another biological drug (called the “reference drug”) that has already received Food and Drug Administration (FDA) approval. Both the reference drug

and biosimilar drugs are made from living organisms, but they may be made in different ways and with slightly different substances. To be called a biosimilar drug, a biological drug must be shown to be as safe and effective as the reference drug, and it has to work in the same way. It must also be used in the same way, at the same dose and for the same condition as the reference drug. Biosimilar drugs must be approved by the Food and Drug Administration (FDA) and may cost less than the reference drugs. Several biosimilar medications have been approved to treat some types of NHL. See **Table 5** (an asterisk denotes a biosimilar drug in this table) starting on page 41. Emerging studies on the use of biosimilars in NHL treatment are confirming that these drugs have an impact on overall survival that is as good as that of the original product.

Factors That Influence Treatment. Patients should discuss treatment options with their doctor and ask for help to understand the benefits and risks of different treatment approaches. The most effective treatment plan for each patient who has NHL is individualized based on:

- The subtype of NHL—knowing whether the lymphoma cells are related to T cells, B cells or natural killer (NK) cells gives the doctor key clues about appropriate treatments
- The stage and category of the disease, which is important information that is factored into treatment decisions (see **Table 2** and **Figure 2** on page 14).
- The presence of fever, drenching night sweats and/or loss of more than 10 percent of body weight over 6 months, referred to as B symptoms
- Whether there is lymphoma in areas of the body outside of the lymph nodes (extranodal involvement)
- Other prognostic factors, such as age and any underlying medical conditions

The patient's age may be a factor in treatment, but older age is no longer a major determinant in treatment decisions for most patients. However, the patient's overall health status, including other medical problems, and their wishes concerning treatment are significant considerations. When making these decisions, it is important for patients to discuss with their doctors the effects on fertility and other possible long-term and late effects of their treatment.

The International Prognostic Index (IPI). The IPI is a risk-stratification tool that predicts the prognosis of patients who have NHL. Compiled by an international collaboration among several cancer research groups in North America and Europe that evaluated thousands of patients with aggressive forms of NHL, the IPI score identifies several unfavorable prognostic factors.

The IPI score is calculated for all patients by totaling the sum of the points scored for each of the risk factors listed below. The score goes from 0 to 5 in the scale reflecting risk factors in patients older than 60 years and from 0 to 3 for the age-adjusted version, reflecting risk factors in patients aged 60 years or younger.

Risk factors in patients older than 60 years

(1 point is assigned for each of the following factors):

- Older than 60 years
- Elevated serum lactate dehydrogenase (LDH) level
- Eastern Cooperative Oncology Group (ECOG) performance status score of 2 to 4 points (see **Table 3** on page 18)
- Stage III or IV disease
- Extranodal involvement in two or more sites

Risk factors in patients 60 years of age and younger

(1 point is assigned for each of the following factors):

- Elevated serum LDH level
- ECOG performance status score of 2 to 4 points (see **Table 3** on page 18)
- Stage III or IV disease

The ECOG performance status is determined by a scale used to evaluate a person's ability to perform activities of daily living (ADLs) without help. See **Table 3** on page 18.

The IPI index helps doctors predict overall survival and the risk of relapse and also provides a basis for recommending whether to use an aggressive or lower-intensity treatment option for high-risk patients.

The number of risk factors a person has determines the IPI risk group that they are in. This helps predict their risk of relapse. Each point represents some level of increased risk for disease relapse.

The following risk categories and corresponding point totals are for patients older than 60 years:

- Low risk (0 to 1 point)
- Low-intermediate risk (2 points)
- High-intermediate risk (3 points)
- High risk (4 to 5 points)

For patients 60 years of age and younger, the risk categories and corresponding point totals are slightly different. They are:

- Low risk (0 points)
- Low-intermediate risk (1 point)
- High-intermediate risk (2 points)
- High risk (3 points)

Patients may want to discuss risk factors with their healthcare team in order to understand their treatment options, including participation in clinical trials.

Pretreatment Considerations. Adults of childbearing age and parents of children diagnosed with NHL should ask their doctors for information about possible long-term and late effects, including effects on fertility (the ability to have children) (see *Long-Term and Late Effects of Treatment* on page 34).

For more information about pretreatment considerations, see the free LLS booklet *Fertility and Cancer*. Visit www.LLS.org/FamilyWorkbook and the chapter, *Beyond Treatment*, to find information about childhood long-term and late effects. Visit www.LLS.org/SurvivorshipWorkbook to reach the children and adolescent, young adult and adult books called *Navigating Life During and After a Blood Cancer Diagnosis*.

Table 3. Eastern Cooperative Oncology Group (ECOG) Performance Status

Grade	ECOG Performance Status
0	Fully active, able to carry on all pre-disease performance without restriction
1	Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature (eg, light housework, office work)
2	Ambulatory and capable of all self-care but unable to carry out any work activities; up and about more than 50% of waking hours
3	Capable of only limited self-care; confined to bed or chair more than 50% of waking hours
4	Completely disabled; cannot carry on any self-care; totally confined to bed or chair
5	Deceased

Source: Oken M, et al. *American Journal of Clinical Oncology*, 1982. See complete References section in this booklet.

Treatment Setting. Patients may undergo treatments over long periods, but most therapies can be administered in an outpatient setting. Radiation therapy, chemotherapy or immunotherapy can be administered in the outpatient clinic of an oncology center. Short periods of hospitalization are sometimes required. Particularly intensive therapies can cause prolonged or severe decreases in red blood cell, white blood cell and/or platelet counts. Therefore, transfusion of appropriate blood products and administration of cytokines (hormones that enhance blood cell production) may be needed. Outpatient treatment is still possible in some cases that require blood transfusion and/or cytokine treatment. If fever or other signs and/or symptoms of infection occur, hospitalization and administration of antibiotics may be necessary.

For more information about transfusion of blood products, see the free LLS booklet *Blood Transfusion*.

Treatment Considerations for Children, Adolescents and Young Adults.

Non-Hodgkin lymphoma accounts for an estimated 6 percent of cancers in children younger than 14 years and 7 percent in adolescents ages 15 to 19 years.

Aggressive B-cell lymphomas are the most common NHL types in children; they include Burkitt lymphoma (BL) and diffuse large B-cell lymphoma (DLBCL).

Children and adolescents with NHL should be referred to medical centers that have a specialized pediatric oncology team to ensure that they receive optimal treatment, support and follow-up care. Young adults and parents of children diagnosed with NHL should talk to members of the oncology team about the stage and specific subtype of NHL. Doctors use this information to determine the most effective therapy for the patient. It is also important to discuss the planned therapy with members of the oncology team to learn about the drugs that will be used, the potential short- and long-term side effects including effects on fertility, and the treatment schedule. See *Pretreatment Considerations* on page 18.

For children with NHL, different treatment strategies may be used than those used for adults. The choice of therapy for adolescents and young adults can be challenging and is a topic of ongoing research. Pediatric treatment strategies are used for adults who have certain subtypes of NHL, including Burkitt lymphoma and lymphoblastic lymphoma. Adolescents and young adults should consider being evaluated and treated in a pediatric oncology center, or with a pediatric protocol as part of a clinical trial. With current treatments, NHL is highly curable in most children. The results depend on achieving a precise diagnosis, a thorough staging of the disease, and using complex, multi-drug treatments.

Childhood, adolescent and young adult cancer survivors require close follow-up care because cancer therapy side effects may either persist or develop months, or even years, after treatment.

Visit www.LLS.org/FamilyWorkbook and the chapter, *Beyond Treatment*, to find information about childhood long-term and late effects.

Visit www.LLS.org/SurvivorshipWorkbook to find the books called *Navigating Life During and After a Blood Cancer Diagnosis* for children and adolescents, young adults, and adults.

Treatment of Aggressive Subtypes

New treatments may have been approved since this book was printed. Check www.LLS.org/DrugUpdates or call (800) 955-4572.

Every patient should be evaluated individually by a hematologist-oncologist who specializes in treating non-Hodgkin lymphoma (NHL) and who will discuss the disease subtype, stage and treatment options. It is also important to receive treatment at a center where the doctors have experience in treating NHL.

Treatment for aggressive B-cell NHL subtypes starts at the time of diagnosis. Patients with fast-growing NHL are generally treated with chemotherapy that consists of four or more drugs. In most cases this is the combination therapy called “**R-CHOP**” (see **Table 6** on page 49). This intensive, multi-drug chemotherapy can be very effective for the treatment of aggressive lymphomas, and cures have been achieved. Chemotherapy may be supplemented by radiation therapy in select cases, for instance, when large NHL masses are found during the diagnostic and staging process.

Diffuse Large B-Cell Lymphoma (DLBCL). This is the most common NHL subtype, accounting for about 30 percent of cases of NHL diagnosed in the United States. It is a cancer of B cells (a type of lymphocyte). Diffuse large B-cell lymphoma is named for its appearance under a microscope. The disease shows a wide or diffuse pattern of growth, meaning that the malignant cells grow throughout tissue rather than in clusters. The name above also refers to the large size of the cancer cells present.

Some subtypes of DLBCL originate in B cells found within germinal centers inside lymphatic organs. Germinal centers are short-lived structures formed in response to an outside antigen. Changes occur within the germinal center of B cells in preparation for making antibodies. Other subtypes of DLBCL originate in B cells that have been released from germinal centers.

Diffuse large B-cell lymphoma grows rapidly in the lymph nodes and frequently involves the spleen, liver, bone marrow or other organs. Usually, DLBCL development starts in lymph nodes in the neck or abdomen and is characterized by masses of large B cells. In addition, patients with DLBCL often experience B symptoms (fever, night sweats and loss of more than 10 percent of body weight over 6 months).

For some patients, DLBCL may be their initial diagnosis. For other patients, an indolent lymphoma, such as a small-cell lymphocytic lymphoma or a follicular lymphoma, transforms into DLBCL. Although DLBCL can occur at any age, it most frequently occurs in middle-aged and older people. Most cases have no known cause.

Gene expression profiling (see page 10) has been used to categorize patients into groups by DLBCL subtype. For example, one group of patients may have different responses to therapy than others; another group may have a different clinical presentation based on the number and types of genes that are either more active or less active in the tumor sample. To date, gene expression profiling studies have distinguished two molecular subtypes of DLBCL based on the cell of origin. They are:

- Germinal center B-cell (GCB)
- Activated B-cell (ABC)

These distinct DLBCL subtypes arise due to specific genetic changes. Because gene expression profiling is not commercially available, most hematologist-oncologists, working with hematopathologists, perform immunophenotyping to identify the specific proteins that are associated with either the GCB or the non-GCB subtypes of DLBCL.

According to some studies, DLBCL patients who have the GCB subtype experience significantly better treatment outcomes than those with non-GCB subtypes. A number of clinical trials are underway to investigate whether using new approaches to therapy improves treatment outcomes for patients with non-GCB subtypes of DLBCL.

The following treatment options are for previously untreated patients:

- **Rituximab (Rituxan®)** in combination with **CHOP** (see **Table 6** on page 49) or other anthracycline-based chemotherapy regimens. R-CHOP can be very effective, and most patients with early-stage DLBCL are cured with this treatment regimen. At this time, there is no standard maintenance treatment for DLBCL. Studies are ongoing to see if maintenance treatment is an appropriate option for these patients.
- **Rituximab and hyaluronidase human (Rituxan Hycela®)**, in combination with CHOP or other anthracycline-based chemotherapy regimens. This drug should be started only after patients have received at least one full dose of a rituximab product by intravenous (IV) infusion before receiving Rituxan Hycela by subcutaneous injection.
- **Polatuzumab vedotin-piiq (Polivy®)**, in combination with a rituximab product, cyclophosphamide, doxorubicin, and prednisone (R-CHP).

High-grade B-cell lymphoma with double or triple hits (HBL). The 2022 revision of the World Health Organization (WHO) classification for lymphoma (see **Table 1** on page 5) included a new category of lymphoma, termed “diffuse large B-cell lymphoma/high-grade B-cell lymphoma with MYC and BCL2 rearrangements.”

Historically, “**double-hit**” is the term used to describe a lymphoma in which the malignant cells exhibit mutations on two significant genes. These patients have rearrangements (mutations) of the *MYC* gene and either a *BCL2* or a *BCL6* gene rearrangement. When all three rearrangements are present, it is called a “**triple-hit**” lymphoma. Double- and triple-hit lymphomas account for 8 to 10 percent of DLBCL cases. These lymphomas are considered a distinct group of DLBCL and are sometimes termed as “high-grade B-cell lymphoma.”

These lymphoma subtypes do not respond as well to the standard R-CHOP therapy, have an increased risk of central nervous system (CNS) involvement and progression, and the prognosis for patients is unfavorable. B-cell lymphomas that overexpress MYC and BCL2 proteins, but do not have MYC and BCL2 translocations, are called “**double expressors.**” They are associated

with an intermediate prognosis, which falls between double-hit lymphomas and DLCLs without double-hit or double expression.

There are CAR T-cell therapies approved for double-hit and triple-hit lymphomas. Clinical trials continue to explore how well CAR T-cell therapy agents, monoclonal antibodies, and other targeted therapies work for these patients.

