Intracranial Pressure Monitoring

ICP

A Guide for Family and Friends

Contributing Editors:

Karen Poor, R.N., M.N.
Judith Kanschatt, R.N., B.S.N., M.S.
Michael Pollay, M.D.

Table of Contents

Introduction 4

The Skull and Brain:
Structures and Functions 7

Brain Injury 13

Diagnostic Tests 17

Intracranial Monitoring 21

What You Can Do 27

Glossary 29

Introduction

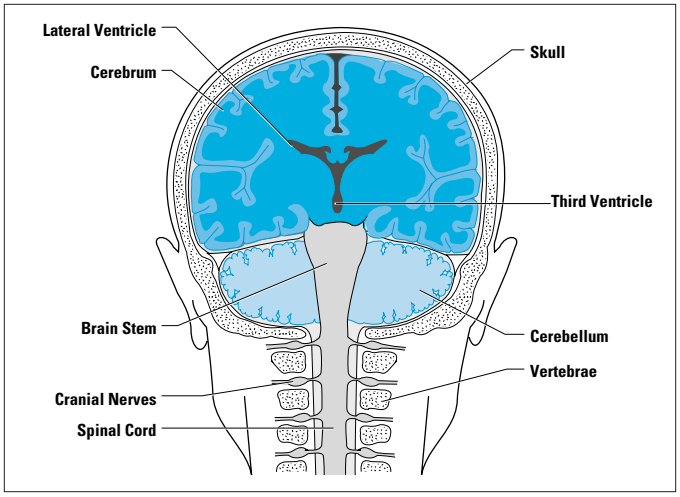
A change in an individual's normal state of health—as a result of an injury to the head or brain—is frightening for the individual's family and friends. The nature of the injury and the unknown outcome creates uncertainty for the future of the patient and hence his/her family. It is important for all concerned to be informed about plans for treatment and care as a means of alleviating some of the anxiety associated with uncertainty.

The following pages will provide you with explanations and methods of treatment for patients who have experienced an injury to the head and/or brain. Patients who have had this kind of injury can develop changes in intracranial pressure. Intracranial pressure is described as pressure within the skull and the protective covering of the brain. This pressure is influenced by events affecting brain tissue, cerebrospinal fluid and the blood flow within the brain. To assist with the management of increased intracranial pressure of patients who have suffered a head/brain injury, monitoring of this pressure might be ordered by the physician.

To better support your understanding of intracranial pressure and methods of managing it, the following sections will define:

- The structure and function of the skull and the brain
- Brain injury and corresponding diagnostic tests
- Methods of managing increased intracranial pressure

We hope you find this information helpful in the days ahead.



Uppermost view of the head.

The Skull and Brain

Structures and Functions

The Skull

The skull is the bony casing that houses and protects the brain from injury, such as everyday bumps and bruises. The roof of the skull is formed from four thin, curved bones that are firmly fixed together in childhood.

The Brain

Understanding the brain and how it functions is the first step to understanding the possible effects of a head/brain injury.

The brain and spinal cord comprise the central nervous system. The adult brain is one of the largest organs of the body. It is the control center for the body's functions such as breathing, blood pressure, movement, behavior, feelings, memory, speech, and the ability to see, hear, taste, touch and smell.

There are three main sections of the brain: the cerebrum, the brain stem and the cerebellum. The brain itself is protected by what are called the cranial meninges. The following paragraphs describe the functions of these three sections.

The Cerebrum

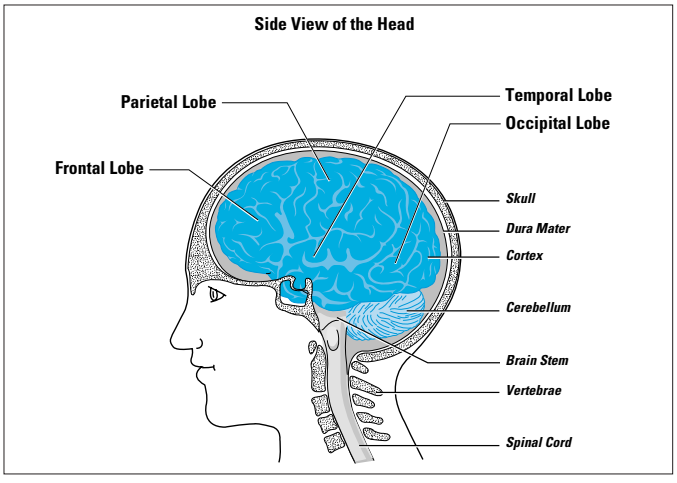
The **cerebrum** is the largest section of the brain. It is divided into two connected sides (hemispheres). The cerebrum is the seat of intelli-

gence, allowing us the ability to interpret sensory impulses, control muscular movement and control complex unifying functions such as memory, emotions, reasoning, will, judgment, personality traits and intelligence.

