BRAIN AND SPINAL CORD TUMORS IN CHILDREN

What is cancer?

Cancer develops when cells in a part of the body begin to grow out of control. Although there are many kinds of cancer, all begin because of out-of-control growth of abnormal cells.

Normal body cells grow, divide, and die in an orderly fashion. During the early years of a person's life, normal cells divide more rapidly until the person becomes an adult. After that, cells in most parts of the body divide only to replace worn-out or dying cells and to repair injuries.

Because cancer cells continue to grow and divide, they are different from normal cells. Instead of dying, they outlive normal cells and continue to form new abnormal cells.

Cancer cells often travel to other parts of the body, where they begin to grow and replace normal tissue. This process, called metastasis, occurs as the cancer cells get into the bloodstream or lymph vessels of our body. When cells from a cancer like breast cancer spread to another organ like the liver, the cancer is still called breast cancer, not liver cancer.

Cancer cells develop because of damage to their DNA. DNA is in every cell and directs all its activities. Most of the time when DNA becomes damaged the cell is able to repair it. In cancer cells, the damaged DNA is not repaired.

People can inherit damaged DNA, which accounts for inherited cancers. Many times though, a person's DNA becomes damaged by exposure to something in the environment, like smoking.

Most people think of cancer as a solid tumor. But some cancers, like leukemia, do not form tumors. Instead, these cancer cells involve the blood and blood-forming organs, and circulate through other tissues where they grow.

Remember that not all tumors are cancerous. Benign (non-cancerous) tumors do not spread to other parts of the body (metastasize) and, with very rare exceptions, are not life-threatening.

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

Cancer is the second leading cause of death in the United States. It is the second leading cause of death after accidents in children from ages 1 to 14. Half of all men and one third of all women in the United States will develop cancer during their lifetimes. Today, millions of people are living with cancer or have had cancer. The risk of developing most types of adult cancers can be reduced by changes in a person's lifestyle, for example, by quitting smoking, reducing sun exposure, and eating a healthier diet. These risks do not apply to children. Generally, the sooner a cancer is found and treatment begins, the better are the chances for living for many years.

What are the differences between cancers in adults and children?

The types of cancers that develop in children are different from the types that develop in adults. Although there are exceptions, childhood cancers tend to respond better to chemotherapy. Children also tolerate chemotherapy better than adults. But, because chemotherapy can have some long-term side effects, children who survive their cancer need careful attention for the rest of their lives.

Since the 1960s, most children and adolescents with cancer have been treated at specialized centers designed for them. Being treated in specialized centers offers them the advantage of a team of specialists who know the differences between adult and childhood cancers, as well as the unique needs of children with cancers. This team usually includes pediatric oncologists, pathologists, surgeons, radiation oncologists, pediatric oncology nurses, and nurse practitioners.

These centers also have psychologists, social workers, child life specialists, nutritionists, rehabilitation and physical therapists, and educators who can support and educate the entire family.

Most children with cancer in the United States are treated at a center that is a member of the Children's Oncology Group (COG). All of these centers are associated with a university or children's hospital. As we have learned more about treating childhood cancer, it has become even more important that treatment be given by experienced experts.

What are the differences between cancers in adults and children?

Children and adolescents with brain and spinal cord tumors and their families have special needs that can be best met by cancer centers for children and adolescents working closely with the child's primary care physician. Treatment in specialized centers takes advantage of a team of specialists who know the differences between cancers that occur in adults compared to those that occur in children and adolescents, as well as the unique needs of children and adolescents with cancers. This team should include pediatric oncologists, neurosurgeons, radiation oncologists, neuroradiologists, neurologists, neuropathologists, endocrinologists, psychologists, pediatric oncology nurses, and nurse practitioners.

The treatment of cancer in children and adolescents also involves many professionals other than nurses and doctors. Children's cancer centers have social workers, child life specialists, nutritionists, rehabilitation and physical therapists, and educators who can support and educate the entire family. Since the 1960s, most children with cancer have been treated at specialized centers designed for children.

Most children with cancer in the United States are treated at a center that is a member of the Children's Oncology Group (COG). All of these centers are associated with a university or children's hospital. To find the pediatric cancer center closest to you, see the American Cancer Society document, "Pediatric Cancer Centers" or go to the COG Web site at www.curesearch.org.

What are brain and spinal cord tumors in children?

Brain tumors are masses of abnormal cells that have grown out of control. In most other parts of the body, it is very important to distinguish between benign (non-cancerous) tumors and malignant (cancerous) ones. Benign tumors in other parts of the body are almost never life threatening. The main reason cancers are so dangerous is because they can spread throughout the body. Most brain cancers can spread through the brain tissue but rarely spread to other areas of the body. Even so-called "benign" tumors can, as they grow, compress normal brain tissue, causing damage that is often disabling and sometimes fatal. For this reason, doctors usually speak of "brain tumors" rather than "brain cancers." The major differences are how readily they spread through the rest of the central nervous system and whether they can be removed and not come back.

Brain and spinal cord tumors are different in adults and children. They often form in different places, develop from different cell types, and may have a different treatment and prognosis (outlook). This document refers only to children's tumors. Brain and spinal cord tumors in adults are discussed in a separate American Cancer Society document.

To understand brain and spinal cord tumors, it helps to know about the normal structure and function of the central nervous system.

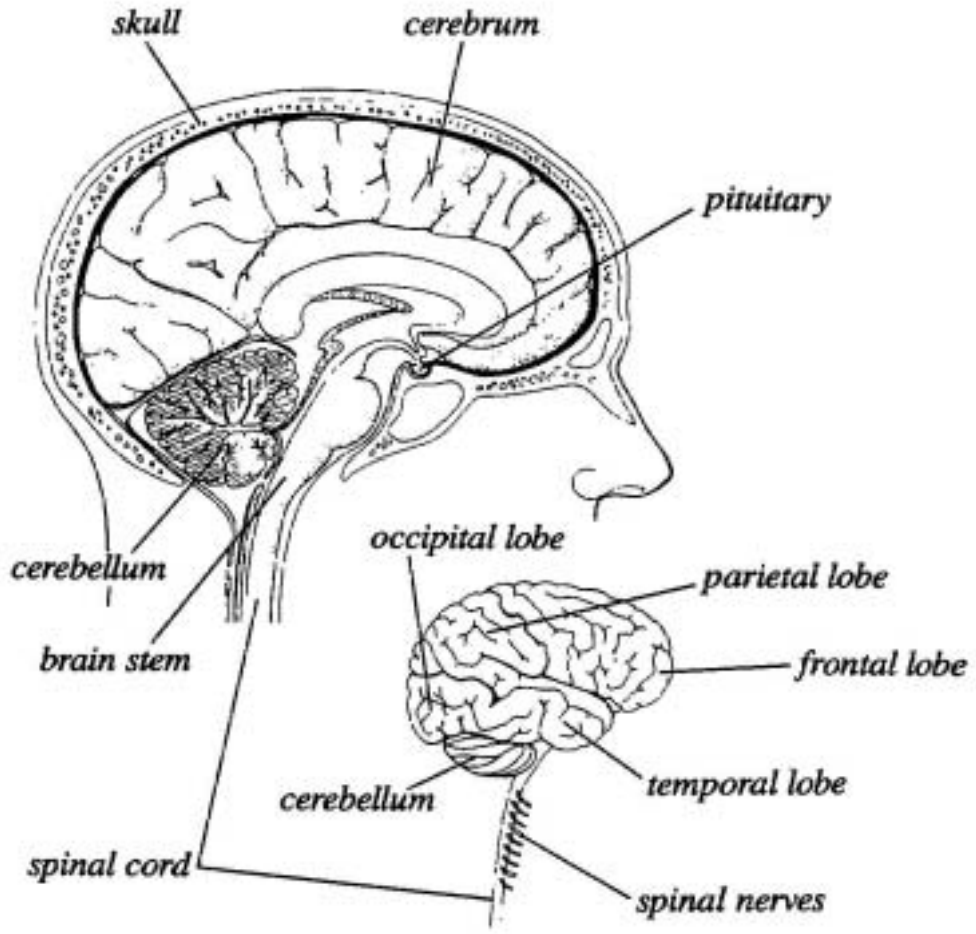
The central nervous system

The central nervous system (CNS) is the medical name for the brain and spinal cord.

The brain is the center of thought, feeling, memory, speech, vision, hearing, movement, and much more. The spinal cord and special nerves in the head called cranial nerves carry messages between the brain and the rest of the body. These messages tell our muscles how to move, transmit information gathered by our senses, and help coordinate our internal organs. The brain is located within and protected by the skull. Likewise, the spinal cord is protected by the bones (vertebrae) of the spinal column.

The brain and spinal cord are surrounded and cushioned by a special fluid, called cerebrospinal fluid (CSF). Cerebrospinal fluid is made by the choroid plexus, which is located in cavities within the brain called ventricles. The ventricles, as well as the spaces around the brain and spinal cord, are filled with CSF.

Parts of the brain and spinal cord



The brain and spinal cord are the 2 main parts of the central nervous system.

The main areas of the brain include the cerebrum, cerebellum, and brain stem. Each of these parts has a special purpose.

Cerebrum: The cerebrum, which is made up of 2 hemispheres (halves), controls reasoning, thought, emotion, and language. It is also responsible for your planned muscle movements (throwing a ball, walking, chewing, etc.) and for taking in sensory information such as vision, hearing, smell, touch, and pain.

The symptoms caused by a tumor in a cerebral hemisphere depend on the part of the hemisphere in which the tumor develops. Common symptoms include:

- seizures

- trouble speaking
- a change of mood such as depression
- a change in personality
- weakness or paralysis of part of the body
- changes in vision, hearing, or sensation

Cerebellum: The cerebellum controls coordination of movement. Tumors of the cerebellum can cause problems with coordination in walking, trouble with fine movements of arms and legs, impairment of synchronized eye movements, and changes in rhythm of speech.

Brain stem: The brain stem has bundles of very long nerve fibers that carry signals controlling muscles and sensation or feeling between the cerebrum and the rest of the body. In addition, most cranial nerves (which carry signals directly between the brain and the face, eyes, tongue, and mouth) start in the brain stem. Special centers in the brain stem also control breathing and the beating of the heart.

Tumors in this critical area of the brain may cause weakness, stiff muscles, or problems with sensation, hearing, facial movement, or swallowing. Double vision is a common early symptom of brain stem tumors, as are problems with coordination in walking. Because tumors of the brain stem often intermingle with normal nerve cells and the brain stem is so essential for life, it may not be possible to surgically remove these tumors.

Spinal cord: The spinal cord, like the brain stem, has bundles of very long nerve fibers that carry signals that control muscles, sensation or feeling, and bladder and bowel control. Spinal cord tumors may cause weakness, paralysis, or numbness. Because the spinal cord is such a narrow structure, tumors that develop there usually cause symptoms on both sides of the body (for example, weakness or numbness of both legs). This is different from tumors of the brain, which usually affect only one side of the body. Moreover, most tumors of the spinal cord develop below the neck after the nerves to the arms have branched off the spinal cord, so that only lower body functions -- bowel, bladder, or leg movement or sensation -- are affected.

Cranial nerves: Tumors may also develop in the cranial nerves, which are nerves that extend directly out of the base of the brain (as opposed to coming out of the spinal cord). The most common cranial nerve tumors in children are *optic gliomas*, which are tumors of the optic nerve (the large nerve that runs from the brain to the eye) that cause vision problems. Tumors starting in other cranial nerves may cause trouble swallowing, hearing loss in one or both ears, facial paralysis, or facial numbness or pain.