Relapsed DLBCL. For patients whose first treatment did not work (refractory disease), or whose cancer returned (relapsed disease) within a year of first treatment, CAR T-cell therapy is an available option. For patients whose disease relapsed beyond one year of their first treatment with the intention to proceed to transplant, additional chemotherapy (called a “salvage” treatment) followed by high-dose therapy and autologous stem cell transplant is recommended. For patients not intending to proceed to transplant or are transplant ineligible, treatment options include lisocabtagene maraleucel, polatuzumab with or without bendamustine and rituximab, and tafasitamab with lenalidomide. For relapsed DLBCL, when at least two kinds of treatment have failed, additional treatment options include:

- **Chimeric antigen receptor (CAR) T-cell therapy**
(For more information about CAR T-cell therapy, see the free LLS booklet *Chimeric Antigen Receptor [CAR] T-Cell Therapy*.)
 - **Axicabtagene ciloleucel (Yescarta®)**
 - **Lisocabtagene maraleucel (Breyanzi®)**
 - **Tisagenlecleucel (Kymriah®)**
- **Loncastuximab tesirine-lpyl (Zynlonta®)**
- **Polatuzumab vedotin-piiq (Polivy®)**
- **Selinexor (Xpovio®)**
- **Tafasitamab-cxix (Monjuvi®)**
- **Glofitamab-gxbm (Columvi™)**
- **Epcoritamab-bysp (Epkincy™)**

See **Table 5**, beginning on page 41, for full FDA approval information and indications for these medications. The Package Insert and/or the Full Prescribing Information for each medication is available on the internet.

High-dose chemotherapy and an autologous stem cell transplant (ASCT) may be used to treat patients whose disease has relapsed after disease remission, but only a minority of patients achieve long-term remissions with this therapy. Allogeneic stem cell transplantation remains a potential cure for relapsed DLBCL, but some patients may not qualify for a transplant due to their advanced age or the presence of other medical conditions. The efficacy of reduced-intensity transplantation is being evaluated in clinical trials. See *Stem Cell Transplantation* on page 29.

Acquired Immunodeficiency Syndrome (AIDS)-Associated Lymphoma.

The NHL subtypes that occur most frequently in people with AIDS are DLBCL, Burkitt lymphoma and primary central nervous system (CNS) lymphoma. Treatment outcomes are affected by how well the patient with AIDS is responding to treatment and managing the effects of chemotherapy as reflected in their blood counts. The number of people who develop AIDS-associated NHL has decreased in the last several years because of improved HIV treatments.

Burkitt Lymphoma (BL). This rare and aggressive B-cell subtype grows and spreads very quickly and accounts for about 2 percent of NHL cases. It may involve the jaw, bones of the face, bowel, kidneys, ovaries, marrow, blood, central nervous system and other organs. This disease develops most often in children and young adults.

Burkitt lymphoma was named after Dr. Dennis Burkitt, a surgeon working in equatorial Africa. There, the disease usually appears in children as a mass in a facial bone, especially the jaw, and Epstein-Barr virus (EBV) is usually present in the lymphoma cells, along with an abnormality of chromosome 8. Burkitt lymphoma occurs far less frequently in other parts of the world. There are three main types of Burkitt lymphoma. They are:

- Endemic Burkitt lymphoma—the most common form of childhood cancer in Africa, associated with EBV
- Sporadic Burkitt lymphoma—which occurs throughout the world and accounts for 1 to 2 percent of all adult lymphoma cases in the United States and Western Europe. It is more common in the pediatric population, accounting for 30 percent of lymphoma cases in children, and it affects more males than females. Sporadic cases are associated with EBV, and the most common area of involvement is the abdomen, particularly the intestines.
- Immunodeficiency-related Burkitt lymphoma—often seen in patients who have AIDS, individuals with congenital immunodeficiency and in some patients following stem cell transplantation.

Burkitt lymphoma is characterized by the rearrangement of the *MYC* gene caused by a translocation in chromosome 8. This abnormality is seen in 80% of all BL patients. This type of lymphoma may spread to the brain and spinal cord (part of the CNS); therefore, prophylactic treatment to prevent it from spreading to the CNS should be included in any treatment regimen for Burkitt lymphoma. CHOP or CHOP-like chemotherapy regimens do not produce favorable results. Instead, a highly aggressive chemotherapy regimen is used to treat this subtype of NHL, often requiring admission to the hospital. Commonly used regimens include:

- **CODOX-M/IVAC**
- **Hyper-CVAD**
- **DA-EPOCH-R**

- **Rituximab (Rituxan®)** used in combination with hyperCVAD (in a small number of studies)
- **Rituximab (Rituxan®)** in combination with chemotherapy

See **Table 5** on page 41, for FDA approval information and **Table 6** on page 49 for drug combinations. The Package Insert and/or the Full Prescribing Information for each medication is available on the internet.

Studies report that BL is curable in a significant group of patients when treated with high-dose, multi-drug chemotherapy regimens that include central nervous system (CNS) prophylaxis. About 60 to 90 percent of children and young adults with the disease achieve durable remissions if treated timely and appropriately. Older patients with BL have less favorable outcomes than younger patients.

Patients with relapsed or refractory BL are encouraged to participate in clinical trials. Consolidation treatment with a high-dose conditioning therapy and autologous stem cell transplantation (or allogeneic transplantation, if a donor is available) may be considered for patients who achieve remission after their second-line treatment. See *Stem Cell Transplantation* on page 29. Additionally, new drugs are being evaluated in clinical trials.

Primary Central Nervous System (CNS) Lymphoma. Primary CNS lymphoma forms in the brain and/or the spinal cord. It is often a feature of AIDS-associated lymphoma but can also affect persons undergoing solid organ transplantation or those with autoimmune disorders. Secondary CNS lymphoma develops when a lymphoma, already present in other parts of the body, spreads to the brain and/or the spinal cord. Both primary and secondary CNS lymphomas are uncommon.

The symptoms of CNS lymphoma depend on the location of the tumor. Patients may experience headache, nausea and vomiting, blurred vision, leg and arm weakness, changes in mental alertness or confusion, hearing loss, seizures, back pain, leg weakness or incontinence.

Treatment options depend on the stage, location of the disease within the CNS, whether the disease has either just been diagnosed or has relapsed, and the patient's age and general health. There is no single accepted treatment regimen for CNS lymphoma. Treatments being studied in a clinical trial may be the best option. Therapy may include methotrexate-based combinations that include rituximab (Rituxan®); chemotherapy and monoclonal antibodies; corticosteroid drugs; and/or radiation therapy. Chemotherapy followed by stem cell transplantation or CAR T-cell therapy could be other options for relapsed CNS. See *Stem Cell Transplantation* on page 29.

Please visit www.LLS.org/cns for additional information about CNS lymphoma.

Primary mediastinal B-cell lymphoma (PMBCL). This is a subtype of NHL characterized by the overgrowth of scar-like lymph tissue. A tumor generally forms behind the breastbone and may cause coughing and difficulty breathing. The tumor is often very large and can cause pressure on the blood vessels or the heart and lungs. It occurs mainly in adolescents and young adults. The median age at diagnosis is 35 years and it affects slightly more women than men.

Patients with PMBCL often need more intensive treatment. There are two standard combination regimens: **R-EPOCH** and **R-CHOP** (see **Table 6** on page 49). The **R-EPOCH** regimen is being used more often as a treatment for PMBCL, as there is less need for radiation therapy with this regimen. Treatment for people whose disease is refractory to treatment or has relapsed includes the monoclonal antibody **pembrolizumab (Keytruda®)** and the CAR T-cell therapy product **axicabtagene ciloleucel (Yescarta®)**. Another option includes **nivolumab (Opdivo®)** with or without **brentuximab vedotin (Adcetris®)**.

T-Cell Lymphoblastic Lymphoma (T-LBL). This is the most common type of pediatric T-cell lymphoma. It is most frequently seen in adolescent males. Patients with this diagnosis are treated in the same way as patients with acute lymphoblastic leukemia. **For more information about the diagnosis and treatment of acute lymphoblastic leukemia, see the free LLS booklets *Acute Lymphoblastic Leukemia in Children and Teens* and *Acute Lymphoblastic Leukemia in Adults*.**

Treatment of Indolent Subtypes

New treatments may have been approved since this book was printed. Check www.LLS.org/DrugUpdates or call (800) 955-4572.

The management of indolent lymphoma subtypes at initial diagnosis ranges from observation with careful monitoring (“watch-and-wait” approach, or “active surveillance”) to aggressive therapy. Appropriate management is highly individualized and depends on the patient’s:

- Prognostic factors
- Stage of disease
- Age and other medical conditions

Treatment Options. Standard treatment for indolent B-cell non-Hodgkin lymphoma (NHL) subtypes includes the following options:

For early-stage disease

- The watch-and-wait approach
- Radiation therapy
- **Rituximab (Rituxan®)**, either with or without chemotherapy

For advanced-stage disease

- The watch-and-wait approach for asymptomatic patients
- Immunotherapy: rituximab, **obinutuzumab (Gazyva®)**, **ytrium90+ibrutinomab tiuxetan (Zevalin®)**
- Chimeric antigen receptor (CAR) T-cell therapy: **axicabtagene ciloleucel (Yescarta®)**, **lisocabtagene maraleucel (Breyanzi®)**, **tisagenlecleucel (Kymriah®)**
- Alkylating agents: **cyclophosphamide (Cytoxan®)**, **chlorambucil (Leukeran®)**, **bendamustine hydrochloride (Bendeka®)**
- Combination chemotherapy

The Watch-and-Wait Approach. Many doctors consider observation, called the “watch-and-wait” approach, involving careful monitoring and follow-up care, to be an active form of therapy. Patients need to discuss with their doctors the potential benefits of the watch-and-wait approach, versus initiating chemotherapy and/or other therapies right after diagnosis. Studies comparing the watch-and-wait approach to early treatment have shown no survival advantage in the group of patients who were treated at diagnosis compared to those who were observed.

Some patients with indolent lymphomas need an aggressive initial therapy after diagnosis. However, patients with no symptoms and limited extent of disease can often be observed over long periods of time. Sometimes their condition remains stable for years, and these patients can avoid the side effects of unnecessary therapy during this time. Treatment should start when a patient shows signs and/or symptoms of lymphoma progression, such as new or enlarging lymph nodes, bone or other organ involvement, or a decrease in blood cell formation that causes low blood cell counts. The specific decision to treat indolent lymphoma is made collaboratively by the oncologist and patient. Each case is evaluated individually, and treatment approaches vary among patients.

For more information on the watch-and-wait approach, see the free LLS booklet *Watch and Wait*.

Follicular Lymphoma (FL). This is the second most common subtype of NHL, accounting for about 22 percent of newly diagnosed cases of NHL. The median age at diagnosis is 65 years.

Most follicular lymphoma cells have a specific chromosome abnormality (a translocation between parts of chromosomes 14 and 18) that causes the overexpression of a gene called *BCL2*, which makes the cells resistant to treatment.

Most often, FL patients are diagnosed at stage III or IV rather than I or II. The cancer stage refers to the extent of the cancer in the body. Some patients with slow-growing FL may not need to start treatment for several years, whereas others have extensive lymph node or organ involvement and need treatment

right away. In a small percentage of patients, FL may transform into a more aggressive disease.

Follicular Lymphoma Treatment. Stage I or stage II FL may be treated with:

- The watch-and-wait approach
- Radiation therapy
- Chemotherapy with rituximab (Rituxan®)
- Rituximab (Rituxan®) alone

Some patients with FL who respond to their initial treatment may be subsequently monitored without any need for further therapy. However, periodic observation continues to be important, so doctors can identify those who need additional treatment.

For patients who have stage II FL with large lymph nodes, stage III or stage IV FL, or advanced-stage relapsed FL, treatment options are based on the signs and/or symptoms, the patient's age and health status, the extent of disease and the patient's wishes. Those who require treatment may want to consider taking part in a clinical trial.

Other treatment options for FL include:

- The watch-and-wait approach
- Radiation therapy to lymph nodes that are causing symptoms, or to a large, localized mass, if one is present
- Rituximab (Rituxan®) alone
- A single chemotherapy drug—for example, **cyclophosphamide**, **chlorambucil** or **bendamustine hydrochloride (Bendeka®)**—in combination with rituximab
- A combination chemotherapy plus rituximab, such as **R-CVP**—rituximab plus cyclophosphamide (Cytoxan®), hydroxydoxorubicin (doxorubicin), vincristine, prednisone—or **R-CHOP** (see **Table 6** on page 49)
- Maintenance therapy with rituximab after completion of initial therapy with either rituximab alone or rituximab in combination with chemotherapy. This involves a single dose of rituximab administered on a prescribed schedule, generally every 2 to 3 months, which may be continued for 2 years.
- Autologous or allogeneic stem cell transplantation may be considered for certain patients who have refractory or relapsed FL. See *Stem Cell Transplantation* on page 29.
- Targeted therapy kinase inhibitors for refractory or relapsed disease, such as
 - The BTK inhibitor **zanubrutinib (Brukinsa®)** in combination with obinutuzumab
 - The EZH2 inhibitor **tazemetostat (Tazverik™)**

- Immunomodulatory drugs, such as **lenalidomide (Revlimid®)**
- Immunotherapy with monoclonal antibodies, either alone or in combination
 - **Yttrium-90+ibritumomab tiuxetan (Zevalin®)**
 - **Obinutuzumab (Gazyva®)**—may include obinutuzumab maintenance
 - The combination of the monoclonal antibody **rituximab and the enzyme endoglycosidase hyaluronidase human (Rituxan Hycela™)**
- Immunotherapy with bispecific antibodies
 - **Mosunetuzumab-axgb (Lunsumio™)**
- CAR T-cell therapy
 - **Axicabtagene ciloleucel (Yescarta®)**
 - **Tisagenlecleucel (Kymriah®)**

See **Table 6** on page 49 for drug combinations and **Table 5**, starting on page 41, for FDA approval information for the drugs mentioned in this section. The Package Insert and/or the Full Prescribing Information for each medication is available on the internet.