The left side of the brain controls movement and receives messages from the right side of the body.

The right side of the brain controls movement and receives messages from the left side of the body.

Each person has a dominant hemisphere. The left hemisphere, usually the dominant one, is more logic-oriented. It controls the abilities to read, write and do arithmetic. The right hemi-



Side view of the head showing the lobes of the brain.

sphere influences creativity and spatial perception as well as musical skills.

Each cerebral hemisphere is divided into four lobes. The lobes are named after the bones of the skull that cover them: frontal, parietal, temporal and occipital.

The **frontal lobe** is located in the front of the brain just behind the forehead. It is concerned with higher mental functions such as intellect, memory, judgment and behavior.

The **parietal lobe** sits just behind the frontal lobe. It interprets and integrates spatial relationships and information from sensory areas. It also receives and processes sensations of touch, including pain, heat, cold, pressure, size, shape and texture.

The **temporal lobe** is located alongside the frontal and parietal lobes. It corresponds to the temporal bone of the skull—above the ear and approximately where the temples are located. The temporal lobe is concerned with the reception and interpretation of sounds, smells and taste. The left hemisphere of the temporal lobe receives and interprets sounds as words. Both temporal lobes play an important role in memory.

The **occipital lobe** is located in back of the cerebrum, behind the parietal and temporal lobes. The occipital lobe is the center for sight. It also relates present to past visual experiences, recognizing and evaluating what is seen.

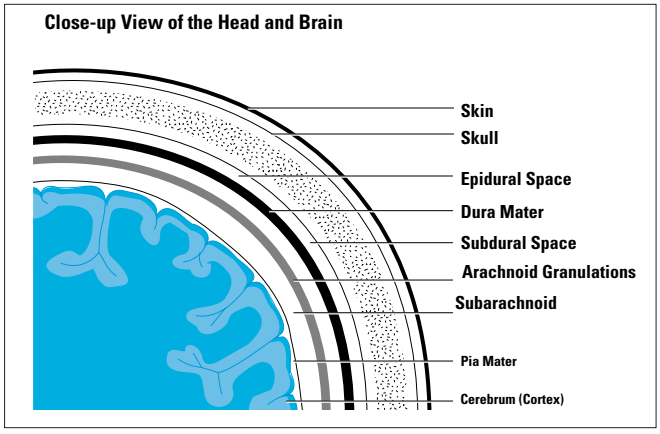
The Brain Stem

The brain stem is located at the base of the cerebrum; it connects the spinal cord to the cerebrum. The brain stem acts as a relay station between the cerebrum and the rest of the body. The brain stem is responsible for regulating several vital body functions such as the rate and force of the heartbeat, blood pressure and the basic rhythm of breathing. The twelve cranial nerves originate in the brain stem and control the basic functions of smell, hearing, vision, eye movement, facial sensations, taste, swallowing, sneezing, coughing and hiccuping, as well as movement of the face, neck, shoulder and tongue muscles.

The Cerebellum

The cerebellum is a much smaller section of the brain than the cerebrum. It assists in the transmission of information between the brain stem and the cerebrum. The cerebellum lies beneath the cerebrum in the back of the skull. Parts of the cerebellum carry signals that ensure precise, voluntary movements and maintain equilibrium

and posture. For instance, the cerebellum transmits and coordinates signals from the cerebrum that control the movement of voluntary muscles, such as those in the arms and legs.

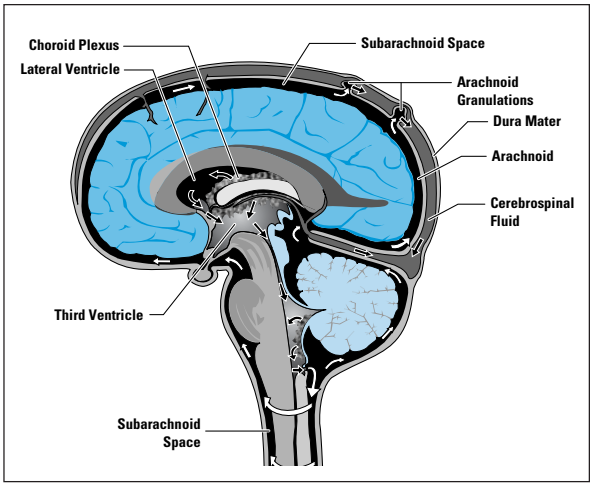


Close-up view of the head and brain.