Peripheral nervous system: The peripheral nervous system consists of the parts of the nervous system other than the brain and spinal cord (which make up the central nervous system). Tumors that start in the nerves of the peripheral nervous system generally cause pain, weakness, and/or loss of sensation in the area served by that nerve.

Types of cells and body tissues in the brain and spinal cord

The brain and spinal cord contain different kinds of tissues and cells,which means different types of tumors can develop. These tumors can have varying outlooks for survival and may be treated differently.

Neurons (nerve cells): These are the most important cells within the brain. They send signals through their nerve fibers (axons). These may be very short (in the brain) or 2 to 3 feet long (in the spinal cord). Electric signals carried by neurons determine thought, memory, emotion, speech, muscle movement, and just about everything else that the brain and spinal cord do. Unlike many other types of cells that can grow and divide to repair damage from injury or disease, neurons stop dividing about a year after birth (with a few exceptions). Neurons do not usually form tumors, but they can be damaged by tumors that start nearby.

Glial cells: Glial cells are the supporting cells of the brain. Most brain and spinal cord tumors develop from glial cells. They are sometimes referred to as a group called gliomas. Normal glial cells grow and divide very slowly. They continue to increase in number until a child is about 5 years of age. At this time, the brain reaches its maximum size and will be the same size until late in adulthood, when it may shrink some.

There are 3 types of glial cells -- astrocytes, oligodendrocytes, and ependymal cells. A fourth cell type called microglia is part of the immune system and is not truly glial in origin.

- **Astrocytes** help support and nourish neurons. When the brain is injured, astrocytes form scar tissue that helps repair the damage. The main tumors starting in these cells are called astrocytomas or glioblastomas.

- **Oligodendrocytes** make *myelin*, a substance that surrounds and insulates axons of the brain and spinal cord. This allows oligodendrocytes to help neurons transmit electric signals through axons. Tumors starting in these cells are called oligodendrogliomas.

- **Ependymal cells** line the ventricles (fluid-filled areas) within the central part of the brain and form part of the pathway through which cerebrospinal fluid travels. Tumors starting in these cells are called ependymomas.

- **Microglia** are the immune (infection fighting) cells of the central nervous system.

Neuroectodermal cells: These are primitive cells that are probably the remains of embryonic cells. They are found throughout the brain. The most common tumor that comes from these cells is the medulloblastoma, which arises in the cerebellum from forerunners of nerve cells called granule cells.

Meninges: These are tissues that line the brain and spinal cord. The meninges help form the spaces through which CSF travels. The most common tumors that start in these cells are called meningiomas.

Choroid plexus: The choroid plexus is the area of the brain within the ventricles that makes CSF, which nourishes and protects the brain. Choroid plexus papillomas and carcinomas arise from this site.

Pituitary gland and hypothalamus: The pituitary is a small gland found at the base of the brain. The hypothalamus is the part of the brain to which the pituitary gland is connected. Both help regulate the activity of several other glands. For example, they control the amount of thyroid hormone made by the thyroid gland, the production and release of milk by the breasts, and the amount of male or female hormones made by the testicles or ovaries. They also make growth hormone, which stimulates body growth, and vasopressin, which regulates water balance by the kidneys.

The growth of tumors in or near the pituitary or hypothalamus, as well as surgery and/or radiation therapy in this area, can interfere with these functions. Consequently, a child may have low levels of one or more hormones and may need hormone treatments to correct any hormone deficiency.

Pineal gland: The pineal gland is not strictly part of the brain. It is, in fact, an endocrine gland that sits between the cerebral hemispheres. Its main function is probably to make melatonin, a hormone that regulates sleep, in response to changes in light.

Blood-brain barrier: Unlike the case with most other organs, the small blood vessels (capillaries) in the brain and spinal cord have a protective inner lining that serves as a very selective barrier between the blood and the tissues of the central nervous system. This normally keeps harmful toxins from getting into the brain. Unfortunately, it also keeps out most chemotherapy drugs that are used to kill cancer cells, which in some cases limits their usefulness.

Types of brain and spinal cord tumors in children

Tumors can form in any type of tissue or cell in the brain or spinal cord. Some tumors have a mixture of cell types.

Unlike other cancerous tumors, tumors arising within the brain or spinal cord rarely spread (metastasize) to distant organs. They cause damage because they spread locally and destroy normal tissue where they arise.

Tumors in different areas of the central nervous system may be treated differently and have a different prognosis (outlook for survival).

Gliomas

Gliomas are not a specific type of cancer. Glioma is a general term for a group of tumors that start in glial cells. A number of tumors can be considered gliomas, including glioblastoma multiforme, anaplastic astrocytoma, astrocytoma, oligodendroglioma, ependymoma, brain stem glioma, optic glioma, and choroid plexus tumors. Most brain and spinal cord tumors in children are gliomas.

Astrocytomas: Most tumors that develop within the brain itself start in brain cells called astrocytes, a kind of glial cell. These tumors are called astrocytomas. About half of all childhood brain tumors are astrocytomas. When these tumors occur in the brain stem, they are referred to as **brain stem gliomas**.

Most astrocytomas can spread widely throughout, and intermingle with, the normal brain tissue, which can make them very hard to remove by surgery. Sometimes they spread along the cerebrospinal fluid pathways. It is very rare for them to spread outside of the brain or spinal cord.

Astrocytomas are classified as low grade, intermediate grade, or high grade, based on how the cells look under the microscope.

- Low-grade astrocytomas are the slowest growing and the most common type of astrocytoma in children.

- Intermediate-grade astrocytomas, or **anaplastic astrocytomas**, grow at a moderate rate.

- The highest-grade astrocytoma, known as **glioblastoma multiforme** (or just glioblastoma), is the fastest growing.

There are some special types of astrocytomas that tend to have a good prognosis.

- **Juvenile pilocytic astrocytomas** most commonly occur in the cerebellum but also occur in the optic nerve, hypothalamus, brain stem, or other areas.

- **Subependymal giant cell astrocytomas** occur in the ventricles and are almost always linked with tuberous sclerosis (an inherited condition which may also cause epilepsy, mental retardation, and tumors of the skin and kidneys).

- **Optic gliomas** are low-grade astrocytomas of childhood that start in the optic nerve. They are often linked with an inherited condition called neurofibromatosis type 1. These tumors can sometimes be treated successfully by surgery. At other times radiation therapy or chemotherapy may be required. These tumors are rarely lethal but may cause substantial visual loss and injury to nearby brain tissue.

Oligodendrogliomas: These tumors start in brain glial cells called oligodendrocytes. Like astrocytomas, most of these can spread or infiltrate into nearby brain tissue and cannot be

completely removed by surgery. Oligodendrogliomas may spread along the cerebrospinal fluid pathways but rarely spread outside the brain or spinal cord.

Ependymomas: Almost 10% of brain tumors in children are ependymomas. These tumors arise from the ependymal cells that line the ventricles or central canal of the spinal cord. They can range from fairly low-grade (less aggressive) tumors to higher grade ones, which are called anaplastic ependymomas.

Ependymomas may block the flow of cerebrospinal fluid out of the ventricles, causing the ventricles to become very large -- a condition called hydrocephalus. Unlike astrocytomas and oligodendrogliomas, ependymomas usually do not spread into or infiltrate normal brain tissue. As a result, some (but not all) ependymomas can be removed and cured by surgery. Spinal cord ependymomas have the greatest chance of being cured. Ependymomas may spread along the cerebrospinal fluid pathways but do not spread outside the brain or spinal cord.

Choroid plexus tumors: These rare tumors arise in the choroid plexus within the ventricles of the brain. Most are benign (choroid plexus papillomas) and cured by surgery. However, some are malignant (choroid plexus carcinomas).

Primitive neuroectodermal tumors

These tumors start in primitive (immature) cells of the central nervous system. About 1 out of 4 brain tumors in children are of this type. They are rare in adults. Primitive neuroectodermal tumors (PNETs) tend to grow fast and frequently spread throughout the cerebrospinal fluid pathways. These tumors sometimes have different names depending on where they occur.

Medulloblastomas: PNETs that start in the cerebellum are called medulloblastomas. About 15% of childhood brain tumors are medulloblastomas. These tumors can often be treated effectively and tend to have a better prognosis than PNETs in other parts of the brain. They are treated with surgery and radiation therapy, sometimes with added chemotherapy.

Pineoblastomas: Primitive neuroectodermal tumors are called pineoblastomas when they occur in the pineal gland. The outlook for pineoblastomas is not as favorable as for medulloblastomas.

Craniopharyngiomas

This type of slow-growing tumor grows above the pituitary gland but below the brain itself. It may compress the pituitary gland and the hypothalamus, causing hormonal problems. Most craniopharyngiomas are very close to the optic nerve, making them hard to remove surgically because of possibly damaging the child's vision. Some are cured by surgery; others require radiation therapy, either alone or combined with surgery.

Mixed glial and neuronal tumors

Certain tumors that occur in children and young adults (and rarely in older adults) seem to have both glial and neuronal cell components. They tend to have a fairly good prognosis.

- **Pleomorphic xanthoastrocytoma** and **dysembryoplastic neuroepithelial tumors** appear malignant under the microscope, but these tumors are relatively benign and most are cured by surgery alone.

- **Ganglioglioma** is a type of tumor that has both mature neurons and glial cells. Most can be cured by surgery alone or surgery combined with radiation therapy.

Schwannomas (neurilemomas)

This type of tumor starts in Schwann cells that surround and insulate cranial nerves and other nerves. Schwannomas are usually benign tumors. They often form near the cerebellum in the cranial nerve responsible for hearing and balance, in which case they are called **acoustic neuromas**. They may also arise from spinal nerves after the point where they have left the spinal cord. When this is the case, they can compress the spinal cord, causing weakness, sensory loss, and bowel and bladder problems.

These tumors are rare in children. When present in this age group, particularly if there is more than one, they might suggest an inherited tumor syndrome such as neurofibromatosis.

Other tumors that can start in or near the brain

Meningiomas: These tumors arise from the meninges, the tissues that surround the outer part of the brain and spinal cord. Meningiomas cause symptoms by pressing on the brain or spinal cord. They are much less common in children than in adults.

Meningiomas are benign and are usually cured by surgery. Some, however, are located dangerously close to vital structures in the brain and cannot be cured by surgery.

Meningiosarcomas are rare but very malignant (cancerous) tumors of the meninges that may come back many times after surgery or, rarely, spread to other parts of the body.

Chordomas: These tumors start in the bone at the base of the skull or at the lower end of the spinal column. Chordomas may come back many times over a period of 10 to 20 years, causing progressive neurologic damage and deterioration. They usually do not spread or metastasize to other organs.

Germ cell tumors: Germ cell tumors develop from germ cells that normally form eggs in women and sperm in men. During normal embryonic and fetal development, germ cells migrate to the ovaries or testicles and develop into eggs or sperm cells. Sometimes, however, a few germ cells may not migrate properly and end up in abnormal locations such as the brain. They may then develop into germ cell tumors similar to those that can form in the ovaries or testicles.

Germ cell tumors of the nervous system usually occur in children, most often in the pineal gland or above the pituitary gland. Germ cell tumors can sometimes be diagnosed without a biopsy by measuring certain chemicals in the cerebrospinal fluid or blood.