The Follicular Lymphoma International Prognostic Index (FLIPI). The FLIPI is a scoring system used to predict which patients with follicular lymphoma may be at higher risk for disease recurrence. This information helps doctors determine appropriate care for patients who have been treated for follicular lymphoma. One point is assigned for each of the following risk factors (known by the acronym NoLASH):

- **N**umber (No in NoLASH) of nodal sites involved—five or more
- **L**actate dehydrogenase (LDH) level—higher than the upper limit of normal
- **A**ge older than 60 years
- **S**tage III or stage IV disease
- **H**emoglobin concentration—less than 12 grams per deciliter (g/dL)

Each point represents an increased risk for disease recurrence. The total number of points determines the risk group, as follows: low risk (0 to 1 point); intermediate risk (2 points); high risk (3 to 5 points). Patients may want to discuss risk factors with their doctor to understand their treatment options, including participation in clinical trials.

Transformed B-Cell Follicular Lymphoma. Follicular lymphoma can transform into an aggressive large B-cell lymphoma, such as diffuse large B-cell lymphoma (DLBCL). This occurs in about 15% of patients. Risk factors for transformed FL include advanced-stage disease, high-risk group per FLIPI score, elevated LDH and the presence of B symptoms at initial diagnosis. Patients with transformed B-cell FL appear to benefit from rituximab therapy, either alone or in combination

with chemotherapy. Another option is the bispecific antibody epcoritamab (Epkiny™). Other options include chimeric antigen receptor (CAR) T-cell therapy with **axicabtagene ciloleucel (Yescarta®)**, **lisocabtagene maraleucel (Breyanzi®)** or **tisagenlecleucel (Kymriah®)**.

For more information about chimeric antigen receptor (CAR) T-cell therapy, see the free LLS booklet *Chimeric Antigen Receptor (CAR) T-Cell Therapy*.

Reduced-intensity transplantation, within a clinical trial, may also be considered in cases of FL transformation. Several novel drug combinations are being studied for the treatment of refractory/relapsed FL.

Stem Cell Transplantation

The goal of stem cell transplantation is to cure the patient's cancer by destroying the cancer cells with high doses of chemotherapy, and then replacing them with healthy blood-forming stem cells. The main types of stem cell transplantation are:

- Allogeneic—using stem cells from a matched or partially matched donor, either related or unrelated to the patient
- Autologous—using the patient's own stem cells (taken before the conditioning chemotherapy is given)
- Reduced-intensity—a form of allogeneic transplantation in which patients receive lower doses of chemotherapy drugs and/or radiation therapy in preparation for the transplant

Autologous stem cell transplantation remains a key component of standard medical care for patients with aggressive forms of non-Hodgkin lymphoma (NHL). For indolent lymphomas (indolent means that the disease is not progressing or is growing slowly), autologous stem cell transplantation is primarily used to treat patients with relapsed NHL. Allogeneic transplantation may be considered for the treatment of indolent forms of NHL, particularly in younger patients whose disease behaves more aggressively or has high-risk features.

Stem cell transplantation can cause serious side effects that can be life-threatening, so it may not be a treatment option for all NHL patients. The risks and benefits of transplantation must always be considered when making treatment choices. The decision to undergo a transplant should be discussed with the treating doctor. The doctor will consider many factors, including the patient's age, general health, certain prognostic factors, previous treatments, and, for allogeneic transplants, whether the patient has a well-matched donor.

For more information on stem cell transplantation, see the free LLS booklet *Blood and Marrow Stem Cell Transplantation*.

Clinical Trials for Blood Cancers

Every new cancer drug goes through a series of carefully controlled research studies before it can become part of standard cancer care. These research studies are called clinical trials and they are used to find better ways to care for and treat people with cancer.

In the United States, the FDA (U.S. Food and Drug Administration) requires that all new drugs and other treatments be tested in clinical trials before they can be used. At any given time, there are thousands of cancer clinical trials taking place. Doctors and researchers are always looking for new and better ways to treat cancer.

Researchers use cancer clinical trials to study new ways to:

- Treat cancer using
 - A new drug
 - An approved drug to treat a different kind of cancer
 - A new combination of drugs
 - A new way of giving a drug—by mouth (pill), intravenously (IV)
- Manage cancer symptoms and ease treatment side effects
- Find and diagnose cancer
- Keep cancer from coming back after treatment
- Manage long-term side effects

By taking part in a clinical trial, patients can see doctors who are experts in their disease, gain access to new, cutting-edge therapies, and provide helpful information for future patients. The treatments and information we have today are due in large part to patients being willing to join clinical trials. Anyone interested in being part of a clinical trial should talk to their hematologist-oncologist about whether a clinical trial might be right for them. During this conversation it may help to:

- Have a list of questions to ask about the risks and benefits of each trial (visit www.LLS.org/WhatToAsk for lists of suggested questions).
- Ask a family member or friend to go with you to your doctor visit—both for support and to take notes.

Clinical trials can be difficult to navigate and figure out, but The Leukemia & Lymphoma Society is here to help. Patients and caregivers can work with Clinical Trial Nurse Navigators who will help find potential clinical trials, overcome barriers to enrollment and provide support throughout the entire clinical trial process. **Our Clinical Trial Nurse Navigators** are registered nurses who are experts in pediatric and adult blood cancers and clinical trials. Your

Clinical Trial Nurse Navigator will:

- Talk with you about your treatment goals
- Help you to understand the clinical-trial process, including your rights as a patient
- Ask you for details about your diagnosis (like past treatments, treatment responses, and your cancer genetic profile), your current health, and your medical history—because these might impact whether you can take part in certain clinical trials
- Help you understand how your finances, insurance coverage, support network, and ability and willingness to travel might impact your choice of clinical trials
- Guide you and help you in your efforts to find and enroll in a clinical trial, including connecting you with trial sites
- Help deal with any problems you might have as you enroll in a trial
- Support you throughout the clinical trial process

Call an LLS Information Specialist at (800) 955-4572 or visit www.LLS.org/CTSC for more information about clinical trials and the Clinical Trial Support Center (CTSC) at LLS.

Also, visit www.LLS.org/booklets to view the free LLS booklet *Understanding Clinical Trials for Blood Cancers*.

Side Effects of Treatment

The side effects of treatment for lymphoma depend on the intensity and type of treatment and other factors, such as which area(s) of the body are treated with radiation therapy, the patient's age and coexisting medical conditions (eg, diabetes mellitus, chronic renal disease, etc). In addition, certain drugs can affect certain tissues—for example, the drug called vincristine typically affects nerve tissue.

In recent years, new drugs and other therapies have made it possible for doctors to control troublesome side effects, such as nausea and vomiting. When side effects do occur, most are short-term and resolve when therapy is completed. The benefits of receiving treatment for non-Hodgkin lymphoma (NHL), with the goal of remission (and, in some cases, cure), generally outweigh the associated risks and discomfort.

Suppressed Blood Cell Formation. Decreases in blood cell counts may occur in patients treated with chemotherapy. Blood transfusions may be necessary for some patients with low blood cell counts. If decreases in white blood cell counts are severe and continue over extended periods of time, an infection may develop and require antibiotic treatment. Sometimes, chemotherapy dosages or the time between chemotherapy cycles must be altered to allow the patient's blood cell counts to recover from the effects of treatment. A granulocyte-colony

stimulating factor (G-CSF), such as Neupogen® or Neulasta®, is sometimes used to stimulate the production of white blood cells when they are depleted. G-CSF is given by subcutaneous injection to increase the number of white blood cells that help prevent infection.

Infections. Chemotherapy and radiation therapy can make patients more susceptible to infection because these treatments weaken immune cell function and can lower the number of normal white blood cells. Removal of the spleen, a treatment option for patients with some types of NHL (such as splenic marginal zone lymphoma) also contributes to the risk of severe infection.

Infections can be very dangerous. It is important to take fevers seriously and get to the hospital if you have a fever of over 100.4° F.

Vaccinations. Patients with NHL are advised to receive certain vaccinations, including vaccinations for pneumococcal pneumonia and influenza, once they have finished their treatment. There are two types of pneumococcal vaccines available for adults: a pneumococcal polysaccharide vaccine (PPSV23) and a pneumococcal conjugate vaccine (PCV13). Patients with NHL should not be given vaccines that use live organisms or those with high viral loads, such as the herpes zoster (shingles) vaccine, but they can receive Shingrix® because it is an inactivated shingles vaccine. COVID-19 and other vaccines are also recommended. Your doctor can give you more information.

Viral Reactivation. Hepatitis B virus (HBV or Hep B) reactivation has been reported in some patients treated with chemotherapy, either with or without immunotherapy drugs. Carriers of the hepatitis B virus, especially those treated with anti-cluster of differentiation 20 (anti-CD20) monoclonal antibodies, including rituximab (Rituxan®), ofatumumab (Arzerra®) and obinutuzumab (Gazyva®), have a high risk of virus reactivation and disease.

Preventive antiviral therapy is recommended for patients who test positive for HBV if they are going to receive an NHL therapy. Cytomegalovirus (CMV) reactivation may occur in patients with chronic lymphocytic leukemia (CLL) or small-cell lymphocytic lymphoma (SLL) receiving alemtuzumab (Campath®) therapy. This occurs most frequently between 3 to 6 weeks after the start of therapy, when T-cell counts reach their lowest point. This complication happens in up to 25 percent of treated patients. Current practices to prevent CMV reactivation include the use of a prophylactic antiviral drug (ganciclovir), to be administered if the patient tests positive for CMV prior to alemtuzumab treatment. Patients being treated with regimens containing alemtuzumab should be monitored frequently for the CMV virus (every 2 to 3 weeks) during the treatment and for 2 months after the completion of therapy.

Lymphedema. In this condition, extra lymph fluid builds up in tissues, causing swelling and discomfort. Cancers that involve lymph nodes and lymph vessels can cause lymphedema. It can also develop due to surgery to remove lymph

nodes or to radiation therapy. Swelling may occur during treatment, or it may appear years after therapy is finished. Treatment for this condition includes massage, exercise and the use of compression sleeves.

Bone Loss and Fractures. Drug regimens that contain corticosteroids have been associated with an increased risk of fractures and treatment-induced bone loss in patients with NHL. The risk of bone loss is higher among young women with chemotherapy-induced premature menopause and older patients receiving chemotherapy. Patients with newly diagnosed NHL are also at risk of low bone mineral density, which may worsen during treatment with systemic corticosteroids. Evaluation of vitamin D levels and post-treatment bone loss is recommended for patients receiving systemic corticosteroids. Patients should also maintain an adequate calcium intake because corticosteroids block calcium absorption and increase the risk of fractures. Pamidronate and zoledronic acid are part of a group of drugs called “bisphosphonates.” These drugs can help stabilize bone mineral density, prevent bone loss and reduce the risk of new fractures in patients with NHL.

Neuropathy. Some chemotherapeutic agents, such as vincristine (Oncovin®), brentuximab vedotin (Adcetris®) or polatuzumab vedotin (Polivy®), can cause nerve damage called “neuropathy.” Initially, the patient experiences numbness and tingling in the fingertips and toes. The sensation might be temporary, but if it continues, it may become permanent. In general, treatment options are limited. The patient should be monitored for these side effects between each cycle of chemotherapy. If the neuropathy becomes severe, the drug dosage may need to be adjusted.

Tumor Lysis Syndrome (TLS). Patients with NHL, especially those with very high white blood cell counts before the beginning of treatment, may be at high risk for developing acute tumor lysis syndrome (TLS). This condition is characterized by metabolic abnormalities caused by the sudden release of the cellular contents of dying cells into the bloodstream that the kidneys cannot remove. If untreated, TLS can lead to heart arrhythmias, seizures, loss of muscle control, acute kidney failure and even death. Patients with a high level of uric acid may be given the drug allopurinol (Zyloprim®) to minimize the buildup of uric acid in the blood. Allopurinol is taken by mouth. Another drug, rasburicase (Elitek®), is given in a single intravenous dose which can rapidly lower an elevated uric acid level.

Progressive Multifocal Leukoencephalopathy (PML). This is a very rare but serious and potentially fatal central nervous system infection caused by the reactivation of latent John Cunningham (JC) virus. Cases of PML typically occur in severely immunocompromised individuals, such as patients who have AIDS or a blood cancer, and are profoundly immunosuppressed due to the underlying disease or its treatment.

The use of rituximab, in combination with chemotherapy, may be associated with an increased risk of PML in immunocompromised patients with chronic

lymphocytic leukemia/small-cell lymphocytic lymphoma (CLL/SLL) and other types of NHL. Signs and/or symptoms of PML include confusion, poor coordination, motor weakness and visual and/or speech changes. To date, there is no effective treatment for this condition. Patients at risk should be carefully monitored for the development of any neurological symptoms.

Other Side Effects. Chemotherapy affects tissues that normally have a high rate of cell turnover, so it may affect the lining of the mouth, the lining of the intestines, the skin and the hair follicles. Common side effects of therapy include:

- Mouth sores
- Nausea and vomiting
- Diarrhea
- Temporary hair loss
- Fatigue
- Cough
- Fever
- Rash

Side effects depend on the medications and dosages used and the responses of the individual patient, so they can range from mild to severe. Fortunately, there are drugs and other supportive measures to either prevent or manage many side effects.

Children may experience side effects of treatment for short or longer periods of time that can affect learning.

For more information about how side effects can affect children, see the free LLS booklet *Learning & Living with Cancer: Advocating for Your Child's Educational Needs*.

Long-Term and Late Effects of Treatment

Long-term effects of cancer therapy are medical problems that persist for months or even years after treatment ends. Late effects are medical problems that do not develop or become apparent until years after treatment ends.

It is important to know about the potential for long-term and late effects of treatment so any problems may be identified early and managed. Various factors can influence the patient's risk, including:

- Type and duration of treatment
- Age at time of treatment
- Gender and overall health

Many survivors of non-Hodgkin lymphoma (NHL) do not develop significant long-term or late effects of treatment. However, it is important for all adult patients, as well as the parents of children who will be treated for NHL, to discuss possible long-term and late effects with members of the treatment team so the proper planning, evaluation and follow-up care can take place.