The Cranial Meninges

Besides the skull, the brain is further protected by the **cranial meninges (*men-ín-jeez*),** membranes covering the brain and spinal cord. There are three cranial meninges which surround the brain and the spinal cord; the outermost is the **dura mater**, or **dura**. It is a tough, leathery membrane which lies underneath the skull and covers the brain. The innermost covering—which comes in direct contact with the brain's surface—is called the **pia mater**. The layer in between the dura and the pia is called the **arachnoid membrane.**

The brain and the spinal cord are surrounded by a cushioning layer of **cerebrospinal fluid** (**CSF**). This fluid is primarily produced and circulated within the **ventricles**—the four hollow chambers or passageways within the brain which serve to transport certain nutrients between blood vessels and the brain.



Side view of the brain showing the ventricles and the flow of cerebrospinal fluid (direction of arrows).

Brain Injury

Injuries to the Brain

Brain injury can result from:

- A blow to the head
- Infections
- Neurosurgery/neurosurgical procedures
- Overdose of/toxic reactions from medications
- Brain Tumor
- Diseases that might affect the nervous system
- Stroke
- Broken blood vessel in the head which can bleed into the brain tissue
- Ruptured artery beneath the skull which can compress brain tissue

Any of the above can cause an increase in cerebrospinal fluid leading to brain cell injury and making intracranial pressure (ICP) monitoring necessary.

Skull Fracture

Skull fractures are usually caused by a blow to the head. There are two main types of skull fractures: *linear* and *depressed.* A linear fracture is comparable to a cracked egg shell, where the shape of the shell remains unchanged and the contents of the shell are undisturbed. It does not usually require surgery, but it should be x-rayed and the patient watched. A depressed skull fracture usually requires surgery to prevent further brain injury, bleeding and infection.

Concussion

A concussion is a transient condition caused by a force exerted against the brain such as a blow to the head or a sudden acceleration or deceleration movement of the head. The blow or the sudden motion puts stress on the nerve fibers of the brain. This will affect the alertness of the patient and can cause a temporary loss of consciousness.

Contusion

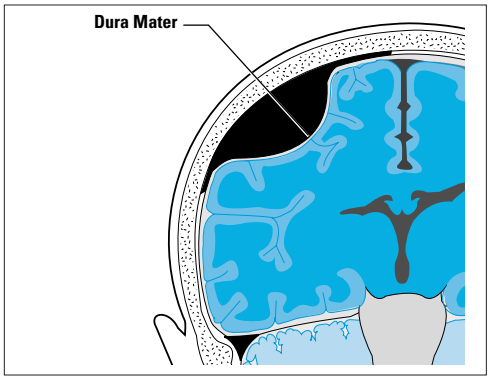
A contusion is a more severe injury than a concussion. A contusion can occur under a skull fracture or from a sudden, violent shifting of the brain to one side of the skull in response to a

blow or impact to the head. It is possible for intracranial pressure to increase since bleeding can occur if the innermost protective layer over the brain is torn as a result of the injury. Blood or fluid would accumulate at the point of injury causing a rise in the intracranial pressure.

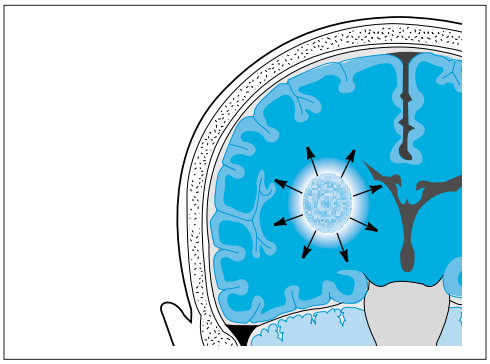
Hematoma

A hematoma is an accumulation of blood. This occurs from a strong blow to the head or tearing of brain tissue (laceration) from penetrating wounds caused by a bullet or sharp instruments or weapons.