The most common germ cell tumor of the nervous system is the *germinoma*, which can be cured by radiation therapy and possibly chemotherapy in almost all cases. Other tumors that originate in germ cells, such as choriocarcinoma or yolk sac tumors are rarely cured by surgery. Both radiation therapy and chemotherapy are used in their treatment, although in some cases this may not control the tumor completely.

Neuroblastomas: This type of nerve cell tumor is the third most common cancer in children. Neuroblastomas rarely develop in the brain or spinal cord; most develop from nerve cells inside the abdomen or chest. This type of cancer is most commonly diagnosed during early infancy. For more information, see the separate American Cancer Society document, *Neuroblastoma*.

Cancers that spread to the brain from other sites

Sometimes brain tumors are found not to have started in the brain but rather to have spread (metastasized) from some other part of the body. Tumors that start in other organs and then spread to the brain are called *metastatic brain tumors* (as opposed to primary brain tumors, which start in the brain). This is important because metastatic and primary brain tumors are usually treated differently.

In children, metastatic tumors to the brain are much less common than primary brain tumors. This document only covers primary brain tumors.

What are the key statistics about brain and spinal cord tumors in children?

Brain and spinal cord tumors are the second most common cancers in children (after leukemia). They account for about 21% of childhood cancers. Around 3,400 central nervous system tumors are diagnosed each year in children under the age of 20. About one fourth of these are considered benign tumors. The incidence rate (number per 100,000 children) of these cancers has not changed much in recent years.

Boys are affected slightly more often than are girls.

About 3 out of 4 children with brain tumors (all types combined) survive *at least* 5 years after being diagnosed. The outlook varies according to the type and location of the tumor. For more specific information on a particular tumor type, see "How are brain and spinal cord tumors in children treated?"

What are the risk factors for brain and spinal cord tumors in children?

A risk factor is anything that affects the chance of getting a disease such as cancer. Different cancers have different risk factors. For example, exposing skin to strong sunlight is a risk factor for skin cancer. But risk factors don't tell us everything. Having a risk factor, or even several, does not mean that a person will get the disease, and many people who have no known risk factors get cancer.

Unlike many adult cancers, lifestyle-related risk factors do not seem to play a large role in childhood cancers. On top of this, very few risk factors for brain tumors have been found. There is no clear cause for most brain tumors.

Environmental risk factors

Radiation

The only well established environmental risk factor for brain tumors is radiation exposure to the head, which most often comes from the treatment of other conditions. Before the risks of radiation were well known (over 50 years ago), children with ringworm of the scalp (a fungal infection) often received low-dose radiation therapy. This was found to increase their risk of brain tumors later in life. Today, most radiation-caused brain tumors are the result of radiation to the head given to treat other cancers such as certain leukemias.

Other factors

Other suggested environmental risk factors, include exposure to vinyl chloride (an odorless gas used in manufacturing plastics); exposure to aspartame (a sugar substitute); exposure to

electromagnetic fields from cell phones or high-tension wires; the parents' smoking history; certain infections; and previous injury to the head. So far there is very little evidence to support these factors as possible risks. More studies are needed to determine which, if any, of these are true risk factors for childhood brain tumors.

Inherited and genetic conditions

In rare (fewer than 1 in 10) cases, children may inherit abnormal copies of genes from a parent that put them at increased risk for certain types of brain tumors. In some cases, the abnormal genes are not inherited but occur as a result of changes (mutations) in the gene before birth.

People with inherited tumor syndromes often have multiple tumors that start to occur when they are young. Some of the more well-known disorders are listed below.

Neurofibromatosis type 1 (von Recklinghausen disease): This is the most common inherited cause of brain or spinal cord tumors. It may be linked with optic gliomas or other gliomas of the brain or spinal cord, as well as with neurofibromas (benign tumors of peripheral nerves). Changes in the NF1 gene cause this disorder.

Neurofibromatosis type 2: Less common than von Recklinghausen disease, this condition is associated with cranial or spinal nerve schwannomas, especially acoustic neuromas. It is also linked to an increased risk of meningiomas, as well as spinal cord gliomas or ependymomas. Changes in the NF2 gene are responsible for neurofibromatosis type 2.

Tuberous sclerosis: This condition may be associated with subependymal giant cell astrocytomas, as well as with other benign tumors of the brain, skin, heart, or kidneys. It is caused by changes in either the TSC1 or the TSC2 gene.

Von Hippel-Lindau disease: This disease is associated with an inherited tendency to develop hemangioblastomas (blood vessel tumors) of the cerebellum, spinal cord or retina as well as kidney cancer. It is caused by changes in the VHL gene.

Li-Fraumeni syndrome: This condition results in an increased risk of developing gliomas, as well as breast cancer, soft tissue sarcomas, leukemia, and adrenal gland cancers. It is caused by changes in the p53 gene.

Other inherited conditions, including Gorlin syndrome, Turcot syndrome, Cowden syndrome, and hereditary retinoblastoma are also linked with increased risks of certain types of brain and spinal cord tumors. Other families may have genetic disorders that are not well recognized or that may even be unique to a particular family.

Do we know what causes brain and spinal cord tumors in children?

The cause of most central nervous system tumors is not fully understood. But researchers are making progress toward understanding some of the chemical changes that occur in normal brain cells that may lead them to form brain tumors.

Normal human cells grow and function based mainly on the information contained in each cell's chromosomes. Chromosomes are long molecules of DNA in each cell. Brain tumors, like other tumors, are caused by abnormal changes (mutations) in a person's DNA. DNA is the chemical in each of our cells that makes up our genes -- the instructions for how our cells function. We usually resemble our parents because they are the source of our DNA. However, DNA affects more than how we look.

Some genes contain instructions for controlling when our cells grow, divide, and die. Certain genes that speed up cell division are called *oncogene*s. Others that slow down cell division, or cause cells to die at the right time, are called *tumor suppressor genes*. Cancers can be caused by DNA mutations (changes) that "turn on" oncogenes or "turn off" tumor suppressor genes. These gene changes can be inherited from a parent (as is sometimes the case with childhood cancers) or may happen during a person's lifetime as cells in the body divide to form 2 new cells.

In recent years, researchers have found the gene mutations that cause some rare inherited syndromes (like neurofibromatosis, tuberous sclerosis, Li-Fraumeni, and von Hippel-Lindau) and increase the risk of developing some central nervous system tumors. For example, the Li-Fraumeni syndrome is caused by mutation of the p53 tumor suppressor gene. Normally, this gene prevents cells with damaged DNA from growing. When mutated, it increases the risk of developing brain tumors (particularly astrocytomas), as well as some other cancers.

Most brain and spinal cord tumors in children are not the result of known inherited syndromes. A number of gene or chromosome changes have been found in some of these tumors, although it's not clear if these changes have specific causes. Still, research into these changes may lead to new treatments for central nervous system tumors in the future.

In most cases, it is not known why people without inherited syndromes develop changes in their central nervous system cells. Most risk factors for cancer somehow damage genes. For example, cigarette smoke is a risk factor for lung cancer and several other cancers because it contains chemicals that can damage genes. The brain is relatively protected from cigarette smoke and other cancer-causing chemicals that we all breathe or eat, so these factors are unlikely to play a major role in these cancers.

The vast majority of brain tumors happen for no apparent reason and are not associated with anything that the child (or parents) did or didn't do, or any known exposures in the environment.

Can brain and spinal cord tumors in children be prevented?

Most brain and spinal cord tumors in children have not been linked with any known risk factors. As a result, most of these tumors cannot be prevented at this time.

Can brain and spinal cord tumors in children be found early?

At this time there are no blood tests or other screening exams that can be used routinely to detect brain tumors before they start to cause symptoms. These tumors usually come to light as a result of signs or symptoms the child is having. In most cases, survival of patients with brain tumors depends on the type of tumor and its location, not how early it is detected. But as with any disease, earlier detection and treatment is likely to be helpful.

How are brain and spinal cord tumors in children diagnosed?

Brain and spinal cord tumors are usually found as the result of signs or symptoms a child is having.

Symptoms of brain and spinal cord tumors

Symptoms from brain and spinal cord tumors may occur gradually and become worse over time, or they may happen suddenly.

General symptoms

In some children, *epileptic seizures* are the first symptom of a brain tumor. It is important to remember that most seizures in children are not caused by brain tumors. Still, your child's doctor may want to consult a neurologist to make sure a brain tumor didn't cause the seizure.

Headache is often a major symptom of brain tumors. In very young children who can't complain of headache, a parent may notice an increase in head size, with or without bulging of the soft spots of the skull (fontanelles). This happens because the several bones that make up the skull haven't grown together yet, and the increased pressure from the tumor can push them apart.

Tumors in any part of the brain may cause the pressure within the skull (known as intracranial pressure) to rise. This is due to the growing tumor and slowing or blockage of

cerebrospinal fluid circulation. Increased pressure within the skull may cause headache, nausea, vomiting, or blurred vision. Another symptom might be drowsiness. In some children, the increased pressure causes crossed eyes and double vision. In others, it may cause trouble seeing. A doctor can often identify the presence of increased intracranial pressure by looking in the child's eyes for swelling of the optic nerve (known as papilledema).

In the school-aged child, poor school performance, fatigue, personality changes, and complaints of headaches are common. In the first few years of life, symptoms can include irritability, vomiting, loss of appetite, developmental delay, and a drop in intellectual and motor abilities.

Symptoms based on tumors in different parts of the central nervous system

Tumors of different parts of the central nervous system can cause different symptoms. These symptoms, however, can be caused by any disease in that particular location in the brain -- they do not necessarily mean a brain tumor is present.

Brain and spinal cord tumors often cause problems with the specific functions of the region they develop in. For example, spinal cord tumors often cause numbness and/or weakness in both legs. Tumors in parts of the brain that control movement or sensation may cause weakness or numbness of part of the body. Tumors in an area of the brain called the basal ganglia typically cause abnormal movements and abnormal body positions.

If the tumor is in the cerebellum, where coordination is controlled, the child may have trouble walking or with other normal functions, even eating.

Tumors in or around the pituitary gland, the optic nerve, or certain other cranial nerves may cause vision problems. Tumors in other cranial nerves may lead to loss of hearing, balance problems, or weakness of some facial muscles.

Again, it's important to note that other disorders may also cause these symptoms, and they do not necessarily mean your child has a brain or spinal cord tumor. Still, if your child's symptoms suggest that a brain or spinal cord tumor may be present, consult a doctor so that the cause can be evaluated and treated, if needed.

Medical history and physical exam

If your child has symptoms that suggest a central nervous system tumor may be present, the doctor will want to take a complete medical history and perform a physical exam to evaluate your child's brain function (known as a neurologic exam), if possible. Your child's

pediatrician or primary care doctor may do this special type of exam. It commonly means testing reflexes, muscle strength, eye and mouth movement, coordination, alertness, and other functions. If the results are abnormal, a more detailed exam may be done by a doctor specializing in diagnosing and treating nervous system diseases (neurologist) or a surgeon who specializes in treating nervous system diseases (neurosurgeon).

Imaging tests

If your child's doctor thinks a brain problem may be present, he or she will probably order one or more imaging tests. These studies provide different types of pictures of internal organs such as the brain and spinal cord. The pictures may be looked at by doctors specializing in this field (neurosurgeons, neurologists, and radiologists) as well as by your child's doctor.

Computed tomography scan

Although computed tomography **(**CT or CAT) scans formerly were used quite often to find brain and spinal cord tumors, they have been largely replaced by MRI scans, which provide more detailed imaging. One advantage of CT scans over MRIs, particularly for children who have trouble being still, is that they take much less time.