Heart Disease. Radiation therapy to the chest and treatment with chemotherapy containing alkylating agents (eg, cyclophosphamide) or anthracyclines (eg, doxorubicin) has been linked to heart disease. This includes inflammation of the sac surrounding the heart (the pericardium), dysfunction of the heart valves, heart failure (when the heart is unable to pump blood effectively), coronary arterial disease, or a classic heart attack (myocardial infarction).

Secondary Cancers. For as long as 3 decades after diagnosis, patients are at a significantly elevated risk for second primary cancers, such as cancers of the breast, lung, brain, bladder, skin, and blood cells. Autologous bone marrow or peripheral blood stem cell transplantation and treatment with chemotherapy-containing alkylating agents are associated with an increased risk of myelodysplastic syndromes and acute myeloid leukemia.

Fertility. Patients may have decreased fertility after treatment for NHL. The risk of infertility varies according to the nature of the treatment, including the type and amount of chemotherapy, the area(s) of the body targeted by radiation therapy and the patient's age. Male patients who are at risk of infertility should consider sperm banking before treatment, and female patients should discuss all their fertility preservation options. Females who have ovarian failure after treatment will experience premature menopause and require hormone replacement therapy.

It is important to discuss all your options and treatment concerns with your doctor. If possible, you may also want to discuss these options with a doctor who specializes in fertility and reproduction. Many cancer centers have reproductive specialists who will suggest specific options for each patient. For couples of childbearing age in which one partner has received treatment, the incidence of pregnancy loss and the health of a newborn are very similar to those of healthy couples.

For more information about fertility, see the free LLS booklet *Fertility and Cancer*. Visit www.LLS.org/FamilyWorkbook and the chapter, *Beyond Treatment*, to find information about childhood long-term and late effects.

Follow-up Care. Follow-up care is important for patients who have NHL. If the disease recurs, many treatment options are still available. Follow-up care needs to be individualized and should be based on several factors, including how the disease initially manifested. Patients whose disease is in remission should continue to be monitored by clinical assessment as determined by their doctor. In the past, computed tomography (CT) or other diagnostic imaging scans were

done routinely in an attempt to detect relapse. However, there is an increasing awareness that undergoing too many scans may be harmful, and that CT scans performed in otherwise asymptomatic patients have a relatively low likelihood of finding recurrent lymphoma. The frequency of clinical visits, laboratory tests and CT scans or other imaging tests should be discussed with the treating doctor.

Periodic assessment of the patient's state of health, blood cell counts and, if indicated, bone marrow is important. Over time, the interval between assessments may be lengthened, but assessments should be continued indefinitely for most patients.

For additional information about survivorship, see one of the three free LLS booklets *Navigating Life During and After a Blood Cancer Diagnosis: Adults, Young Adults, or Children and Adolescents*.

Financial Concerns

Non-Hodgkin lymphoma (NHL) patients are living longer, primarily because of the development of new and effective drugs. While this progress is exciting, for some NHL patients' treatment consists of drug combinations that require continuous use. This can result in financial burden for patients, limited access to medications and lower adherence to treatments. Patients can speak to their doctor if they have any concerns about being able to afford their medications. A member of the treatment team may be able to provide information and resources that can help.

Although health insurance plans may not cover all the costs of cancer care, there are several resources available to find assistance in paying for prescription drugs. These include resources from organizations, foundations and prescription assistance programs. In addition, several major pharmaceutical manufacturers provide patient assistance or prescription assistance programs. These companies may be able to help by providing both insured and uninsured patients with either free or reduced-cost medications.

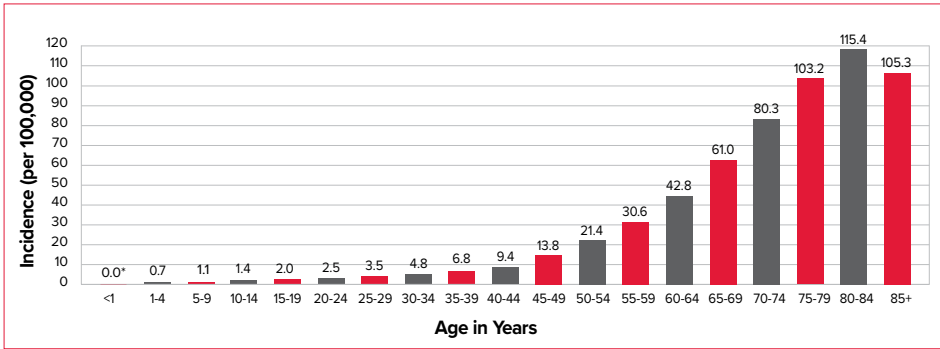
You can contact an LLS Information Specialist at (800) 955-4572 for information about our financial assistance programs.

For more information and resources to cope with the financial aspects of cancer care, please see the free LLS booklet *Cancer and Your Finances*.

Incidence, Causes and Risk Factors

Incidence. About 80,620 new cases of non-Hodgkin lymphoma (NHL) are expected to be diagnosed in the United States in 2024. Non-Hodgkin lymphoma occurs in individuals at virtually all ages, but it is uncommon in children. The disease is more common in males than females, and among whites. It is most frequently diagnosed in people 80 to 84 years old (see **Figure 3**).

Figure 3. Age-Specific Incidence Rates for Non-Hodgkin Lymphoma, 2015-2019



Source: SEER*Explorer: An interactive website for SEER cancer statistics [Internet]. Surveillance Research Program, National Cancer Institute. [Cited 2023 February 19]. Available at <https://seer.cancer.gov/explorer/>.

*Estimates based on less than 16 cases are suppressed and not shown.

Causes and Risk Factors. The exact cause of NHL is not known, but there are risk factors that may increase the likelihood of developing the disease. Factors affecting people’s risk of developing NHL have been studied extensively. Some of these factors are immune disorders, medicines, infections, lifestyle, genetics, race, family history and occupational factors.

- Obesity has been found to be a risk factor for diffuse large B-cell lymphoma (DLBCL).
- Genome wide-association studies, an approach used in genetics research to associate specific genetic variations with particular diseases, have found sites on a gene or mutations on a chromosome that are associated with excessive risk for follicular lymphoma, marginal zone lymphoma and DLBCL.
- Immune suppression is one of the most clearly established risk factors for NHL. People with autoimmune diseases, such as rheumatoid arthritis and systemic lupus erythematosus, acquired immunodeficiencies including HIV/AIDS, and organ transplant recipients have an elevated risk for NHL. Whether this increased risk is related only to the autoimmune disease, or to the immunosuppressive therapies employed to treat it, is not clear.
- A number of occupational and environmental factors have also been associated with NHL. Farming communities have a higher incidence of NHL, and farm work has been linked to major NHL subtypes and to NHL overall. This observation has led to research on agricultural chemicals, such as pesticides, solvents, fuels, oils and other agents that are potentially carcinogenic.

Some studies suggest that specific substances in herbicides and pesticides, such as organochlorine, organophosphate and phenoxy acid compounds, are linked to lymphoma. For example, the occupational exposure to non-arsenic

insecticides during spraying and application has been classified by the International Agency for Research on Cancer as a “probable human carcinogen.”

The number of lymphoma cases caused by exposures to herbicides and pesticides has not been determined. More studies are needed to understand these associations.

- Exposure to ionizing radiation. This can include exposure to radiation from nuclear facilities, atomic bombs and medical radiation therapy.
- The risk factors identified for peripheral T-cell lymphomas include celiac disease, an extensive smoking history, working with textiles or electrical equipment and some immune suppressive agents for autoimmune conditions.
- Exposure to certain viruses and bacteria is associated with NHL. It is thought that being infected with either a certain virus or bacterium can lead to rapid lymphoid cell reproduction, increasing the probability of a cancer-causing event in a cell. Here are some examples:
 - Epstein-Barr virus (EBV) infection in patients from specific geographic regions in Africa is strongly associated with Burkitt lymphoma. The role of the virus is unclear, since Burkitt lymphoma in Africa also occurs among people who have not been infected with EBV.
 - Epstein-Barr virus infection may also play a role in the increased risk of NHL in people with a suppressed immune system as a result of organ transplantation and its associated therapy. This infection is closely associated with both Burkitt lymphoma and extranodal natural killer (NK)/T cell lymphoma (ENK/TL), nasal type.
 - Human T-cell lymphotropic virus-1 (HTLV-1) is associated with a type of T-cell lymphoma in patients from certain geographic regions in southern Japan, the Caribbean, South America and Africa.
 - HIV/AIDS is associated with the development of certain types of NHL that generally occur in older patients.
 - The bacterium *Helicobacter pylori* (*H pylori*) causes ulcers in the stomach and is associated with the development of gastric mucosa-associated lymphoid tissue (MALT) lymphoma in the stomach wall.
 - Hepatitis C is associated with the development of marginal zone lymphoma and DLBCL. Associations with other types of lymphoma are being explored.
 - The bacteria *Borrelia burgdorferi* (*B burgdorferi*) and *Chlamydia psittaci* (*C psittaci*) are thought to be associated with the development of marginal zone lymphomas.
 - The bacterium *Coxiella burnetti* (*C burnetti*) has been proposed as a risk factor for DLBCL and follicular lymphoma.
- Other conditions, such as Sjögren syndrome (primary Sjögren syndrome patients have a 10–44–fold greater risk of lymphoma than healthy individuals), Wiskott-

Aldrich syndrome and Klinefelter syndrome, can predispose individuals to later development of NHL. Patients with NHL are also more likely to develop primary Sjögren syndrome than healthy individuals. These inherited disorders are uncommon, but the concept of predisposition genes is under study to determine if they play a role in the random occurrence of NHL in otherwise healthy individuals.

For more information, contact an LLS Information Specialist at (800) 955-4572 or visit www.LLS.org/ResourceDirectory (click on Disease registries and other disease studies under Blood Cancer–General Information.)

Drug Information

The three tables that follow (Tables 4, 5, and 6) include information about drug classification and treatments for non-Hodgkin lymphoma.

Table 4. Drug Classes and Drug Functions

Alkylating Agents (DNA-Damaging Drugs)	These drugs work by either stopping or slowing the growth of cancer cells in the body.
Antibody-Drug Conjugates	Antibody-drug conjugates (ADCs) are immunotherapy drugs designed to target specific proteins (antigens) on the surface of cancer cells. Others are coupled with a chemotherapy drug or attached to a radioactive particle, so they are called “antibody-drug conjugates.” They circulate throughout the body until they attach to the target antigen and then deliver the toxic substance to the cancer cell.
Antifolate	Antifolates stop cells from using folic acid to make DNA and cause cells to die.
Antimetabolites	Antimetabolites mimic the building blocks of DNA or RNA that cancer cells need to survive and grow. When the cancer cell uses an antimetabolite instead of natural substances, it cannot produce normal DNA or RNA, and the cell dies.
Antitumor Antibiotics	Antitumor antibiotics prevent cell division by either binding to DNA to prevent the cells from duplicating or inhibiting RNA synthesis.
B-Cell Lymphoma 2 (BCL2) Inhibitor	These drugs inhibit the production of a protein that controls whether a cell lives or dies.
Bispecific Antibody	A type of antibody that can bind to two different antigens at the same time.
Bruton Tyrosine Kinase (BTK) Inhibitors	These inhibitors help stop growth signals that allow cancer cells to multiply.
Chimeric Antigen Receptor (CAR) T-Cell Therapy	This is a type of immunotherapy that uses a patient’s own T cells to identify and attack cancer cells. The T cells are taken from the patient’s blood and sent to a laboratory, where they are genetically modified to attack cancer cells. The engineered T cells are then multiplied and later re-infused into the patient’s bloodstream.

Corticosteroids	Certain hormones (corticosteroids) can kill lymphocytes. They are believed to work by blocking cell metabolism through their effect on specific genes. In high doses, these synthetic hormones—relatives of the natural hormone cortisol—can kill malignant lymphocytes.
DNA Repair Enzyme Inhibitor	Can selectively kill cancer cells with a defect in the DNA damage response or DNA repair.
Enhancer of Zeste Homolog 2 (EZH2) Inhibitor	These inhibitors target EZH2 enzymes and suppress their overactivity, thereby inhibiting tumor formation.
Histone Deacetylase (HDAC) Inhibitors	Histone deacetylase inhibitors cause a chemical change that stops cancer cells from dividing.
Immunomodulatory Drugs (IMiDs)	Immunomodulatory drugs act in multiple ways to kill lymphoma cells and affect other cells, including immune system cells and structural cells. These drugs induce a cancer suppressor response directed by the immune system.
Mitotic Inhibitors	Drugs that prevent cell division by blocking mitosis.
Monoclonal Antibodies	Monoclonal antibodies are laboratory-produced proteins that target specific antigens on the cancer cell's surface to interfere with the cell's function and destroy it. Once the antibody finds and attaches to its target, it can "recruit" (harness) other parts of the immune system to destroy cells that contain the antigen. Some monoclonal antibodies work by themselves and are therefore known as "naked antibodies." Some monoclonal antibodies are combined with a toxin or radioactive substance.
Phosphatidylinositol 3-Kinase (PI3K) Inhibitors	These drugs block a type of enzyme that transmits signals in cells and that helps control cell growth. Some malignant cells have higher-than-normal levels of PI3K.
Proteasome Inhibitors (PIs)	These drugs block the function of the proteasome, leading to the accumulation of proteins in the cancer cells and thereby causing their destruction.
Small Molecule Inhibitor	These drugs block major enzymes that act as signals for cancer cell development. By obstructing these cell signals, they can prevent the cancer cells from developing and spreading.
Tyrosine Kinase Inhibitor (TKI)	These drugs inhibit the action of enzymes called tyrosine kinases. Tyrosine kinases are a part of many cell functions, including cell signaling, growth and division.