The CT scan is an x-ray test that can produce detailed cross-sectional images of your child's brain and spinal cord. Instead of taking one picture, like a regular x-ray, a CT scanner takes many pictures as it rotates around your child while he or she lies on a table. A computer then combines these pictures into images of slices of the part of the body being studied. Unlike a regular x-ray, a CT scan creates detailed images of the soft tissues in the body.

Your child may get an injection of a contrast dye through an IV (intravenous) line. This helps better outline any tumors that are present. The contrast may cause some flushing (a feeling of warmth, especially in the face). Some people are allergic and get hives. Rarely, more serious reactions like trouble breathing or low blood pressure can occur. Be sure to tell the doctor if your child has ever had a reaction to any contrast material used for x-rays.

CT scans take longer than regular x-rays. Your child will need to lie still on a table while they are being done. During the test, the table moves in and out of the scanner, a ring-shaped machine that completely surrounds the table. Some people feel a bit confined by the ring they have to lie in while the pictures are being taken. In some cases, your child may need to be sedated before the test to keep them as still as possible and help make sure the pictures come out well.

In recent years, *spiral CT* (also known as helical CT) has become available in many medical centers. This type of CT scan uses a faster machine. The scanner part of the machine rotates

around the body continuously, allowing doctors to collect the images much more quickly than with a standard CT. This lowers the chance of "blurred" images occurring as a result of motion. It also lowers the dose of radiation received during the test. The biggest advantage may be that the "slices" it images are thinner, which yields more detailed pictures and allows doctors to look at suspicious areas from different angles.

Magnetic resonance imaging scan

Magnetic resonance imaging (MRI) scans are particularly helpful in looking at the brain and spinal cord and are considered the best way to look for tumors in these areas. In some cases, a special form of this test, known as *magnetic resonance angiogram* (MRA), may be done to look at the blood vessels in the brain. This can be very useful before surgery to help the surgeon plan an operation.

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

MRI scans are a little more uncomfortable than CT scans. First, they take longer -- often up to an hour. Second, your child has to lie inside a narrow tube, which can be confining. Newer "open" MRI machines may help with this, although your child may need to be sedated before testing. The machine also makes buzzing and clicking noises that may be disturbing.

Positron emission tomography scan

Positron emission tomography **(**PET) scans involve injecting glucose (a form of sugar) that contains a radioactive atom into the blood. The amount of radioactivity used is very low. Because cancer cells in the body are growing quickly, they absorb large amounts of the radioactive sugar. A special camera can then create a picture of areas of radioactivity in the body. The picture is not finely detailed like a CT or MRI scan, but it can provide helpful information about whether abnormal areas seen on other tests (such as MRIs) are likely to be cancerous or not.

A PET scan is sometimes useful in diagnosing brain tumors and seeing how they respond to treatment. After treatment, abnormal areas may still show up on an MRI scan. PET scans can help determine if the abnormality is remaining tumor or if it is just scar tissue.

Angiogram

This is another imaging test sometimes used to evaluate brain and spinal cord tumors. A special dye is injected into blood vessels near the tumor and the area then is viewed with x-rays. This helps doctors look at the blood supply of a tumor. This test has largely been replaced by magnetic resonance angiography (MRA) in recent years.

The brain tumor team

If a brain tumor is diagnosed or strongly suspected, your child should be seen at a children's cancer center by a team of specialists. At first a neurosurgeon usually takes overall responsibility for your child's evaluation and then does the surgery. Before treatment, the team's social worker will help you, as a parent, understand the tests that need to be done. The social worker will also counsel you about the problems you and your child may have during and after surgery, and may be able to help you find housing and financial aid if needed.

Other team members, such as a psychologist, endocrinologist, and specialists in rehabilitation, may also see your child before treatment. For example, if the tumor is slow growing and your child's condition is stable, he or she may be seen by a psychologist before treatment to assess any damage done by the tumor. Most of the work of these specialists takes place after treatment.

Biopsies to obtain tissue samples

A biopsy is the removal of a sample of tissue to see whether cancer cells are present. Different kinds of biopsies may be used to diagnose a brain tumor or to help determine how far it may have spread.

Brain or spinal cord tumor biopsy

Imaging tests such as MRI and CT scans may show that a brain or spinal cord tumor is present (or very likely). But usually a definite diagnosis as to the type of tumor can be made only by removing some of the tumor tissue and looking at it under a microscope.

In some cases, such as for many brain stem gliomas, tumor removal may not be possible, and the diagnosis may be made based solely on how the tumor looks on imaging tests (without getting a tumor sample).

Surgical (open) biopsy: In most cases, the sample is obtained during surgery to remove as much of the tumor as possible. (Surgery is described in more detail in "How are brain and spinal cord tumors in children treated?")

Stereotactic biopsy: This procedure may be used in cases where the risks of surgery might be too high (such as with some tumors deep within the brain) but a sample is still needed to make a diagnosis.

For this procedure, the surgeon injects a local anesthetic into areas of skin above the skull to numb them. (The brain itself does not feel pain.) A rigid frame may then be fixed onto the child's head. This helps make sure the surgeon is targeting the tumor precisely. An incision is made in the scalp and a small hole is drilled in the skull. An MRI or CT scan is often used along with the frame to help the neurosurgeon guide a hollow needle into the tumor and remove a small piece of tissue. Another approach is to attach markers to the scalp, obtain an MRI or CT, and then use an image-guidance system to direct the needle into the tumor.

Once the tissue is removed, it is looked at under a microscope by a neuropathologist, a doctor who specializes in diagnosing diseases of the nervous system by lab tests. The doctor will determine exactly what type of tumor is present. This is very important in helping to determine the chances of survival and the best course of treatment.

Lumbar puncture (spinal tap)

This procedure is used to look for cancer cells in the cerebrospinal fluid (CSF), which is the liquid that bathes the brain and spinal cord. For this test, the doctor first numbs an area in the lower part of the back near the spine. The doctor may also recommend that the child be given something to make him or her sleep so the child won't squirm during the procedure. Squirming may keep the spinal tap from being done cleanly. A small, hollow needle is then placed between the bones of the spine to withdraw some of the fluid.

The fluid is looked at under a microscope to see if cancer cells are present. Tests can be also done on the CSF to check for certain substances released by some germ cell tumors.

Bone marrow aspiration and biopsy

Because some tumors (especially medulloblastomas) can spread beyond the nervous system, in some instances the doctor may recommend looking at cells in your child's bone marrow to determine if the tumor has spread there.

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

In bone marrow *aspiration*, the skin over the hip and the surface of the bone are numbed with local anesthetic. This test can be painful, so the child will likely also be given other medicines to reduce pain or even be asleep during the procedure. A thin, hollow needle is then inserted into the bone and a syringe is used to suck out a small amount of liquid bone marrow.

A bone marrow *biopsy* is usually done just after the aspiration. A small piece of bone and marrow (about 1/16 inch in diameter and 1/2 inch long) is removed with a slightly larger needle that is twisted as it is pushed down into the bone. Once the biopsy is done, pressure is applied to the site to help stop any bleeding

The specimen is then looked at by a pathologist to identify tumor cells.

Blood and urine tests

These lab tests are rarely involved in the diagnosis of brain and spinal cord tumors, but they may be done if your child has been sick for some time to check how well the liver, kidneys, and some other organs are working. Routine blood cell counts may also be needed, especially before any planned surgery.

How are brain and spinal cord tumors in children staged?

Staging is the process of gathering information from exams and imaging tests to determine how widespread a cancer is. A staging system is a standardized way in which the cancer care team describes the extent to which the cancer may have spread. For most cancers, the stage (extent) of the cancer is one of the most important factors in selecting treatment options and in determining the outlook for chances of cure (prognosis).

Because most central nervous system tumors do not usually spread, they are not formally staged. Some of the most important factors that determine your child's prognosis (survival outlook) include:

- the type of tumor (such as astrocytoma, ependymoma, etc.)
- the grade of the tumor (how quickly the tumor is likely to grow, based on how the cells look under a microscope)
- the location of the tumor
- how much of the tumor can be removed by surgery (if it can be done)
- your child's age

- your child's functional level (related to side effects caused by the tumor)
- whether or not the tumor has spread through the cerebrospinal fluid (CSF) to other parts of the brain and/or spinal cord
- whether or not tumor cells have spread beyond the central nervous system

Medulloblastoma risk groups

More formal systems have been proposed for staging some childhood brain tumors. For example, many clinical trials for treating medulloblastoma use a system that places children into either standard-risk or high-risk groups. Children are placed in the high-risk group if they are younger than 3, have a large amount of tumor that can't be removed during surgery, and/or have cancer cells in the CSF or spread to other parts of the brain or elsewhere. Doctors are still refining this system to make it as accurate as possible.

How are brain and spinal cord tumors in children treated?

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

The treatment information in this document is not official policy of the Society and is not intended as medical advice to replace the expertise and judgment of your cancer care team. It is intended to help you and your family make informed decisions, together with your doctor.

Your doctor may have reasons for suggesting a treatment plan different from these general treatment options. Don't hesitate to ask him or her questions about your treatment options.

The first part of this section describes the various types of treatments used for brain tumors in children. This is followed by a description of the most common approaches used for these tumors based on the type of tumor.

General domments about treatment

Children and adolescents with brain and spinal cord tumors and their families have special needs that can be best met by cancer centers for children and adolescents working closely with the child's primary care doctor. Treatment in these centers takes advantage of a team of specialists who know the differences between cancers in adults and those in children and adolescents, as well as the unique needs of younger people with cancers. This team often includes several different types of doctors, nurses, and other specialists.

Children with central nervous system tumors may be treated by surgery, radiation therapy, and/or chemotherapy. Treatment is different for different kinds of tumors. Each child's treatment must be approached individually to give the child the best chance of cure. The possible long-term side effects of treatment must also be considered.

Surgery

Surgery to remove the tumor

Generally, the first step in brain tumor treatment is for the neurosurgeon (a surgeon who specializes in operating on the brain and other parts of the nervous system) to remove as much of the tumor as he or she can. Surgery alone or combined with radiation therapy may cure many tumors, including some low-grade astrocytomas, pleomorphic xanthoastrocytomas, dysembryoplastic neuroepithelial tumors, ependymomas, craniopharyngiomas, gangliogliomas, and meningiomas.

Children with infiltrating tumors (tumors that grow into surrounding areas), such as anaplastic astrocytomas or glioblastomas, are not cured by surgery. But surgery can reduce the amount of tumor that needs to be treated by radiation or chemotherapy, and this may improve the results of these treatments.

Surgery may also improve some of the symptoms caused by brain tumors, particularly those caused by a build up of pressure within the skull. These can include headaches, nausea, vomiting, and blurred vision. Surgery can also improve symptoms of epilepsy and make the seizures more controllable with medications.

Craniotomy: This is the most common surgery for removal of a brain tumor. For this operation, the child may either be put under general anesthesia (in a deep sleep) or may remain awake (with the surgical area numbed) if brain function needs to be assessed during the operation. The neurosurgeon makes an incision in the scalp and then removes a piece of bone from the skull to expose the area of brain over the tumor. Once the tumor is located, the surgeon removes as much as is safely possible. The surgeon is always careful to avoid damaging normal brain tissue. After removing the tumor, the surgeon replaces the bone and closes the incision.

Surgery to place a shunt

Blockage of the cerebrospinal fluid flow by a tumor can cause increased pressure inside the skull. This pressure can cause the symptoms noted above and may even cause permanent damage to the brain. To drain excess cerebrospinal fluid and lower the pressure, the neurosurgeon may put a plastic tube called a shunt (sometimes referred to as a

ventriculoperitoneal or VP shunt) in place. One end of the shunt is placed in the ventricle of the brain (which has cerebrospinal fluid) and the other end is placed in the abdomen or, less often, the heart. Cerebrospinal fluid flow is controlled by a valve placed along the tubing. The tube runs under the skin of the head, neck, and chest. Shunts may be temporary or permanent. They may be placed before or after the surgery to remove the tumor.

Possible risks and side effects of surgery

Surgery on the brain or spinal cord is a serious operation, and surgeons are very careful to try to limit any problems either during or after surgery. Complications during surgery such as bleeding or reactions to anesthesia are rare, but they can happen. One of the biggest concerns when removing brain tumors is possible loss of brain function afterward, which is why doctors are very careful to remove only as much tissue as is necessary.

For more extensive information on surgery as a treatment for cancer, see the separate American Cancer Society document, *Surgery*.

Radiation therapy

Radiation therapy uses high-energy rays or particles to kill cancer cells. Children whose brain tumors cannot be removed completely by surgery are usually treated with radiation therapy. The exception to this is children younger than 3 years, who are usually not given radiation because of potential long-term side effects such as developmental delay and problems with intellectual development. Instead, the treatment relies mainly on surgery and chemotherapy.

Radiation treatment can even cause problems in older children. Radiation oncologists (doctors who treat tumors with radiation) try very hard to deliver high doses of radiation to the tumor with the lowest possible dose to normal surrounding brain areas.

Types of radiation therapy

In most cases, the radiation is focused precisely on the tumor from a source outside the body. This is called *external beam radiation therapy (EBRT).*

External beam radiation therapy is much like getting an x-ray, although the dose of radiation is much higher. In most cases, the total dose of radiation is divided into daily fractions (usually given Monday thru Friday) over many weeks. For each session, your child lies on a special table while a machine delivers the radiation from a precise angle. The treatment is not

painful. Each session lasts about 15 to 30 minutes, with most of the time being spent making sure the radiation is aimed correctly. The actual treatment time each day is much shorter.

Several newer techniques have been developed in recent years to try to improve upon standard EBRT.

Three-dimensional conformal radiation therapy (3D-CRT): 3D-CRT uses the results of imaging tests such as MRI and special computers to precisely map the location of the tumor. Several radiation beams are then shaped and aimed at the tumor from different directions. Each beam alone is fairly weak, which makes it less likely to damage normal tissues, but the beams converge at the tumor to give a higher dose of radiation there.

Intensity modulated radiation therapy (IMRT): IMRT is an advanced form of 3D therapy. It uses a computer-driven machine that actually moves around the patient as it delivers radiation. In addition to shaping the beams and aiming them at the tumor from several angles, the intensity (strength) of the beams can be adjusted to minimize the dose reaching the most sensitive normal tissues. This may allow the doctor to deliver a higher dose to the tumor.

Conformal proton beam radiation therapy: Proton beam therapy is related to 3D-CRT and uses a similar approach. But instead of using x-rays, this technique focuses proton beams on the cancer. Protons are positive parts of atoms. Unlike x-rays, which release energy both before and after they hit their target, protons cause little damage to tissues they pass through and then release their energy after traveling a certain distance. This means that proton beam radiation may be able to deliver more radiation to the tumor and do less damage to nearby normal tissues. The machines needed to make protons are expensive, and there are only a handful of them in use in the United States at this time.

Stereotactic radiosurgery/stereotactic radiotherapy: This is a type of radiation treatment that delivers a large, precise radiation dose to the tumor area in a single session. (There is no actual "surgery" involved in this treatment.) This treatment may be useful for some small brain and spinal cord tumors in areas where surgery would damage important tissues or when a child's condition does not permit surgery.

First, a head frame is attached to the skull to help precisely aim the radiation beams. Once the exact location of the tumor is known from the CT or MRI scans, radiation from a machine called a Gamma Knife can be focused at the tumor from hundreds of different angles for a short period of time.

A similar approach uses a movable linear accelerator (a machine that creates radiation) that is controlled by a computer. Instead of delivering many beams at once, this machine moves around to deliver radiation to the tumor from different angles. Several machines with names such as X-Knife, CyberKnife, and Clinac are used in this way for stereotactic radiosurgery.

Stereotactic radiosurgery typically uses a single session to deliver the whole radiation dose, though it may be repeated if needed. Sometimes doctors give the radiation in several

treatments to deliver the same or slightly higher dose. This is called fractionated radiosurgery or stereotactic radiotherapy.

Brachytherapy (interstitial radiotherapy): Unlike the external radiation approaches above, brachytherapy involves inserting radioactive material directly into or near the tumor. The radiation given off travels a very short distance, so it affects only the tumor. This technique is most often used along with external radiation. It provides a high dose of radiation at the tumor site, while the external radiation treats nearby areas with a lower dose.

Whole brain and spinal cord radiation therapy (craniospinal radiation): If tests such as an MRI scan or lumbar puncture find the tumor has spread along the spinal cord covering, the meninges, and surrounding fluid, then radiation may be given to the whole brain and spinal cord. Some tumors such as medulloblastoma or other primitive neuroectodermal tumors spread in this manner more often and because of this, more often require craniospinal radiation.

Effectiveness of radiation therapy

Up to one half of all medulloblastomas and virtually all germinomas are cured by radiation therapy. Unfortunately, radiation does not cure most other brain tumors. If there is a small amount of the tumor remaining after surgery, astrocytomas, oligodendrogliomas, and ependymomas can sometimes be controlled (but usually not cured) by radiation therapy.

Possible effects of radiation therapy

Radiation is more harmful to tumor cells than it is to normal cells. Still, normal brain tissue is also damaged by radiation, especially in younger children.

During the course of radiation therapy, some children may become irritable and tired. Nausea, vomiting, and headaches are unusual side effects of radiation therapy. Spinal radiation can cause nausea and vomiting more often than brain radiation. Some weeks after radiation therapy, children may become drowsy or neurologic symptoms may appear to worsen. This is called the radiation somnolence syndrome or early-delayed radiation effect. It usually passes after a few weeks. Sometimes dexamethasone (Decadron), a cortisone-like drug, can help relieve the symptoms.

Children may lose some brain function if large areas of the brain receive radiation. Problems can include memory loss, personality changes, and trouble learning at school. Other symptoms could include seizures and slowed growth. There may also be other symptoms depending on the area of the brain treated and how much radiation was given. These risks must be balanced against the risks of not using radiation and having less control of the tumor. If brain damage occurs, it sometimes is hard to determine whether it was caused by the

tumor, the surgery, the radiation therapy, or a combination of all these. Researchers are constantly testing lower doses or different ways of giving radiation to see if these doses can be as effective without causing as many problems.

Because normal brain cells grow quickly in the first several years of life, radiation therapy is often not used or is postponed if your child is younger than 3 years old. This is done to avoid damage that might severely impair his or her future intellectual growth. This needs to be balanced with the risk of tumor regrowth. Early radiation therapy may be lifesaving. It is important that you talk with your child's doctor about the risks and benefits of treatment.

Rarely (in less than 5% of patients), a large mass of dead tissue forms at the site of an irradiated tumor. This occurs months to many years after radiation is given and is called *radiation necrosis*. In most cases the dead tissue includes both cancerous and non-cancerous cells. Occasionally, surgery is needed to remove the necrotic tissue.

Radiation can damage genes. As a result, radiation therapy is associated with a very small risk of developing a second cancer in area that got the radiation -- for example, a meningioma of the coverings of the brain, or less likely a bone cancer in the skull -- usually many years after the radiation is given. This small risk should not keep children who need radiation from getting treatment. More importantly, parents should continue close follow-up with their child's doctors so that early intervention is possible if problems arise.

For more information on radiation therapy, see the separate American Cancer Society document, *Understanding Radiation Therapy: A Guide for Patients and Families*.

Chemotherapy

Chemotherapy uses anti-cancer drugs that are usually given into a vein intravenously (IV) or taken by mouth. These drugs enter the bloodstream and reach almost all areas of the body. However, many chemotherapy drugs are not able to enter the brain and reach tumor cells. For some brain tumors, the drugs may be given directly into the cerebrospinal fluid (CSF) in the brain or into the spinal canal below the spinal cord.

In general, chemotherapy is used for higher grade tumors. Some types of brain tumors, such as medulloblastoma, tend to respond well to chemotherapy.

Chemotherapy may be given before or after surgery and radiation therapy. It may be used instead of radiation therapy in children 3 years and younger.

Some of the chemotherapy drugs used to treat children with brain tumors include:

- carboplatin
- carmustine (BCNU)

- cisplatin
- cyclophosphamide
- etoposide
- lomustine (CCNU)
- methotrexate
- temozolomide
- thiotepa
- vincristine

These drugs may be used alone or in various combinations, depending on the type of brain tumor.

Possible side effects of chemotherapy

Chemotherapy drugs work by attacking cells that are dividing quickly, which is why they often work against cancer cells. But other cells in the body, such as those in the bone marrow, the lining of the mouth and intestines, and the hair follicles, also divide quickly. These cells are also likely to be affected by chemotherapy, which can lead to side effects.

The side effects of chemotherapy depend on the type of drugs, the amount taken, and the length of treatment. Possible side effects can include:

- hair loss
- mouth sores
- loss of appetite
- nausea and vomiting
- increased chance of infections (due to low white blood cell counts)
- easy bruising or bleeding (due to low blood platelet counts)
- fatigue (due to low red blood cell counts)

Along with the risks above, some chemotherapy drugs have specific side effects (although these are relatively uncommon). For example, cisplatin and carboplatin can also cause kidney damage and hearing loss. Your doctor will check your child's kidney function and hearing periodically if he or she is given these drugs. Some of these side effects may last after treatment is stopped.

Your child's doctor and treating team will watch closely for any side effects that develop. Most side effects can be treated effectively or even prevented altogether. For example, drugs can be given to help prevent or reduce nausea and vomiting. Do not hesitate to discuss any questions about side effects with the cancer care team.

For more information on chemotherapy, see the separate American Cancer Society document, *Understanding Chemotherapy: A Guide for Patients and Families*.

Other drug treatments

Other drugs may be used to help control symptoms or other effects caused by tumors, although they don't treat the tumors directly. Cortisone-like drugs (corticosteroids) such as dexamethasone (Decadron) are often given to reduce the swelling that often occurs around brain tumors. This may help relieve headaches and other symptoms. Drugs may also be given to help prevent seizures, which happen often in people with brain tumors. The drug that is most often prescribed is called phenytoin (Dilantin).

If the pituitary gland has been damaged by the spread of the tumor or by treatments (surgery or radiation therapy), your child may need to take some or most of the pituitary hormones to replace those missing.

Clinical trials

You may have had to make a lot of decisions since you've been told your child has cancer. One of the most important decisions you will make is deciding which treatment is best. You may have heard about clinical trials being done for this type of cancer. Or maybe someone on your health care team has mentioned a clinical trial to you. Clinical trials are one way to get state-of-the art cancer care. Still, they are not right for everyone.

Here we will give you a brief review of clinical trials. Talking to your health care team and your family can help you make the best treatment choice for your child.