New treatments may have been approved since this book was printed. Check www.LLS.org/DrugUpdates or call (800) 955-4572.

Table 5. Some Drugs Used in the Treatment of Non-Hodgkin Lymphoma

For more information, please see the Package Insert and/or the Full Prescribing Information for each medication on the internet.

Drug Name Type of Drug Administration	FDA-Approved Indications
Acalabrutinib (Calquence®) BTK Inhibitor Oral	Adult patients with: <ul style="list-style-type: none"> • Mantle cell lymphoma who have received at least one prior therapy • Chronic lymphocytic leukemia or small-cell lymphocytic lymphoma
Axicabtagene ciloleucel (Yescarta®) CAR T-Cell Therapy Intravenous (IV)	Adult patients with: <ul style="list-style-type: none"> • Large B-cell lymphoma that is refractory to first-line chemoimmunotherapy or that relapses within 12 months of first-line chemoimmunotherapy • Relapsed or refractory large B-cell lymphoma after two or more lines of systemic therapy, including diffuse large B-cell lymphoma (DLBCL) not otherwise specified, primary mediastinal large B-cell lymphoma, high grade B-cell lymphoma, and DLBCL arising from follicular lymphoma (FL) • Relapsed or refractory follicular lymphoma after two or more lines of systemic therapy.
Bendamustine hydrochloride (Bendeka®) Alkylating Agent Intravenous (IV)	Patients with: <ul style="list-style-type: none"> • Indolent B-cell non-Hodgkin lymphoma that has progressed during or within 6 months of treatment with rituximab or a rituximab-containing regimen • Chronic lymphocytic leukemia
Bortezomib (Velcade®) Proteasome Inhibitors Intravenous (IV) or Subcutaneous Injection (sub-Q or SC)	Adult patients with mantle cell lymphoma
Brentuximab vedotin (Adcetris®) Antibody-Drug Conjugate Intravenous (IV)	Adult patients with: <ul style="list-style-type: none"> • Previously untreated systemic anaplastic large cell lymphoma (sALCL) or other CD30-expressing peripheral T-cell lymphomas (PTCLs), including angioimmunoblastic T-cell lymphoma and PTCL not otherwise specified, in combination with cyclophosphamide, doxorubicin, and prednisone • Systemic anaplastic large cell lymphoma after failure of at least one prior multi-agent chemotherapy regimen • Primary cutaneous anaplastic large cell lymphoma (pcALCL) or CD30-expressing mycosis fungoides who have received prior systemic therapy

<p>Brexucabtagene autoleucl (Tecartus®) CAR T-Cell Therapy Intravenous (IV)</p>	Adult patients with relapsed or refractory mantle cell lymphoma
<p>Carmustine (BCNU, BiCNU®) Alkylating Agent Intravenous (IV)</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Chlorambucil (Leukeran®) Alkylating Agent Oral</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Cisplatin (Platinol®) Alkylating Agent Intravenous (IV)</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Cladribine (Leustatin®) Antimetabolite Intravenous (IV)</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Crizotinib (Xalkori®) Tyrosine Kinase Inhibitor (TKI) Oral</p>	Pediatric patients 1 year of age and older and young adults with relapsed or refractory systemic anaplastic large cell lymphoma that is anaplastic lymphoma kinase (ALK)-positive
<p>Cyclophosphamide (Cytosan®) Alkylating Agent Intravenous (IV) Oral</p>	<ul style="list-style-type: none"> • Burkitt lymphoma • Non-Hodgkin lymphoma
<p>Dexamethasone (Decadron) Corticosteroid Intravenous (IV) Oral</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Doxorubicin (Adriamycin®) Antitumor Antibiotic Intravenous (IV)</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Duvelisib (Copiktra®) PI3K Inhibitor Oral</p>	Adult patients with relapsed or refractory chronic lymphocytic leukemia or small lymphocytic lymphoma after at least two prior therapies.
<p>Epcoritamab-bysp (Epkiny™) Bispecific Antibody Subcutaneous Injection (sub-Q or SC)</p>	Adult patients with relapsed or refractory diffuse large B-cell lymphoma (DLBCL), not otherwise specified, including DLBCL arising from indolent lymphoma, and high-grade B-cell lymphoma after two or more lines of systemic therapy

<p>Etoposide (Etopophos®, VePesid®, VP-16) DNA Repair Enzyme Inhibitor Oral</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Fludarabine (Fludara®) Antimetabolite Intravenous (IV)</p>	Chronic lymphocytic leukemia/small cell lymphocytic lymphoma (CLL/SLL), including CLL/SLL that has not responded to or reoccurred after standard therapy.
<p>Gemcitabine (Gemzar®) Antimetabolite Intravenous (IV)</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Glofitamab-gxbm (Columvi™) Bispecific Antibody Intravenous (IV)</p>	Adult patients with relapsed or refractory diffuse large B-cell lymphoma, not otherwise specified (DLBCL, NOS) or large B-cell lymphoma (LBCL) arising from follicular lymphoma, after two or more lines of systemic therapy
<p>Ibrutinib (Imbruvica®) BTK Inhibitor Oral</p>	<ul style="list-style-type: none"> • Adult patients with <ul style="list-style-type: none"> • Chronic lymphocytic leukemia/small lymphocytic lymphoma • Chronic lymphocytic leukemia/small lymphocytic lymphoma with 17p deletion • Waldenström’s macroglobulinemia • Adult and pediatric patients age 1 year and older with chronic graft versus host disease (cGVHD) after failure of one or more lines of systemic therapy
<p>Idarubicin (Idamycin®) Antineoplastics Intravenous (IV)</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Idelalisib (Zydelig®) PI3K Inhibitor Oral</p>	Patients with relapsed chronic lymphocytic leukemia, in combination with rituximab, in patients for whom rituximab alone would be considered appropriate therapy due to other comorbidities
<p>Ifosfamide (Ifex®) Alkylating Agent Intravenous (IV)</p>	Untreated and relapsed/refractory non-Hodgkin lymphoma
<p>Lenalidomide (Revlimid®) Immunomodulatory Drug (IMiD) Oral</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> • Mantle cell lymphoma whose disease has relapsed or progressed after two prior therapies, one of which included bortezomib • Previously treated follicular lymphoma, in combination with a rituximab product • Previously treated marginal zone lymphoma, in combination with a rituximab product

<p>Lisocabtagene maraleucel (Breyanzi®) CAR T-Cell Therapy Intravenous (IV)</p>	<ul style="list-style-type: none"> • Adult patients with large B-cell lymphoma (LBCL), including diffuse large B-cell lymphoma (DLBCL) not otherwise specified (including DLBCL arising from indolent lymphoma), high-grade B-cell lymphoma, primary mediastinal large B-cell lymphoma, and follicular lymphoma grade 3B, who have: <ul style="list-style-type: none"> • Refractory disease to first-line chemoimmunotherapy or relapse within 12 months of first-line chemoimmunotherapy; or • Refractory disease to first-line chemoimmunotherapy or relapse after first-line chemoimmunotherapy and are not eligible for hematopoietic stem cell transplantation (HSCT) due to comorbidities or age; or • Relapsed or refractory disease after two or more lines of systemic therapy • Adult patients with relapsed or refractory chronic lymphocytic leukemia (CLL) or small lymphocytic lymphoma (SLL) who have received at least 2 prior lines of therapy, including a Bruton tyrosine kinase (BTK) inhibitor and a B-cell lymphoma 2 (BCL-2) inhibitor
<p>Loncastuximab tesirine-lpyl (Zynlonta®) Antibody-Drug Conjugate Intravenous (IV)</p>	<p>Adult patients with relapsed or refractory large B-cell lymphoma after two or more lines of systemic therapy, including diffuse large B-cell lymphoma (DLBCL) not otherwise specified, DLBCL arising from low grade lymphoma, and high-grade B-cell lymphoma</p>
<p>Melphalan (Alkeran®) Alkylating Agent Intravenous (IV) Oral</p>	<p>Untreated and relapsed/refractory non-Hodgkin lymphoma</p>
<p>Methotrexate (Trexall®) Antimetabolite Intravenous (IV)</p>	<ul style="list-style-type: none"> • Untreated and relapsed/refractory non-Hodgkin lymphoma • Central nervous system lymphoma
<p>Mogamulizumab (Poteligeo®) Monoclonal Antibody Intravenous (IV)</p>	<p>Adult patients with relapsed or refractory mycosis fungoides or Sézary syndrome after at least one prior systemic therapy</p>
<p>Mosunetuzumab-axgb (Lunsumio™) Bispecific Antibody Intravenous (IV)</p>	<p>Adult patients with relapsed or refractory follicular lymphoma after two or more lines of systemic therapy</p>

<p>Obinutuzumab (Gazyva®) Monoclonal Antibody Intravenous (IV)</p>	<ul style="list-style-type: none"> • In combination with chlorambucil, for the treatment of patients with previously untreated chronic lymphocytic leukemia • In combination with bendamustine followed by obinutuzumab monotherapy, for the treatment of patients with follicular lymphoma whose disease relapsed after, or is refractory to, a rituximab-containing regimen • In combination with chemotherapy followed by obinutuzumab monotherapy in patients achieving at least a partial remission, for the treatment of adult patients with previously untreated stage II bulky, III or IV follicular lymphoma
<p>Ofatumumab (Arzerra®) Monoclonal Antibody Intravenous (IV)</p>	<ul style="list-style-type: none"> • In combination with chlorambucil, for the treatment of previously untreated patients with chronic lymphocytic leukemia (CLL) for whom fludarabine-based therapy is considered inappropriate • In combination with fludarabine and cyclophosphamide for the treatment of patients with relapsed CLL • For extended treatment of patients who are in complete or partial response after at least two lines of therapy for recurrent or progressive CLL • For the treatment of patients with CLL refractory to fludarabine and alemtuzumab.
<p>Pembrolizumab (Keytruda®) Monoclonal Antibody Intravenous (IV)</p>	<p>Adult and pediatric patients with refractory primary mediastinal large B-cell lymphoma (PMBCL), or whose disease has relapsed after two or more prior lines of therapy</p>
<p>Pirtobrutinib (Jaypirca™) BTK Inhibitor Oral</p>	<p>Adult patients with:</p> <ul style="list-style-type: none"> • Relapsed or refractory mantle cell lymphoma (MCL) after at least two lines of systemic therapy, including a BTK inhibitor • Chronic lymphocytic leukemia or small lymphocytic lymphoma (CLL/SLL) who have received at least two prior lines of therapy, including a BTK inhibitor and a BCL-2 inhibitor
<p>Polatuzumab vedotin-piiq (Polivy®) Antibody-Drug Conjugate Intravenous (IV)</p>	<ul style="list-style-type: none"> • In combination with a rituximab product, cyclophosphamide, doxorubicin, and prednisone (R-CHP) for the treatment of adult patients who have previously untreated diffuse large B-cell lymphoma (DLBCL), not otherwise specified (NOS) or high-grade B-cell lymphoma (HGBL) and who have an International Prognostic Index score of 2 or greater • In combination with bendamustine and a rituximab product, for adult patients with relapsed or refractory diffuse large B-cell lymphoma, not otherwise specified, after at least two prior therapies
<p>Pralatrexate (Folotyn®) Antifolate Intravenous (IV)</p>	<p>Adult patients with relapsed or refractory peripheral T-cell lymphoma</p>

<p>Prednisone Corticosteroid Oral</p>	<p>Untreated and relapsed/refractory non-Hodgkin lymphoma</p>
<p>Rituximab (Rituxan®) Monoclonal Antibody Intravenous (IV)</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> • Relapsed or refractory, low grade or follicular, CD20-positive, B-cell NHL as a single agent • Previously untreated follicular, CD20-positive, B-cell NHL in combination with first-line chemotherapy and, in patients achieving a complete or partial response to a rituximab product in combination with chemotherapy, as single-agent maintenance therapy • Non-progressing (including stable disease), low-grade, CD20-positive, B-cell NHL as a single agent after first-line cyclophosphamide, vincristine, and prednisone (CVP) chemotherapy • Previously untreated diffuse large B-cell, CD20-positive, B-cell NHL in combination with cyclophosphamide, doxorubicin, vincristine, prednisone (CHOP) or other anthracycline-based chemotherapy regimens • Previously untreated and previously treated CD20-positive chronic lymphocytic leukemia in combination with fludarabine and cyclophosphamide (FC) <p>Pediatric patients aged 6 months and older with</p> <ul style="list-style-type: none"> • Previously untreated, advanced stage, CD20-positive, diffuse large B-cell lymphoma (DLBCL), Burkitt lymphoma, Burkitt-like lymphoma or mature B-cell acute leukemia in combination with chemotherapy
<p>Rituximab-abbs (Truxima®)* Monoclonal Antibody Intravenous (IV)</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> • Relapsed or refractory, low-grade or follicular, CD20-positive, B-cell non-Hodgkin lymphoma (NHL) as a single agent • Previously untreated follicular, CD20-positive, B-cell NHL in combination with first-line chemotherapy and, in patients achieving a complete or partial response to a rituximab product in combination with chemotherapy, as single-agent maintenance therapy • Non-progressing (including stable disease), low-grade, CD20-positive, B-cell NHL as a single agent after first-line cyclophosphamide, vincristine, and prednisone (CVP) chemotherapy • Previously untreated diffuse large B-cell, CD20-positive NHL in combination with cyclophosphamide, doxorubicin, vincristine, and prednisone (CHOP) or other anthracycline-based chemotherapy regimens • Previously untreated and previously treated CD20-positive chronic lymphocytic leukemia in combination with fludarabine and cyclophosphamide (FC)