What are clinical trials?

Clinical trials are carefully controlled research studies that are done with patients. These studies test whether a new treatment is safe and how well it works in patients, or they may test new ways to diagnose or prevent a disease. Clinical trials have led to many advances in cancer prevention, diagnosis, and treatment.

The purpose of clinical trials

Clinical trials are done to get a closer look at promising new treatments or procedures in patients. A clinical trial is only done when there is good reason to believe that the treatment, test, or procedure being studied may be better than the one used now. Treatments used in clinical trials are often found to have real benefits and may go on to become tomorrow's standard treatment.

Clinical trials can focus on many things, such as:

- new uses of drugs that are already approved by the Food and Drug Administration (FDA)
- new drugs that have not yet been approved by the FDA
- non-drug treatments (such as radiation therapy)
- medical procedures (such as types of surgery)
- herbs and vitamins
- tools to improve the ways medicines or diagnostic tests are used
- medicines or procedures to relieve symptoms or improve comfort
- combinations of treatments and procedures

Researchers conduct studies of new treatments to try to answer the following questions:

- Is the treatment helpful?
- What's the best way to give it?
- Does it work better than other treatments already available?
- What side effects does the treatment cause?
- Are there more or fewer side effects than the standard treatment used now?
- Do the benefits outweigh the side effects?
- In which patients is the treatment most likely to be helpful?

Phases of clinical trials

There are 4 phases of clinical trials, which are numbered I, II, III, and IV. We will use the example of testing a new cancer treatment drug to look at what each phase is like.

Phase I clinical trials: The purpose of a phase I study is to find the best way to give a new treatment safely to patients. The cancer care team closely watches patients for any harmful side effects.

For phase I studies, the drug has already been tested in lab and animal studies, but the side effects in patients are not fully known. Doctors start by giving very low doses of the drug to the first patients and increase the doses for later groups of patients until side effects appear or the desired effect is seen. Doctors are hoping to help patients, but the main purpose of a phase I trial is to test the safety of the drug.

Phase I clinical trials are often done in small groups of people with different cancers that have not responded to standard treatment, or that keep coming back (recurring) after treatment. If a drug is found to be reasonably safe in phase I studies, it can be tested in a phase II clinical trial.

Phase II clinical trials: These studies are designed to see if the drug works. Patients are given the best dose as determined from phase I studies. They are closely watched for an effect on the cancer. The cancer care team also looks for side effects.

Phase II trials are often done in larger groups of patients with a specific cancer type that has not responded to standard treatment. If a drug is found to be effective in phase II studies, it can be tested in a phase III clinical trial.

Phase III clinical trials: Phase III studies involve large numbers of patients -- most often those who have just been diagnosed with a specific type of cancer. Phase III clinical trials may enroll hundreds of patients.

Often, these studies are randomized. This means that patients are randomly put in one of two (or more) groups. One group (called the control group) gets the standard, most accepted treatment. Another group (or more than one group) will get the new one being studied. All patients in phase III studies are closely watched. The study will be stopped early if the side effects of the new treatment are too severe or if one group has much better results than the others.

Phase III clinical trials are usually needed before the FDA will approve a treatment for use by the general public.

Phase IV clinical trials: Once a drug has been approved by the FDA and is available for all patients, it is still studied in other clinical trials (sometimes referred to as phase IV studies). This way more can be learned about short-term and long-term side effects and safety as the drug is used in larger numbers of patients with many types of diseases. Doctors can also learn more about how well the drug works, and if it might be helpful when used in other ways (such as in combination with other treatments).

What it will be like to be in a clinical trial

If your child is in a clinical trial, a team of experts will take care of and watch his or her progress very carefully. Depending on the phase of the clinical trial, your child may receive more attention (such as having more doctor visits and lab tests) than he or she would if treated outside of a clinical trial. Clinical trials are specially designed to pay close attention to your child.

However, there are some risks. No one involved in the study knows in advance whether the treatment will work or exactly what side effects will occur. That is what the study is designed to find out. While most side effects go away in time, some may be long-lasting or even life threatening. Keep in mind, though, that even standard treatments have side effects. Depending on many factors, you may decide to enter your child in a clinical trial.

Deciding to enter a clinical trial

If you would like your child to take part in a clinical trial, you should begin by asking your doctor if your clinic or hospital conducts clinical trials. There are requirements patients must meet to take part in any clinical trial. But whether or not you enter your child in a clinical trial is completely up to you.

Your doctors and nurses will explain the study to you in detail. They will go over the possible risks and benefits and give you a form to read and sign. The form says that you understand the clinical trial and want your child to take part in it. This process is known as giving your informed consent. Even after reading and signing the form and after the clinical trial begins, you are free to withdraw your child from the study at any time, for any reason. Taking part in a clinical trial does not keep your child from getting any other medical care he or she may need.

To find out more about clinical trials, talk to your cancer care team. Here are some questions you might ask:

- Is there a clinical trial that my child could take part in?
- What is the purpose of the study?
- What kinds of tests and treatments does the study involve?
- What does this treatment do? Has it been used before?
- Will I know which treatment my child will receive?
- What is likely to happen in my child's case with, or without, this new treatment?
- What are the other choices and their pros and cons?
- How could the study affect my child's daily life?
- What side effects can be expected from the study?
- Can the side effects be controlled?
- Will my child have to stay in the hospital? If so, how often and for how long?
- Will the study cost me anything? Will any of the treatment be free?
- If my child is harmed as a result of the research, what treatment would I be entitled to?
- What type of long-term follow-up care is part of the study?
- Has the treatment been used to treat other types of cancers?
-

How can I find out more about clinical trials that might be right for us?
The American Cancer Society offers a clinical trials matching service for patients, their family, and friends. You can reach this service at 1-800-303-5691 or on our Web site at http://clinicaltrials.cancer.org.

Based on the information you give about your child's cancer type, stage, and previous treatments, this service can put together a list of clinical trials that match your child's medical needs. The service will also ask where you live and whether you are willing to travel so that it can look for a treatment center that you can get to.

You can also get a list of current clinical trials by calling the National Cancer Institute's Cancer Information Service toll free at 1-800-4-CANCER (1-800-422-6237) or by visiting the NCI clinical trials Web site at www.cancer.gov/clinicaltrials.

For even more information on clinical trials, the American Cancer Society has a document called *Clinical Trials: What You Need to Know.* You can read this on the Web site, www.cancer.org, or have it sent to you by calling 1-800-ACS-2345.

Complementary and alternative therapies

When your child has cancer you are likely to hear about ways to treat his or her cancer or relieve symptoms that are different from mainstream (standard) medical treatment. These methods can include vitamins, herbs, and special diets, or methods such as acupuncture or massage—among many others. You may have a lot of questions about these treatments. Here are some you may have thought of already:

- How do I know if a non-standard treatment is safe?
- How do I know if it works?
- Should we try one or more of these treatments?
- What does my doctor know/think about these methods? Should I tell the doctor that I'm thinking about trying them?
- Will these treatments cause a problem with my child's standard medical treatment?
- What is the difference between "complementary" and "alternative" methods?
- Where can I find out more about these treatments?

The terms can be confusing

Not everyone uses these terms the same way, so it can be confusing. The American Cancer Society uses *complementary* to refer to medicines or methods that are used *along with* regular medical care. *Alternative* medicine is a treatment used *instead of* standard medical treatment.

Complementary methods: Complementary treatment methods, for the most part, are not presented as cures for cancer. Most often they are used to help you feel better. Some methods that can be used in a complementary way are meditation to reduce stress, acupuncture to relieve pain or peppermint tea to relieve nausea. There are many others. Some of these methods are known to help, while others have not been tested. Some have been proven not be helpful. A few have even been found harmful. However, some of these methods may add to your child's comfort and well-being.

There are many complementary methods that can be safely used right along with medical treatment to help relieve symptoms or side effects, to ease pain, and to help your child enjoy life more. For example, some people find methods such as aromatherapy, massage therapy, meditation, or yoga to be useful.

Alternative treatments: Alternative treatments are those that are used instead of standard medical care. These treatments have not been proven safe and effective in clinical trials. Some of these methods may even be dangerous and some have life-threatening side effects. The biggest danger in most cases is that your child may lose the chance to benefit from standard treatment. Delays or interruptions in standard medical treatment may give the cancer more time to grow.

Deciding what to do

It is easy to see why people with cancer may consider alternative methods. You want to do all you can to fight the cancer. Sometimes mainstream treatments such as chemotherapy can be hard to take, or they may no longer be working.

Sometimes people suggest that their method can cure cancer without having serious side effects, and it's normal to want to believe them. But the truth is that most non-standard methods of treatment have not been tested and proven to be effective for treating cancer.

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

- Talk to your child's doctor or nurse about any method you are thinking about using.
- Check the list of "red flags" below.
- Contact the American Cancer Society at 1-800-ACS-2345 to learn more about complementary and alternative methods in general and to learn more about the specific methods you are thinking about.

Red flags

You can use the questions below to spot treatments or methods to avoid. A "yes" answer to any one of these questions should raise a "red flag."

- Does the treatment promise a cure for all or most cancers?
- Are you told not to use standard medical treatment?
- Is the treatment or drug a "secret" that only certain people can give?
- Does the treatment require you to travel to another country?
- Do the promoters attack the medical or scientific community?

The decision is yours

Decisions about how to treat or manage your child's cancer are always yours to make. If you are thinking about using a complementary or alternative method, be sure to learn about the method and talk to your doctor about it. With reliable information and the support of your health care team, you may be able to safely use the methods that can help your child while avoiding those that could be harmful.

Treatment of specific types of brain and spinal cord tumors

The treatment options for brain and spinal cord tumors depend on several factors, including the type of tumor and how far it has grown or spread.

Non-infiltrating astrocytomas
(juvenile pilocytic astrocytomas, subependymal giant cell astrocytomas)

Many doctors consider these benign tumors. Juvenile pilocytic astrocytomas occur most often in the cerebellum in young children, while subependymal giant cell astrocytomas are almost always associated with tuberous sclerosis.

In most cases, these astrocytomas are cured by surgery alone. Radiation therapy may be given if the tumor is not completely removed, although many doctors will wait until there are signs the tumor is growing back before considering it. Even then, repeat surgery may be the first option. The outlook is not as good if the astrocytoma occurs in a place that does not allow it to be removed surgically, such as the hypothalamus or brain stem.

Low-grade astrocytomas

The main treatment for these tumors is surgery when possible. Because these tumors often grow into (infiltrate) nearby normal brain tissue, they may be hard to cure by surgery. Usually the surgeon will try to remove as much of the tumor as safely possible. If the surgeon can remove it all this may be curative.

Radiation therapy may be given after surgery, especially if large amounts of tumor remain. In other cases, it may be postponed until the tumor shows signs of regrowth. (In some cases, a second surgery may be tried before giving radiation.) Radiation may also be used as the main treatment if surgery is not a good option because of where the tumor is located.

For children younger than age 3, if the tumor cannot be completely removed or grows back, chemotherapy may be used until they are older. They may then be treated with radiation.

High-grade astrocytomas (anaplastic astrocytomas, glioblastomas)

Although surgery is often the first treatment, these infiltrating astrocytomas are not curable by surgery. After as much of the tumor as possible is removed, radiation therapy is given, often followed by chemotherapy. For children younger than age 3, radiation may be postponed until they are older. Surgery may be repeated in some cases if the tumor comes back after initial treatment. Because these tumors are hard to cure with current treatments, clinical trials of promising new treatments may be a good option.