<p>Rituximab + hyaluronidase human (Rituxan Hycela®) Monoclonal Antibody Subcutaneous injection (sub-Q or SC)</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> Relapsed or refractory follicular lymphoma as a single agent Previously untreated follicular lymphoma in combination with first-line chemotherapy and, in patients achieving a complete or partial response to rituximab in combination with chemotherapy, as single-agent maintenance therapy Non-progressing (including stable disease), follicular lymphoma as a single agent after first-line cyclophosphamide, vincristine, and prednisone (CVP) chemotherapy Previously untreated diffuse large B-cell lymphoma in combination with cyclophosphamide, doxorubicin, vincristine, prednisone (CHOP) or other anthracycline-based chemotherapy regimens Chronic lymphocytic leukemia in combination with fludarabine and cyclophosphamide (FC) chemotherapy as an initial treatment or as a treatment after disease has recurred <p>This drug should be started only after patients have received at least one full dose of a rituximab product by intravenous infusion.</p>
<p>Rituximab-pvvr (Ruxience®)* Monoclonal Antibody Intravenous (IV)</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> Relapsed or refractory, low-grade or follicular, CD20-positive, B-cell non-Hodgkin lymphoma (NHL) as a single agent Previously untreated follicular, CD20-positive, B-cell NHL in combination with first-line chemotherapy and, in patients achieving a complete or partial response to a rituximab product in combination with chemotherapy, as single-agent maintenance therapy Non-progressing (including stable disease), low-grade, CD20-positive, B-cell NHL, as a single agent after first-line cyclophosphamide, vincristine, and prednisone (CVP) chemotherapy Previously untreated diffuse large B-cell, CD20-positive NHL in combination with CHOP or other anthracycline-based chemotherapy regimens Previously untreated and previously treated CD20-positive chronic lymphocytic leukemia in combination with fludarabine and cyclophosphamide (FC)
<p>Romidepsin (Istodax®) Histone Deacetylase (HDAC) Inhibitor Intravenous (IV)</p>	<p>Adult patients with cutaneous T-cell lymphoma who have received at least one previous systemic therapy</p>
<p>Selinexor (Xpovio®) Small Molecule Inhibitor Oral</p>	<p>For the treatment of adult patients with relapsed or refractory diffuse large B-cell lymphoma (DLBCL), not otherwise specified, including DLBCL arising from follicular lymphoma, after at least two lines of systemic therapy</p>

<p>Tafasitamab-cxix (Monjuvi®) Monoclonal Antibody Intravenous (IV)</p>	<p>In combination with lenalidomide for the treatment of adult patients with relapsed or refractory diffuse large B-cell lymphoma (DLBCL) not otherwise specified, including DLBCL arising from low grade lymphoma, and who are not eligible for autologous stem cell transplant</p>
<p>Tazemetostat (Tazverik®) EZH2 Inhibitor Oral</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> • Relapsed or refractory follicular lymphoma whose tumors are positive for an EZH2 mutation as detected by an FDA-approved test and who have received at least two prior systemic therapies • Relapsed or refractory follicular lymphoma who have no satisfactory alternative treatment options
<p>Tisagenlecleucel (Kymriah®) CAR T-Cell Therapy Intravenous (IV)</p>	<p>Adult patients with relapsed or refractory large B-cell lymphoma after two or more lines of systemic therapy, including diffuse large B-cell lymphoma (DLBCL) not otherwise specified, high grade B-cell lymphoma and DLBCL arising from follicular lymphoma</p>
<p>Venetoclax (Venclexta®) BCL2 Inhibitor Oral</p>	<p>For the treatment of adult patients with chronic lymphocytic leukemia or small lymphocytic lymphoma</p>
<p>Vinblastine (Velban®) Mitotic Inhibitors Intravenous (IV)</p>	<p>Untreated and relapsed/refractory non-Hodgkin lymphoma</p>
<p>Vincristine (Oncovin®) Mitotic Inhibitors Intravenous (IV)</p>	<p>Untreated and relapsed/refractory non-Hodgkin lymphoma</p>
<p>Vorinostat (Zolinza®) Histone Deacetylase (HDAC) Inhibitor Oral</p>	<p>Adult patients with cutaneous T-cell lymphoma who have progressive, persistent or recurrent disease on or following two systemic therapies</p>
<p>Yttrium-90-ibritumomab tiuxetan (Zevalin®) Monoclonal Antibody Intravenous (IV)</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> • Previously untreated follicular lymphoma who achieved a partial or complete response to first-line chemotherapy • Relapsed or refractory, low-grade or follicular B-cell non-Hodgkin lymphoma
<p>Zanubrutinib (Brukinsa®) BTK Inhibitor Oral</p>	<p>Adult patients with</p> <ul style="list-style-type: none"> • Mantle cell lymphoma who have received at least one prior therapy • Waldenström macroglobulinemia • Relapsed or refractory marginal zone lymphoma who have received at least one anti-CD20-based regimen • Chronic lymphocytic leukemia (CLL) or small lymphocytic lymphoma (SLL) • Relapsed or refractory follicular lymphoma (FL), in combination with obinutuzumab, after two or more lines of systemic therapy

*Indicates a biosimilar drug.

Key. BCL2, B-cell lymphoma 2; BTK, Bruton tyrosine kinase; CAR, chimeric antigen receptor; CD, cluster of differentiation; DNA, deoxyribonucleic acid; HDAC, histone deacetylase; PI3K, phosphoinositide 3-kinase; VR-CAP, Velcade (bortezomib), rituximab, cyclophosphamide, doxorubicin, and prednisone.

Table 6. Some Common Drug Combinations Used in the Treatment of Non-Hodgkin Lymphoma (NHL)

- **CHOP:** cyclophosphamide, doxorubicin (hydroxydoxorubicin), Oncovin® (vincristine), prednisone
- **B+O or R:** bendamustine hydrochloride (Bendeka®) plus obinutuzumab (Gazyva®) or rituximab
- **R+ICE:** rituximab plus ifosfamide, carboplatin, etoposide
- **R or O-CHOP:** rituximab or obinutuzumab plus cyclophosphamide, doxorubicin (hydroxydoxorubicin), Oncovin® (vincristine), prednisone
- **R or O-CVP:** rituximab or obinutuzumab plus cyclophosphamide, vincristine and prednisone
- **R-HCVAD:** rituximab plus cyclophosphamide, vincristine, adriamycin (doxorubicin), dexamethasone
- **R²:** rituximab and lenalidomide (Revlimid®)
- **DHAP:** dexamethasone, high-dose cytarabine (ara-C®) and cisplatin (Platinol®)
- **ICE:** ifosfamide, carboplatin, etoposide
- **CODOX-M/IVAC:** cyclophosphamide, vincristine (Oncovin®), doxorubicin and high-dose methotrexate, alternating with IVAC (ifosfamide, etoposide and high-dose cytarabine)
- **Hyper-CVAD:** hyper-fractionated cyclophosphamide, vincristine, doxorubicin (Adriamycin®) and dexamethasone, alternating with methotrexate and cytarabine
- **DA-EPOCH-R:** dose-adjusted etoposide, prednisone, vincristine (Oncovin®), cyclophosphamide, doxorubicin plus rituximab
- **R-EPOCH:** rituximab plus adjusted etoposide, prednisone, vincristine (Oncovin®), cyclophosphamide, doxorubicin

Normal Blood and Bone Marrow

Blood. Blood is the liquid that flows through a person's arteries and veins. It carries oxygen and nutrients throughout the body. It also carries away waste products. Blood is composed of plasma and cells.

Plasma. Plasma is largely made up of water, in which many chemicals are dissolved. These chemicals each have a special role. They include:

- Proteins
 - Albumin, the most common blood protein
 - Blood-clotting proteins (coagulation factors) made by the liver
 - Erythropoietin, a protein made by the kidneys that stimulates red blood cell production
 - Immunoglobulins, proteins that help the body fight infection
- Hormones, such as thyroid hormone and cortisol
- Minerals, such as iron and magnesium

- Vitamins, such as folate (B9) and vitamin B12
- Electrolytes, such as calcium, potassium and sodium

Blood Cells. Blood cells are formed in the bone marrow, a spongy tissue where blood cells grow and develop. Blood cells start as stem cells.

The process of stem cells maturing into blood cells is called “hematopoiesis.”

The blood cells are suspended in the plasma. See **Figure 4** on page 51.

Once the stem cell is created, it will develop into one of the three types of blood cells:

1. Red blood cells (RBCs) (the cells that carry oxygen)

- These make up a little less than half of the body’s total blood volume.
- They are filled with hemoglobin, the protein that picks up oxygen from the lungs and takes it around the body. It binds with carbon dioxide (CO₂) and removes it from the cells and then brings it back to the lungs. When a person exhales (breathes out), the CO₂ is removed from the lungs.

2. Platelets (the cells that help blood to clot)

- These are small cells (one-tenth the size of red blood cells).
- They help stop bleeding from an injury or cut.
- They stick to the torn surface of the vessel, clump together and plug up the bleeding site. They form a clot with the help of proteins, such as fibrin, and electrolytes, such as calcium.

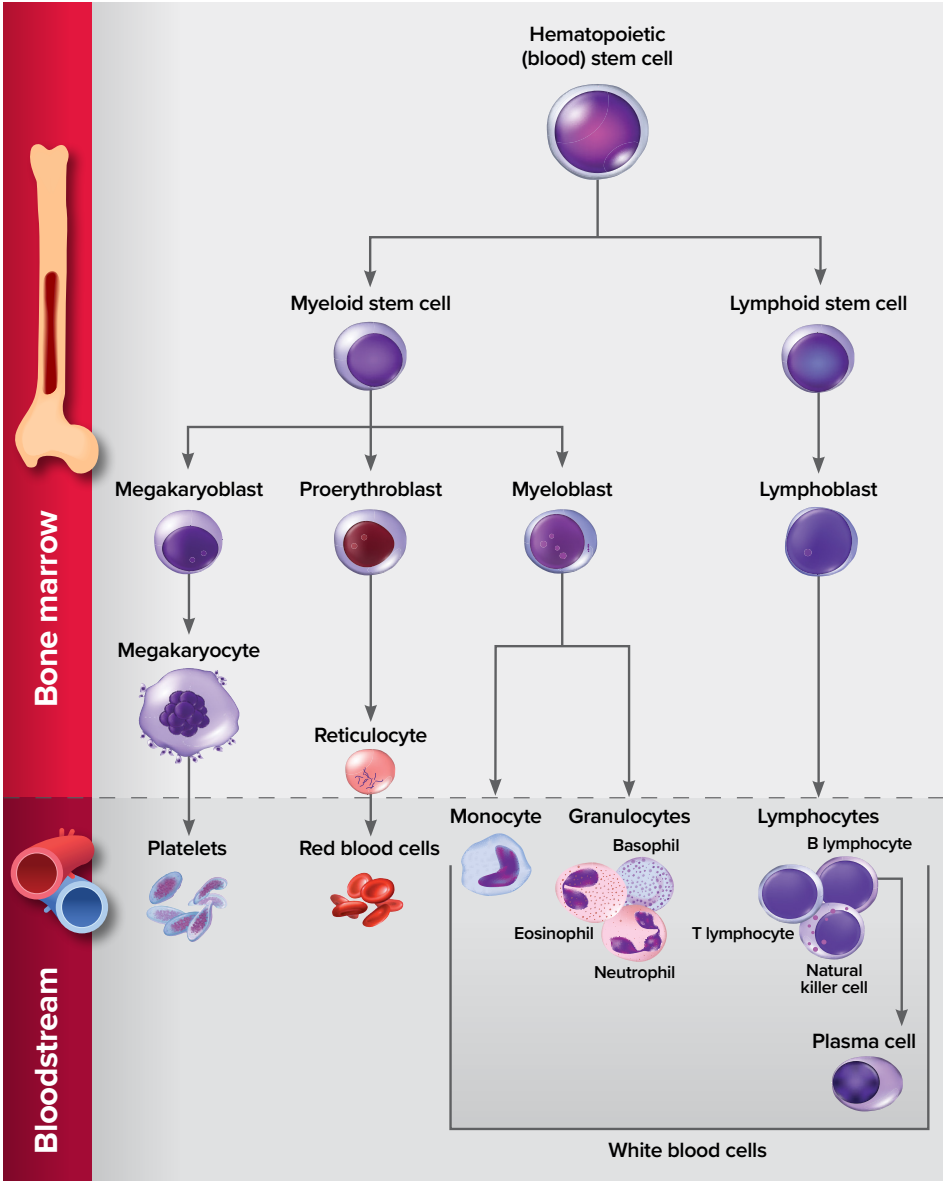
3. White blood cells (WBCs). These are the cells that fight infections.

They include:

- Neutrophils and monocytes. These cells, called “phagocytes,” ingest and destroy bacteria and fungi. Unlike red blood cells and platelets, monocytes can leave the bloodstream and enter tissues to attack invading organisms and fight off infection
- Eosinophils and basophils. These WBCs respond to allergens or parasites.
- Lymphocytes. These WBCs, found mostly in the lymph nodes, spleen and lymphatic channels, are a key part of the immune system. Some enter the bloodstream. There are three major types of lymphocytes:
 - T lymphocytes (T cells)
 - B lymphocytes (B cells)
 - Natural killer cells (NK cells)

Figure 4. Blood Cell & Lymphocyte Development

Most blood cells start as hematopoietic (blood) stem cells in the bone marrow. Hematopoietic stem cells are the most immature blood-forming cells. They must mature (go through many stages) to become a red blood cell, white blood cell or platelet. Some blood cells mature in the bone marrow. Other blood cells leave the bone marrow and travel to other parts of the body to develop into mature blood cells.



Bone Marrow. In healthy people, stem cells in the bone marrow produce new blood cells continuously. When blood cells are fully developed, they enter the bloodstream as it passes through the marrow and then circulate throughout the body.