Oligodendrogliomas

If possible, surgery is the first option for these infiltrating tumors. While they are usually not curable by surgery, it can relieve symptoms and prolong survival. Many of these tumors grow slowly, and surgery may be repeated in many cases if it grows back in the same spot. Chemotherapy and/or radiation therapy may be given after surgery.

For tumors for which surgery is not an option, chemotherapy, with or without radiation therapy, may be helpful. These tumors may respond to chemotherapy better than other brain tumors if certain chromosome changes are present in the tumor cells. You can ask your doctor about testing for these changes.

Ependymomas and anaplastic ependymomas

These tumors do not infiltrate normal brain tissue as extensively as astrocytomas and may sometimes be cured by surgery if the entire tumor can be removed. If some tumor is left behind, a second operation may be done in some cases (often after a short course of chemotherapy). Radiation therapy is usually recommended after surgery to prevent regrowth in most patients, even if it appears that all of the tumor has been removed.

The use of chemotherapy after surgery is still being tested in clinical trials. It may be recommended, although its benefit is still uncertain. It may be more helpful if the tumor is an anaplastic ependymoma. In very young children, chemotherapy may be given to avoid or delay the use of radiation.

Sometimes the tumor cells can spread into the cerebrospinal fluid (CSF). The doctor may test the CSF for cancer cells by performing a lumbar puncture (spinal tap). If there are cancer cells in the CSF, radiation may be extended to include the entire spinal cord.

Optic gliomas

These tumors are often hard to operate on because they are in a place that is hard to reach. They invade the nerves leading to the eye. Depending on their location, removing them may lead to loss of vision in one or both eyes. Because of this, surgery has to be considered carefully. In some cases it may not be needed, as these tumors sometimes grow very slowly.

If the surgeon feels treatment is needed and the tumor can be completely removed without the loss of vision or other serious problems, surgery is preferred. If not curable with surgery, radiation therapy to this area is the preferred treatment even though it can also affect a child's vision. Often, chemotherapy may be given to younger children instead of radiation.

Brain stem gliomas

Most of these tumors are astrocytomas, although a small number are ependymomas or other tumors. These tumors usually have a characteristic appearance on MRI, so the diagnosis can often be made without surgery or a biopsy.

A small number of brain stem gliomas occur as a small tumor with very distinct edges (called a focal brain stem glioma). These tumors can often be treated successfully with surgery. In cases where surgery can't be done, radiation therapy may be effective.

Most brain stem gliomas grow throughout the brain stem, which is vital to life and can't be removed. Surgery in these cases would most likely do more harm than good, so it is usually not attempted. These brain stem gliomas are usually treated with radiation therapy.

Chemotherapy is sometimes added, although it's not clear how helpful it might be. These tumors are very hard to control, and they tend to have a poor prognosis. Certain children, namely those with low-grade astrocytomas and those with neurofibromatosis type I, may have a better outlook.

Primitive neuroectodermal tumors (including medulloblastoma and pineoblastoma)

Primitive neuroectodermal tumors (PNETs) are treated in similar ways, although medulloblastomas tend to have a better outlook than other types of PNETs.

Medulloblastomas: These tumors tend to grow quickly and are among those most likely to spread outside of the brain (usually to the bone or bone marrow). But they also tend to respond well to treatment. Medulloblastomas are treated with surgery followed by radiation therapy to the area where they started. Higher doses of radiation are aimed at the tumor. Because these tumors tend to spread to the cerebrospinal fluid (CSF), lower doses of radiation may be given to the whole brain and the spinal cord (craniospinal radiation) as well.

Chemotherapy is usually given after radiation therapy, and may allow doctors to use lower doses of radiation in some cases. If advanced spread of the tumor is present, standard doses of radiation will be needed.

Pineoblastomas and other PNETs: These tumors also tend to grow quickly, and they are generally harder to treat than medulloblastomas. Although surgery is the main treatment for these tumors, they are usually hard to remove completely. Still, surgery can relieve symptoms and allow other treatments to be more effective. Because these tumors tend to spread to cerebrospinal fluid (CSF), radiation therapy is often given to the whole brain and the spinal cord (craniospinal radiation).

Chemotherapy may be used with radiation therapy so that a lower dose of radiation can be used. If advanced spread of the tumor is present, standard doses of radiation will be required. Chemotherapy is also used to treat tumor recurrence or in children younger than 3 years of age instead of radiation therapy after surgery. Some studies have achieved very good results using chemotherapy in young children.

There are some reports that giving high-dose chemotherapy followed by an autologous stem cell transplant is effective treatment for children with medulloblastomas or other PNETs. Several clinical trials are now studying this. For more information on stem cell transplants, see the separate American Cancer Society document, *Bone Marrow and Peripheral Blood Stem Cell Transplants*.

Meningiomas

Children with these tumors are usually considered cured if the tumor is completely removed surgically. Some tumors, particularly those at the base of the brain, cannot be completely removed, and some are malignant and come back despite apparent complete removal. Radiation therapy may control regrowth of meningiomas that cannot be completely removed or those that come back after surgery. Chemotherapy or hormonal drugs may be tried if surgery and radiation aren't effective, although it is not clear if they offer any benefit.

Schwannomas (including acoustic neuromas)

These slow growing tumors are usually benign and are effectively cured by surgical removal. In some centers, small vestibular schwannomas (also known as acoustic neuromas) are treated by stereotactic radiosurgery (see the previous section on Radiotherapy). For the rare malignant schwannoma, radiation therapy is often given after surgery.

Spinal cord tumors

These tumors are usually treated similarly to those of the same type in the brain. Astrocytomas of the spinal cord usually cannot be completely removed. They may be treated with surgery to remove as much tumor as possible, followed by radiation therapy, or with radiation therapy alone. Chemotherapy may be used in younger children or if the tumor appears to be aggressive.

Meningiomas of the spinal cord are often cured by surgical removal, as are some ependymomas. If an ependymoma cannot be completely removed, radiation therapy will follow surgery.

Choroid plexus tumors

Benign choroid plexus papillomas are usually cured by surgery alone. Choroid plexus carcinomas are malignant tumors that are only sometimes cured by surgery. After surgery, these carcinomas are usually treated with radiation and/or chemotherapy.

Craniopharyngiomas

Craniopharyngiomas can be treated by surgically removing most of the tumor (debulking) followed by radiation in most cases. A conservative surgical approach with partial removal followed by very focused radiation therapy may cause fewer severe side effects than complete removal.

Germ cell tumors

The most common germ cell tumor, germinoma, is usually cured by radiation therapy alone. In very young children, chemotherapy may be used instead of radiation therapy. If other types of germ cell tumors are present, either mixed or not mixed with germinoma, the outlook is usually not as good. Other types of germ cell tumors are usually treated with both radiation therapy and chemotherapy. Sometimes these tumors spread to the spinal fluid, and radiation therapy to the spine and brain is needed.

Survival rates for selected brain and spinal cord tumors

The numbers below come from the Central Brain Tumor Registry of the United States (CBTRUS) and are based on children aged 19 or younger who were treated between 1973 and 2002. There are some important points to note about these numbers:

- The *5-year survival rate* refers to the percentage of patients who live *at least 5 years* after being diagnosed. Many of these patients live much longer than 5 years after diagnosis.

- Although these numbers are among the most current we have available, they represent children who were first diagnosed and treated many years ago. Improvements in treatment since then mean that the survival rates for children now being diagnosed with these cancers may be higher.

- These numbers are for some of the more common types of tumors. Numbers are not readily available for all types of tumors that occur in children, often because they are rare or are hard to classify.

- In some cases, the numbers include a wide range of different types of tumors that may have different outlooks. For example, the numbers for PNETs include medulloblastomas, which tend to have a better outlook than pineoblastomas or PNETs in other parts of the brain.

- Survival statistics can sometimes be useful as a general guide, but they may not accurately represent any one person's prognosis. A number of other factors, including the size and location of the tumor, a child's age, and the amount of tumor that can be removed by surgery, can also affect outlook. Your child's doctor is likely to be a good source as to how well these numbers may apply, as he or she is familiar with the aspects of your child's particular situation.

Type of Tumor	5-Year Survival Rate
Juvenile pilocytic astrocytoma/subependymal giant cell astrocytoma	about 95%
Low-grade astrocytoma	about 80%
Anaplastic astrocytoma	about 50%
Glioblastoma	about 20%
Oligodendroglioma	about 85%
Ependymoma/anaplastic ependymoma	about 55%
PNETs (includes medulloblastoma and pineoblastoma)	about 55%

More treatment information

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

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

What should you ask your doctor about your child's brain or spinal cord tumor?

It is important for you to have frank, open discussions with your child's cancer care team. They want to answer all of your questions, no matter how minor you might think they are. Here are some questions to consider:

- What kind of tumor does my child have?
- Where is the tumor located, and how far has it spread?
- What treatment options are appropriate for my child? What do you recommend? Why?
- What are the risks or side effects that we should expect?
- What disabilities may develop?

- What is the expected prognosis (outlook), based on my child's cancer as you view it?
- What are the chances the tumor will recur (come back) even with the treatment programs we have discussed? What would we do if that happens?
- What should I do to help my child be ready for treatment?

Along with these sample questions, be sure to write down any others you might want to ask. For instance, you might want specific information about recovery times so you can plan your work and your child's school and activity schedule. Or you may want to ask about second opinions concerning the diagnosis and treatment options, as well as about clinical trials for which your child may qualify.

What happens after treatment for brain and spinal cord tumors in children?

After treatment for brain or spinal cord tumors, the main concerns for most families are the immediate and long-term effects of the tumor and its treatment, and concerns about the tumor still being present or coming back.

It is certainly normal to want to put the tumor and its treatment behind you, and to get back to a 'normal' life. But it's important to realize that follow-up care is a central part of this process that offers your child the best chance for recovery and long-term survival.

Looking for tumor progression or recurrence

In some cases, even with slow growing tumors, some of the tumor may still be present after treatment. Even with childhood tumors that are treated successfully, it is important to remember that some may come back even many years later. (Your child's doctor should be able to give you an idea of how likely this might be in his or her case.)

Imaging tests (CT or MRI scans) and physical exams will probably be done after treatment to help determine how successful it was. Whether there is evidence of the tumor still being present or not, your child's cancer care team will probably want to follow up closely with you, especially in the first few months and years after treatment to make sure there is no progression or recurrence. Depending on the type and location of the tumor and the extent of the treatment, the team will decide which tests should be done and how often.

During this time, it is important that any new symptoms be reported to your child's doctor right away, so that the cause can be determined and treated, if need be. Your child's doctor can give you an idea of what to look for. Should further treatment be needed at some point, the doctor will go over potential treatment options with you.

Recovering from the effects of the tumor and its treatment

The possible effects of the tumor and its treatment on physical and mental function can range from very mild to fairly severe. Fortunately, a child's brain is often better able to compensate than an adult's.

Once your child has recovered from treatment, doctors will try to determine the extent of any damage to the brain or other areas. In a very young child this may take time. It is likely that physical exams and imaging tests (CT or MRI scans) will be done after treatment to determine the extent and location of any changes that have occurred in the brain.

Several types of doctors and other health professionals may be involved in assessing any damage and helping your child recover.

A neurologist (a doctor who specializes in treating the nervous system) will assess your child's function in areas such as physical coordination and muscle strength. If there is muscle weakness or paralysis, your child will be seen by physical and/or occupational therapists and perhaps a physiatrist (a doctor who specializes in rehabilitation) while in the hospital and/or as an outpatient for physical therapy.

If the speech center of the brain is damaged, a speech therapist will help your child to improve communication skills.

If needed, an ophthalmologist (a doctor who specializes in eye problems) will check your child's vision and an audiologist can check your child's hearing. If problems with vision or hearing are found, your child may require forms of special education.

After surgery, your child may also be seen by a psychiatrist or psychologist to determine the extent of damage caused by the tumor and surgery. If your child gets radiation therapy and/or chemotherapy, this process may be repeated again after treatment is finished. The doctor will give tests to document your child's development in areas such as general intelligence, speech and hearing, memory, and learning skills.

If your child is in school, a teacher working with the hospital (called the school liaison) may become involved. Before going (back) to school, the liaison may help pave the way for your child by talking with the teachers, explaining your child's problems, and discussing any special education techniques that may be required. In some cases, medicines may be helpful

as well. (For more information, see the separate American Cancer Society document, *Children Diagnosed With Cancer: Returning to School*.)

If the tumor involved the base of the brain (such as a craniopharyngioma) or radiation therapy was given to this area, pituitary hormone production may be affected. Symptoms of pituitary problems can include fatigue, listlessness, poor appetite, cold intolerance, and constipation, which may point to low levels of cortisol and/or thyroid hormone. Other problems can include delayed growth and/or sexual maturation. Sometimes these symptoms may appear even before treatment.

If there is reason to think the pituitary may have been affected, your child may be seen by an endocrinologist (a specialist in hormone disorders). Based on the endocrinologist's evaluation, hormone treatments may be prescribed to restore normal hormone levels. For example, growth hormone can be given to restore normal growth.

Long-term effects

A major concern of both parents and doctors is the potential for long-term effects from treatment. Some of these, such as learning problems or delayed growth and development, were mentioned above. Others may include effects on the reproductive system or an increased risk of other cancers later in life. While doctors do everything they can to minimize the chance of these complications occurring, in some cases they may be an unavoidable part of ensuring the tumor is treated properly.

It is very important to discuss possible long-term complications with your child's health care team, and to make sure there is a plan in place to watch for these problems and treat them, if need be. For more information, see the separate American Cancer Society document, *Childhood Cancer: Late Effects of Cancer Treatment*.

Keeping good medical records

As much as you might want to put the experience behind you once treatment is completed, it is also very important to keep good records of your child's medical care during this time. This should include copies of any pathology or surgery reports (which should include an exact diagnosis), as well as records of any chemotherapy, radiation therapy, or other treatments your child receives. This can be very helpful for your child and his or her doctors later on as an adult.

What's new in research and treatment for brain tumors in children?

There is always research going on in the area of brain tumors. Scientists are looking for causes and ways to prevent brain tumors, and doctors are working to improve treatments.

Imaging and surgery techniques

Recent advances have made surgery for brain tumors much safer and more successful. Such techniques include:

- functional magnetic resonance imaging (fMRI), which can identify the site of important areas of the brain and how close they are to the tumor
- cortical mapping, which helps identify important areas of the brain during the course of surgery
- image-guided surgery, which allows for safer and more extensive resection
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Radiotherapy

Several newer types of radiation therapy now allow doctors to deliver radiation more precisely to the tumor, which helps spare normal brain tissue from getting too much radiation. Newer techniques such as stereotactic radiosurgery, 3-dimensional conformal radiation therapy (3D-CRT), intensity modulated radiation therapy (IMRT), and proton beam therapy are described in the section "How Are Brain and Spinal Cord Tumors in Children Treated?"

The brain is very sensitive to radiation, which can lead to side effects if normal brain tissue receives a large dose, especially in young children. Clinical trials have shown that in some situations, using chemotherapy can allow doctors to use lower doses of radiation therapy without lowering the chance that treatment will be effective. Doctors are now trying to determine if even lower doses of radiation can be used yet still yield the same results.

Chemotherapy

New approaches may help make chemotherapy more effective.

Adjuvant chemotherapy

In some children and infants with brain tumors, chemotherapy is given right after surgery to either delay radiation therapy (particularly in infants) or to decrease the radiation dose needed to treat the tumor. Some studies are looking at whether giving prolonged chemotherapy may even help avoid the need for radiation therapy in certain cases.

High-dose chemotherapy and stem cell transplant

One of the main factors that limits the doses of chemotherapy that can be given safely is its effects on the bone marrow, where new blood cells are normally made. A stem cell transplant allows higher doses of chemotherapy to be given than would normally be possible. First, blood stem cells are removed from either the blood or the bone marrow. The child is then treated with very high doses of chemotherapy. The blood stem cells are then infused back into the body, where they settle in the bone marrow and start making new blood cells.

Although some children have had very good responses to this very toxic treatment, it has not yet been shown to be effective enough to become standard. For now, most doctors consider this treatment experimental. Several clinical trials are under way to determine how effective it is.

Combining chemotherapy with other drugs

Many chemotherapy drugs are limited in their effectiveness because the "blood-brain barrier" prevents them from getting from the bloodstream to the brain. Studies are now looking at combining drugs that open the blood-brain barrier with chemotherapy drugs to see if this might make them more effective.

Getting chemotherapy directly to tumors

Some new approaches may allow doctors to get chemotherapy directly to tumors.

In adults, doctors sometimes place special wafers containing chemotherapy directly at the site of a brain tumor during surgery. The wafers give off doses of chemotherapy over several weeks, keeping a high concentration of the drug at that spot while sparing the rest of the body from the possible side effects. Studies are now under way to see if this will work in children as well.

In another method of getting chemotherapy to the tumor, tiny tubes are placed into the tumor during surgery to allow delivery of drugs right to the tumor later on, avoiding problems with the blood-brain barrier and side effects in the rest of the body. This is also being studied.

Other new treatment strategies

Researchers are also testing some newer approaches to treatment that may help doctors target tumors more precisely. In theory this should allow for more effective treatments that cause fewer side effects. These treatments are all being studied now.

Growth factor inhibitors

Tumor cells are often very sensitive to proteins called growth factors, which cause them to grow and divide. Newer drugs target these growth factors, which may slow the growth or tumor cells or even cause them to die. Several of these targeted drugs are already being used to treat other types of cancer, and are being studied to see if they will work for brain tumors as well.

Angiogenesis inhibitors

Tumors have to create new blood vessels (a process called angiogenesis) to keep their cells nourished. New drugs that attack these blood vessels are used to help treat some cancers. Some of these are now being tested in early clinical trials against brain tumors.

Hypoxic cell sensitizers

Some drugs make tumor cells more likely to be killed by radiation therapy if they are given before treatment. Studies are looking to see if this affects the outcome of treatment.

Immunotherapy

The goal of immunotherapy is to make the body's immune system fight the brain tumor more effectively. Vaccines against brain cancer cells are being tested in clinical trials. Monoclonal

antibodies (manmade versions of immune system proteins) and immune modulators such as interferon are also being studied.

Therapeutic viruses

Researchers have begun to work with viruses that selectively reproduce within brain tumor cells and then cause tumor cell death, leaving normal cells alone. Research in this area is still in the earliest stages.

Although the strategies mentioned above are promising, they are mainly in the experimental stage at this time, and are generally only available through clinical trials.

Additional resources

More information from your American Cancer Society

The following related information may also be helpful to you. These materials may be ordered from our toll-free number, 1-800-ACS-2345 (1-800-227-2345).

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

Because Someone I Love Has Cancer

Childhood Cancer: Late Effects of Cancer Treatment

Children Diagnosed With Cancer: Dealing With Diagnosis (also available in Spanish)

Children Diagnosed With Cancer: Financial and Insurance Issues

Children Diagnosed With Cancer: Returning to School

Children Diagnosed With Cancer: Understanding the Health Care System (also available in Spanish)

Closing the Umbrella

Surgery

Understanding Chemotherapy: A Guide for Patients and Families

Understanding Radiation Therapy: A Guide for Patients and Families

What Happened To You, Happened To Me

When Your Brother or Sister Has Cancer

The following books are available from the American Cancer Society. Call us at 1-800-ACS-2345 to ask about costs or to place your order.

Informed Decisions: The Complete Book of Cancer Diagnosis, Treatment, and Recovery. Second Edition, by Harmon J. Eyre, Dianne P. Lange, and Lois B. Morris. Published by the American Cancer Society, 2002.

Angels and Monsters: A Child's Eye View of Cancer, by Jeff Foxworthy, Lisa Murray, and Billy Howard. Published by the American Cancer Society, 2002.

National organizations and Web sites*

In addition to the American Cancer Society, others sources of patient information and support include:

American Brain Tumor Association
Toll-free number: 1-800-886-2282
Web site: www.abta.org

Children's Brain Tumor Foundation
Toll-free number: 1-866-228-HOPE (1-866-228-4673)
Web site: www.cbtf.org

Candlelighters Childhood Cancer Foundation
Toll-free number: 1-800-366-2223
Web site: www.candlelighters.org

CureSearch (National Childhood Cancer Foundation and Children's Oncology Group)
Toll-free number: 1-800-458-6223
Web site: www.curesearch.org

National Cancer Institute
Toll-free number: 1-800-4-CANCER (1-800-422-6237)
Web site: www.cancer.gov

Pediatric Brain Tumor Foundation of the United States
Toll-free number: 1-800-253-6530
Web site: www.pbtfus.org

Starlight Starbright Children's Foundation
Toll-free number: 1-800-315-2580
Web site: www.starlight.org

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

Other publications*

For Adults

Cancer & Self-Help: Bridging the Troubled Waters of Childhood Illness, by Mark A. Chester, and Barbara K. Chesney. Published by University of Wisconsin Press, 1995.

Childhood Brain and Spinal Cord Tumors: A Guide for Families, Friends, and Caregivers, by Tania Shiminski-Maher, Patsy McGuire Cullen, and Maria Sansalone. Published by O'Reilly and Associates, 2001.

Childhood Cancer: A Parent's Guide to Solid Tumor Cancers, by Honna Janes-Hodder and Nancy Keene. Published by O'Reilly and Associates, 1999.

Childhood Cancer: A Handbook from St Jude Children's Research Hospital, by Grant Steen and Joseph Mirro (editors). Published by Perseus Publishing, 2000.

Childhood Cancer Survivors: A Practical Guide to Your Future, by Nancy Keene, Wendy Hobbie, and Kathy Ruccione. Published by O'Reilly and Associates, 2000.

Children with Cancer: A Comprehensive Reference Guide for Parents, by Jeanne Munn Bracken. Published by Oxford University Press, 2001.

Living with Childhood Cancer: A Practical Guide to Help Families Cope, by Leigh A. Woznick and Carol D. Goodheart. Published by American Psychological Association, 2002.

Surviving Childhood Cancer: A Guide for Families, by Margot Joan Fromer. Published by New Harbinger Publications, 1998.

When Bad Things Happen to Good People, by Harold Kushner. Published by G.K. Hall, 1982.

Your Child in the Hospital: A Practical Guide for Parents. Second Edition, by Nancy Keene. Published by O'Reilly & Associates. 1999. (Also available in Spanish)

For Young People

Chemo, Craziness and Comfort, My Book about Childhood Cancer. Candlelighters Childhood Cancer Foundation. Available at: www.candlelighters.org.

My Book for Kids with Cansur [sic], by Jason Gaes. Published by Viking Penguin, 1998.

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

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

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