In babies, all bones have active marrow. By the time a person reaches young adulthood, the bones of the hands, feet, arms and legs no longer have blood-forming marrow. In adults, marrow is only found in the spine (vertebrae), hip and shoulder bones, ribs, breastbone and skull.

Hematopoietic stem cells are found in the marrow. These stem cells are important because they can be used for transplants. Some stem cells enter the bloodstream and circulate. Doctors know how to stimulate the growth of these cells in the marrow and make them migrate into the bloodstream. Then a special technique called “apheresis” is used to separate them from the circulating blood so they can be collected and stored. Stem cells from the placenta and the umbilical cord of a newborn infant can also be harvested and used for future transplantation.

The Lymphatic System

The lymphatic system is comprised of the tissues and organs that produce, store and carry lymphocytes (a type of white blood cell) that fight infection and other diseases. This system includes the bone marrow, spleen, thymus, lymph nodes and lymphatic vessels (a network of thin tubes that carry lymph and white blood cells.) See **Figure 5** on page 53.

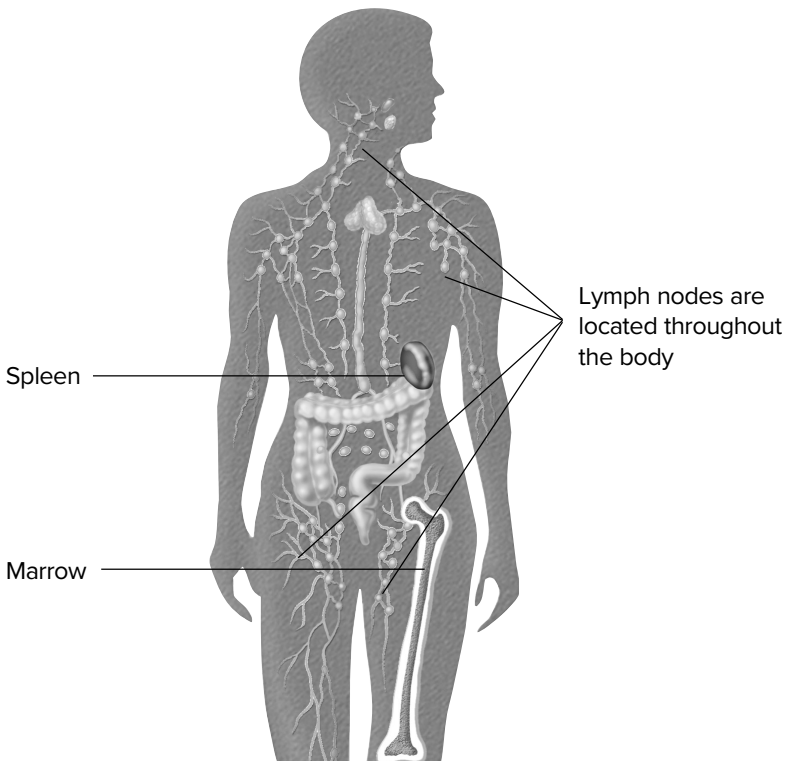
The bone marrow is really two organs in one. It is (1) the organ that forms blood cells, and it is (2) the organ that forms lymphocytes (a type of white blood cell), which make up part of the immune system.

The marrow produces three main types of lymphocytes. They are:

- B lymphocytes (B cells), which make antibodies in response to foreign antigens, especially microbes
- T lymphocytes (T cells), which mature in the thymus. The T lymphocytes have several functions, including assisting B lymphocytes to make antibodies against invading bacteria, viruses or other microbes. The antibody attaches to the microbe, making it possible for other white blood cells to recognize the antibody and pull it into the cell (ingest it) along with its attached microbe. The white blood cell then kills and ingests the microbe.
- Natural killer (NK) cells, which attack virus-infected cells or tumor cells without requiring an antibody or other mediation. T cells and NK cells have other functions as well, and are important elements in research efforts to design immunotherapies to treat lymphoma and other cancers.

The lymphocytes circulate through channels called “lymphatics,” which connect the lymph nodes to each other throughout the body. The lymphatic channels collect into large ducts that empty into blood vessels. Lymphocytes enter the blood via these ducts. Most lymphocytes are found in the lymph nodes and other parts of the lymphatic system, such as the skin, spleen, tonsils and adenoids, intestinal lining, and (in young people) the thymus.

Figure 5. The Lymphatic System



The lymphatic system is part of the immune system. The normal immune system helps to protect the body from infection. The marrow, lymph nodes and spleen are parts of the immune system. There are about 600 lymph nodes throughout the body.

Lymph nodes and other lymphoid tissues that are commonly involved in lymphoma are those around the ears and jaw, in the tonsils and adenoids, in the front and back of the neck, above and below the collar bone, in the armpit, near the elbow, in the chest, in the abdomen, in the pelvis and in the groin. The spleen contains many clusters of lymphocytes that can become malignant and grow, leading to the enlargement of the spleen. The gut-associated (intestinal) lymph tissue may also be the site of lymphoma development.

Resources and Information

LLS offers free information and services for patients and families affected by blood cancers. This section lists various resources you may find helpful.

For Help and Information

Consult with an Information Specialist. Information Specialists can assist you through cancer treatment, financial and social challenges and give accurate, up-to-date disease, treatment and support information. Our Information Specialists are highly trained oncology social workers and nurses. Language services are available. For more information, please:

- Call: (800) 955-4572 (Monday through Friday, from 9 am to 9 pm ET)
- Email and Live Chat: www.LLS.org/InformationSpecialists

Clinical Trials (Research Studies). Research is ongoing to develop new treatment options for patients. LLS offers help for patients and caregivers in understanding, identifying and accessing clinical trials. Pediatric and adult patients and caregivers can work with our Clinical Trial Nurse Navigators who will help find clinical trials and provide personalized support throughout the entire clinical trial process. Visit www.LLS.org/CTSC for more information.

Nutrition Consultations. Schedule a free one-on-one nutrition consultation with one of our registered dietitians who have expertise in oncology nutrition. Consultations are available to patients of all cancer types and their caregivers. Dietitians can assist with information about healthy eating strategies, side effect management and more. Please visit www.LLS.org/nutrition for more information.

Free Information Booklets. LLS offers free education and support booklets for patients, caregivers and healthcare professionals that can either be read online or ordered. Please visit www.LLS.org/booklets for more information.

Telephone/Web Education Programs. LLS offers free telephone/Web and video education programs for patients, caregivers and healthcare professionals. Please visit www.LLS.org/programs for more information.

Financial Assistance. LLS offers financial support to eligible individuals with blood cancer for insurance premiums, co-pays, and non-medical expenses like travel, food, utilities, housing, etc. For more information, please:

- Call: (877) 557-2672
- Visit: www.LLS.org/copy

Podcast. The Bloodline with LLS is here to remind you that after a diagnosis comes hope. Listen in as patients, caregivers, advocates, doctors and other healthcare professionals discuss diagnosis, treatment options, quality-of-life concerns, treatment side effects, doctor-patient communication and other

important survivorship topics. Visit www.LLS.org/TheBloodline for more information and to subscribe to access exclusive content, submit ideas and topics, and connect with other listeners.

3D Models. LLS offers interactive 3D images to help visualize and better understand blood cell development, intrathecal therapy, leukemia, lymphoma, myeloma, MDS, MPNs and lab and imaging tests. Visit www.LLS.org/3D for more.

Free Mobile Apps

- LLS Coloring For Kids™ – Allows children (and adults) to express their creativity and offers activities to help them learn about blood cancer and its treatment. Visit www.LLS.org/ColoringApp to download for free.
- LLS Health Manager™ – Helps you track side effects, medication, food and hydration, questions for your doctor, and more. Visit www.LLS.org/HealthManager to download for free.

Suggested Reading. LLS provides a list of selected books recommended for patients, caregivers, children and teens. Visit www.LLS.org/SuggestedReading to find out more.

Connecting with Patients, Caregivers and Community Resources

LLS Community. The one-stop virtual meeting place for talking with other patients and receiving the latest blood cancer resources and information. Share your experiences with other patients and caregivers and get personalized support from trained LLS staff. Visit www.LLS.org/community to join.

Weekly Online Chats. Moderated online chats can provide support and help cancer patients and caregivers reach out and share information. Please visit www.LLS.org/chat for more information.

Local Programs. LLS offers community support and services in the United States and Canada including the *Patti Robinson Kaufmann First Connection® Program* (a peer-to-peer support program), local support groups and other great resources. For more information about these programs or to contact your region, please:

- Call: (800) 955-4572
- Visit: www.LLS.org/LocalPrograms

Advocacy and Public Policy. Working closely with dedicated volunteer advocates, LLS's Office of Public Policy elevates the voices of patients to state and federal elected officials, the White House, governors and even courts. Together, we advocate for safe and effective treatments. We pursue policies that would make care more accessible to all patients. And, most of all, we advocate for the hope for a cure. Want to join our work? Visit www.LLS.org/advocacy for more information.

Other Helpful Organizations. LLS offers an extensive list of resources for patients and families. There are resources that provide help with financial

assistance, counseling, transportation, patient care and other needs. For more information, please visit www.LLS.org/ResourceDirectory to view the directory.

Additional Help for Specific Populations

Información en español (LLS Information in Spanish). Please visit www.LLS.org/espanol for more information.

Language Services. Let members of your healthcare team know if you need translation or interpreting services because English is not your native language, or if you need other assistance, such as a sign language interpreter. Often these services are free.

Information for Veterans. Veterans who were exposed to Agent Orange while serving in Vietnam may be able to get help from the United States Department of Veterans Affairs. For more information, please:

- Call: the VA (800) 749-8387
- Visit: www.publichealth.va.gov/exposures/AgentOrange

Information for Firefighters. Firefighters are at an increased risk of developing cancer. There are steps that firefighters can take to reduce the risk. Please visit www.LLS.org/FireFighters for resources and information.

World Trade Center (WTC) Survivors. People involved in the aftermath of the 9/11 attacks who were subsequently diagnosed with a blood cancer may be eligible for help from the WTC Health Program. People eligible for help include:

- Responders
- Workers and volunteers who helped with rescue, recovery and cleanup at the WTC-related sites in New York City (NYC)
- Survivors who were either in the NYC disaster area, or who lived, worked or were in school in the area
- Responders to the Pentagon and the Shanksville, PA crashes

For more information, please:

- Call: WTC Health Program at (888) 982-4748
- Visit: www.cdc.gov/wtc/faq.html

People Suffering from Depression. Treating depression has benefits for cancer patients. Seek medical advice if your mood does not improve over time, for example, if you feel depressed every day for a 2-week period. For more information, please:

- Call: The National Institute of Mental Health (NIMH) at (866) 615-6464
- Visit: NIMH at www.nimh.nih.gov and enter “depression” in the search box

Health Terms

Allogeneic Stem Cell Transplantation. A treatment that uses donor stem cells to restore a patient's marrow and blood cells. A type of allogeneic transplant called "reduced-intensity" or "nonmyeloablative" transplant is under study. It uses lower doses of chemotherapy and/or radiation therapy for the conditioning therapy and may therefore be safer, especially for older patients. **For more information about allogeneic stem cell transplantation, see the free LLS booklet *Blood and Marrow Stem Cell Transplantation*.**

Anemia. A decrease in the number of red blood cells and, therefore, the hemoglobin concentration of the blood. This results in a diminished ability of the blood to carry oxygen. Severe anemia can cause a pale complexion, weakness, fatigue and shortness of breath on exertion.

Antibodies. Proteins released by plasma cells (derived from B lymphocytes) that recognize and bind to specific foreign substances called "antigens." Antibodies coat, mark for destruction or inactivate foreign particles, such as bacteria, viruses or harmful toxins.

Antigen. A foreign substance, usually a protein, that stimulates an immune response when it is ingested, inhaled or comes into contact with the skin or mucous membranes. Examples of antigens are bacteria, viruses or allergens. Antigens stimulate plasma cells to produce antibodies.

Apheresis. The process of removing certain components of a donor's blood and returning the unneeded parts back to the donor's bloodstream. The process uses continuous circulation of blood from a donor through a specialized machine and then back to the donor through an intravenous line. Apheresis makes it possible to remove desired elements from large volumes of blood. Platelets, red blood cells, white blood cells and plasma can be removed separately.

Autologous Stem Cell Transplantation. A treatment that uses a patient's own stem cells to delay the progression of certain blood cancers. The autologous transplantation process takes place after the patient achieves a complete response (remission), or a good partial response, to induction drug therapy. **For more information, see the free LLS booklet *Blood and Marrow Stem Cell Transplantation*.**

Bone Marrow. A spongy tissue in the hollow central cavity of the bones, where blood cell formation occurs. By puberty, the marrow in the spine, ribs, breastbone, hips, shoulders and skull is most active in blood cell formation. The marrow is filled with fat cells in other sites.

When marrow cells have matured into blood cells, they enter the blood as it passes through the marrow and then are carried throughout the body in the bloodstream.

Bone Marrow Aspiration. A procedure in which a small sample of bone marrow is removed, usually from the hip bone. A small area of skin and the surface of the bone underneath are numbed with an anesthetic. Then, a special wide gauge needle is pushed into the bone. A sample of liquid bone marrow is removed using a needle attached to a syringe. The specimen of bone marrow is sent to a laboratory to be looked at under a microscope. This procedure may be done at the same time as a bone marrow biopsy.

Bone Marrow Biopsy. A test to examine marrow cells to detect cell abnormalities. This test differs from a bone marrow aspiration in that a small amount of bone filled with marrow is removed, usually from the hip (pelvic) bone. After a local anesthetic is given to numb the skin, a special hollow biopsy needle is used to remove a core of bone containing marrow. The marrow sample is examined under a microscope to determine if abnormal cells are present. Bone marrow aspiration and bone marrow biopsy are almost always done together.

Bone Marrow Transplantation. See Allogeneic Stem Cell Transplantation; Autologous Stem Cell Transplantation.

CD. See Cluster of Differentiation (CD).

Chemotherapy. The use of chemicals (drugs or medications) to kill malignant cells. Numerous chemicals have been developed for this purpose, and most act by injuring the DNA (deoxyribonucleic acid) of the cancer cells. When the DNA is injured, the cells cannot grow or survive.

Chromosomes. Threadlike structures within cells that carry genes in a linear order. Human cells have 23 pairs of chromosomes: chromosome pairs 1 to 22 and one pair of sex chromosomes (XX for females and XY for males). See Translocation.

Clonal. The designation for a population of cells derived from a single transformed parent cell. Virtually all cancers originate in a single cell with an injury (mutation) to its DNA (deoxyribonucleic acid) and are therefore monoclonal. Leukemia, lymphoma and myeloma are examples of clonal cancers; that is, cancers derived from a single abnormal cell.

Cluster of Differentiation (CD). A term used with a number to identify a specific molecule on the surface of an immune cell. It is commonly used in its abbreviated form—for example, CD20, the target of the monoclonal antibody therapy rituximab (Rituxan®) or CD52, the target of the monoclonal antibody therapy alemtuzumab (Campath®). Also called “cluster designation.”

Computed Tomography (CT) Scan. A technique for imaging body tissues and organs. X-ray transmissions are converted to detailed images using a computer to synthesize x-ray data. The images are displayed as a cross-section of the body at any level from the head to the feet. A CT scan of the chest, abdomen or pelvis permits detection of an enlarged lymph node, liver or spleen. A CT scan can be used to measure the size of these organs and other structures both during and after treatment.

CT Scan. See Computed Tomography (CT) Scan.

Cytogenetic Analysis. The process of analyzing the number and size of the chromosomes of cells. It detects chromosome alterations and, in some cases, may identify the actual genes that have been affected. These findings help healthcare professionals diagnose specific types of blood cancers, determine treatment approaches and monitor the response to treatment. The individual who prepares and examines the chromosomes and interprets the results is called a “cytogeneticist.”

DNA. Abbreviation of “deoxyribonucleic acid,” the genetic material in cells. It is made up of a sugar-phosphate backbone with ladderlike “steps” composed of purines and pyrimidines (the building blocks of nucleic acids). The sequence of the purines and pyrimidines in the DNA is responsible for passing genetic information to new cells during the process of cell division; for passing genetic information from one generation to the next during reproduction; and for providing the instructions for building proteins, which in turn carry out the major functions of a cell. A mutation is generally either a change in or loss of the sequence of the purines or pyrimidines of the DNA. Mutations can lead to cell death, to changes in the way a cell functions or, in some cases, to cancer.

Extranodal Lymphoma. Lymphoma that has spread outside the lymph nodes to the organs—the thyroid, lungs, liver, bones, stomach or central nervous system. Doctors adjust their therapeutic approach if organs outside of lymph nodes are involved. If the brain, liver or bones are involved, for example, the treatment approach is likely to

target these areas. If lymphoma is found in any of the organs but not in lymph nodes or multiple lymphatic sites, the disease is called a “solitary extranodal lymphoma.”

FDA. The acronym for The United States Food and Drug Administration.

FISH. See Fluorescence In Situ Hybridization (FISH).

Flow Cytometry. A laboratory method that measures the number of cells, the percentage of live cells, and certain characteristics of cells, such as size and shape, in a sample of blood, bone marrow, or other tissue. The presence of tumor markers, such as antigens, on the surface of the cells are also measured. The cells are stained with a light-sensitive dye, placed in a fluid, and then passed one at a time through a beam of light. The measurements are based on how the stained cells react to the beam of light. One use of flow cytometry is to determine whether a sample of cells is composed of T cells or B cells. This allows the doctor to determine if the leukemia or lymphoma is of the B- or T-cell type.

Fluorescence In Situ Hybridization (FISH). A technique for studying chromosomes in tissue samples using DNA (deoxyribonucleic acid) probes tagged with fluorescent molecules that emit light of different wavelengths and in different colors. The probes bind to the chromosomes within the cells, and the chromosomes glow in color.

Gene Expression Profiling. A research method that uses microarray analysis to identify a combination of genes that are either deactivated or activated in response to a specific condition. A set of genes in a blood or tissue sample can be used to monitor the levels of thousands of genes at once.

Hematologist. A doctor who specializes in the treatment of blood cell diseases. This person is either an internist who treats adults or a pediatrician who treats children.

Hematopathologist. See Pathologist.

Hematopoiesis. The process of blood cell development in the marrow. The most undeveloped cells in the marrow are stem cells, which start the process of blood cell development. The stem cells develop into immature blood cells, such as red blood cells or various types of white blood cells. This process is called “differentiation.” The immature blood cells then further develop into fully functional blood cells. This process is called “maturation.” The mature cells leave the marrow, enter the blood

and circulate throughout the body in the bloodstream. Hematopoiesis is a continuous process that is normally active throughout life. When the marrow is invaded with cancer cells, the constant demand for new blood cells cannot be met, resulting in a severe deficiency in blood cell counts.

Immunophenotyping. A method that uses the reaction of antibodies with cell antigens to identify specific types of cells in a sample of blood, bone marrow or other sample. The antibodies react with specific antigens on the cell. A tag is attached to an antibody so that it can be detected by the laboratory equipment used for the test. As cells carrying their array of antigens are tagged with specific antibodies, they can be identified.

Immunotherapy. The term for several treatment approaches used by doctors to harness the body's immune system to treat lymphoma and other diseases. These therapies include monoclonal antibody therapy, radioimmunotherapy and vaccine therapy. Monoclonal antibodies are proteins made in the laboratory that either react with or attach to antigens on the target cells. The antibodies are used therapeutically in three ways: as “naked” antibodies (monoclonal antibodies); as antibodies to which radioactive isotopes are attached (radioimmunotherapy); and as antibodies to which toxins are attached (immunotoxins). **For more information, see the free LLS booklet *Immunotherapy*.**

Intrathecal. Designation for the space between the covering or lining of the central nervous system (CNS) and the brain or spinal cord, which is called the “meninges.” In some situations, drugs have to be administered directly into the spinal canal when cancer cells are present in the meninges. This procedure is called “intrathecal therapy.”

Lactate Dehydrogenase (LDH). An enzyme that exists in all normal and abnormal cells. It is released from cells into the blood and is present in normal amounts in the liquid portion of blood (the plasma). When blood is collected and allowed to clot, the fluid portion is called the “serum.” Many chemicals can be measured in the serum, including LDH. Normal serum contains low levels of LDH. The level may be elevated in many diseases, such as hepatitis and various cancers. The LDH level is often elevated in lymphoma and lymphocytic leukemias. Changes in the LDH level are nonspecific, but when LDH is elevated in the presence of lymphocytic cancers, the change may reflect the extent of the tumor and the rate of tumor growth. Lactate dehydrogenase monitoring is used in some cases, along with other measures, to plan the intensity of therapy for lymphoma. Also known as “lactic acid dehydrogenase.”

Lymph Nodes. Bean-sized structures that contain large numbers of lymphocytes and are connected with each other by small channels called “lymphatics.” These nodes are distributed throughout the body. In patients with lymphoma and some types of lymphocytic leukemia, the malignant lymphocytes multiply and the lymph nodes may become enlarged. This enlargement of lymph nodes can be seen or felt during physical examination, or measured by computed tomography (CT) scan or magnetic resonance imaging (MRI), depending on the degree of enlargement and the location.

Lymphatic System. The system comprising the lymph nodes, the thymus gland (in the first several decades of life), the lymphatic channels, the lymphatic tissue of the marrow, the gastrointestinal tract, the skin and the spleen, as well as the T, B and natural killer (NK) lymphocytes contained in these sites.

Lymphocyte. A type of white blood cell that is essential to the body’s immune system. There are three major types of lymphocytes: B lymphocytes, which produce antibodies to help combat infectious agents like bacteria, viruses and fungi; T lymphocytes, which have several functions, including assisting B lymphocytes to make antibodies; and natural killer (NK) cells, which can attack virus-infected cells or tumor cells.

Magnetic Resonance Imaging (MRI). A technique that provides detailed images of body structures. It differs from the computed tomography (CT) scan in that the patient is not exposed to x-rays. Signals are generated in the tissues in response to a magnetic field produced by a specialized instrument and are converted by computer software into images of body structures. Healthcare professionals use MRI to measure either the size, or a change in size, of organs such as the lymph nodes, liver and spleen or tumor masses.

Marrow. See Bone Marrow.

Microarray. A laboratory tool used to analyze large numbers of genes or proteins at one time. In a microarray, biologic molecules such as DNA (deoxyribonucleic acid), RNA (ribonucleic acid), or protein are placed in a pattern onto a surface such as a glass slide. Other substances are added to these slides to detect specific patterns of molecules. Microarrays are being used to help diagnose diseases, such as cancer, and to develop treatments for them. See Gene Expression Profiling.

Monoclonal. See Clonal.

Monoclonal Antibody Therapy. See Immunotherapy.

MRI. See Magnetic Resonance Imaging (MRI).

Mutation. An alteration in a gene that results from a change to a part of the stretch of DNA (deoxyribonucleic acid) that represents the gene. A “germ cell mutation” is a mutation that is present in the egg or the sperm and can be transmitted from parent to offspring. A “somatic mutation” is a mutation that occurs in a specific tissue cell and can result in the growth of that cell into a tumor. Most cancers start after a somatic mutation occurs. In leukemia, lymphoma or myeloma, undeveloped marrow (blood-forming) or lymph node cells undergo one or more somatic mutations that lead to the formation of a tumor. If a mutation results from a major chromosome abnormality, such as a translocation, it can be detected by cytogenetic analysis. Sometimes the alteration in the gene is more subtle and requires more sensitive tests to identify the cancer-causing gene called the oncogene.

Oncologist. A doctor who diagnoses and treats patients with cancer. Oncologists are usually internists who undergo additional specialized training to treat adults (or pediatricians, to treat children) who have cancer. Radiation oncologists specialize in the use of radiation to treat cancer, and surgical oncologists specialize in the use of surgical procedures to diagnose and treat cancer. These doctors cooperate and collaborate to provide the best treatment plan for the patient, consisting of surgery, radiation therapy, chemotherapy and/or immunotherapy.

Pathologist. A doctor who identifies diseases by studying tissues under a microscope. A hematopathologist is a type of pathologist who studies diseases of blood cells by examining blood, bone marrow, lymph node and other tissue samples, and uses their expertise to identify diseases such as lymphoma. A hematopathologist uses a microscope to examine specimens and tissue and reviews the laboratory values, flow cytometry and molecular diagnostic test results to make the most accurate diagnosis. The hematopathologist works closely with the patient’s hematologist-oncologist and based upon the diagnosis, will decide on the best treatment for the patient.

Platelets. Small blood cells (about one-tenth the volume of red blood cells) that stick to the site of blood vessel injury, aggregate and then seal off the injured blood vessel to stop bleeding. “Thrombocyte” is a synonym for platelet and is often used as the prefix in terms describing disorders of platelets, such as thrombocytopenia (too few platelets) or thrombocytopenia (too many platelets).

Radiation Therapy. The use of x-rays and other forms of radiation in cancer treatment. Radiation therapy may be useful in the treatment of localized lymphoma masses. Few cases of non-Hodgkin lymphoma are treated solely with radiation therapy because lymphoma cells are likely to be spread widely throughout the body. Radiation therapy can be an important addition to therapy when there are particularly large masses of lymphoma in a localized area, or when enlarged lymph nodes are compressing or invading normal organs or structures and chemotherapy cannot control the problem.

Radioimmunotherapy. See Immunotherapy.

Recurrence/Relapse. The return of a disease after it has been in remission following treatment.

Remission. The disappearance of evidence of a disease, usually as a result of treatment. The terms “complete” and “partial” are used to modify the term “remission.” Complete remission means that all evidence of the disease is gone. Partial remission means that the disease is markedly improved by treatment, but residual evidence of the disease is present. A complete remission is usually required to achieve long-term benefits from treatment, especially in progressive lymphomas.

Serum. See Lactate Dehydrogenase (LDH).

Solitary Extranodal Lymphoma. See Extranodal Lymphoma.

Spleen. An organ located in the left upper portion of the abdomen, just under the left side of the diaphragm. It contains clusters of lymphocytes and also filters old or worn-out cells from the blood. It is often affected in lymphocytic leukemias and lymphomas. Enlargement of the spleen is called “splenomegaly.” Surgical removal of the spleen is known as “splenectomy.”

Stem Cells. Immature (undeveloped) cells in the bone marrow that are essential to the formation of red blood cells, white blood cells and platelets. They are primarily found in the marrow, but some leave the marrow and circulate in the bloodstream. Using special techniques, the stem cells in blood can be collected, preserved by freezing and later thawed and used for stem cell therapy. See Hematopoiesis.

Thrombocytopenia. An abnormally low concentration of platelets in the blood.

Thymus. A lymphoid organ located immediately beneath the breastbone at the level of the heart. The thymus serves a vital role in the formation and development of T lymphocytes (T cells). The human thymus becomes much smaller as puberty approaches.

Toxin. A naturally derived substance that is poisonous to cells. A toxin can bind to antibodies that then attach to cancer cells. The toxin may kill the cancer cells.

Translocation. An abnormality of chromosomes in marrow or lymph node cells that occurs when a piece of one chromosome breaks off and attaches to the end of another chromosome. In a balanced translocation, genetic material is exchanged between two different chromosomes with no gain or loss of genetic information. When a translocation takes place, the gene at which the break occurs is altered. This is one form of somatic mutation that may transform the gene into an oncogene (cancer-causing gene). See Mutation.

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