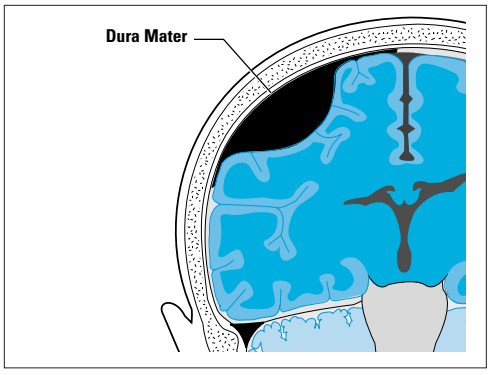
There are three kinds of hematomas: Epidural, subdural and cerebral.



An epidural hematoma is most frequently found when the skull is fractured in the temporal area. What damages the brain is not the blow itself, but pressure from the bleeding on the brain tissues.



An intracerebral hematoma is when bleeding occurs directly in and around the brain tissue. This tends to occur in the frontal and temporal areas of the brain.



A subdural hematoma is when bleeding occurs between the dura mater and the underlying membranes covering the brain's surface. This can cause direct pressure on the brain.

Diagnostic Tests

Diagnostic Tests

After the patient is stabilized, the physician will order a number of tests to determine the extent and severity of the injury. The most common tests include:

- Skull and neck x-ray
- Computerized tomography (CT) or Computed axial tomography (CAT) Scans
- Electroencephalogram (EEG)
- Cerebral angiography
- Magnetic resonance imaging (MRI) Scan

Skull and Neck X-ray

Skull x-rays are usually one of the first diagnostic tests taken if the injury is serious enough. Skull and neck x-rays are the quickest and most efficient ways of determining whether the skull or neck bones have been fractured and the extent of those fractures.

CT or CAT Scan

CT (**computerized tomography**) or **CAT** (**computerized axial tomography**) scans have become a common test within the last decade. CT scanning is a painless procedure which uses a special x-ray technique and a computer. The computer analyzes several x-rays which have been taken in a semi-circle around the patient's head with the patient lying very still.

Thin planes or sections of images of the brain are examined for signs of hemorrhage, fluid collection or tumor.

EEG

The **electroencephalograph** is a machine that records the electrical activity of the brain by means of electrodes attached to the patient's scalp; the electrodes are connected by wires to the electroencephalograph. The machine picks up the impulses of the brain and records them on paper, creating an electroencephalogram (EEG).

The test can take anywhere from a half-hour to three or four hours, depending on the patient's injury or condition. It is a painless test which can be done in the patient's room.

Cerebral Angiography

Cerebral angiography is a study of the blood vessels in the brain.

In cerebral angiography a catheter is inserted into an artery in the leg called the femoral artery. The tube is threaded up through the femoral artery into the aorta, the main artery carrying blood from the heart. Dye injected into the catheter enters the aorta. The aorta sends the dye with the blood to the brain. Areas where the dye cannot be seen are deprived of blood. Narrow areas in the artery indicate a decreased blood supply. Wider parts of arteries may signal an aneurysm (an aneurysm is an abnormal blood-filled swelling of a blood vessel caused by weakness or disease of the vessel wall.)

MRI

An **MRI (magnetic resonance imaging)** scan is another, more advanced form of a CAT scan. The technique uses a magnetic field instead of an x-ray machine. The magnetic field pictures are sent to the computer where they are transformed into a three-dimensional picture of the brain.

MRIs can pick up slight changes that may not be noticeable on an x-ray or CT scan. This is especially important in minor brain injuries.

Photo of a patient entering an MRI (magnetic resonance imaging) machine.

Intracranial Monitoring

Intracranial Pressure

The brain, blood supply to the brain and the cerebrospinal fluid that cushions the brain are the components inside the skull. There is a pressure/volume correspondence amongst these components which determines intracranial pressure. An increase in the volume of any one of these three components would normally cause a decrease in volume of the remaining components. If the volume does not automatically decrease, the result is an increase in intracranial pressure. The increased pressure is due to the buildup of blood or cerebrospinal fluid in or around the brain, in response to a brain injury. These fluids rush to the area that was injured. The pressure from these fluids on the blood vessels of the brain and on the brain itself create an increase in intracranial pressure.

Increased intracranial pressure will cause symptoms varying in severity from a decreased level of alertness to confusion and lethargy, headache, changes in blood pressure, heart rate, breathing patterns and changes in pupillary reaction to light. These symptoms are caused by the decrease in blood flow by compression of the blood vessels in the brain; this in turn lowers the amount of oxygen delivered to the brain. The healthcare team will be on the alert for early signs of increasing intracranial pressure for patients who are at risk for this condition as prompt assessment and intervention can promote a more promising recovery.

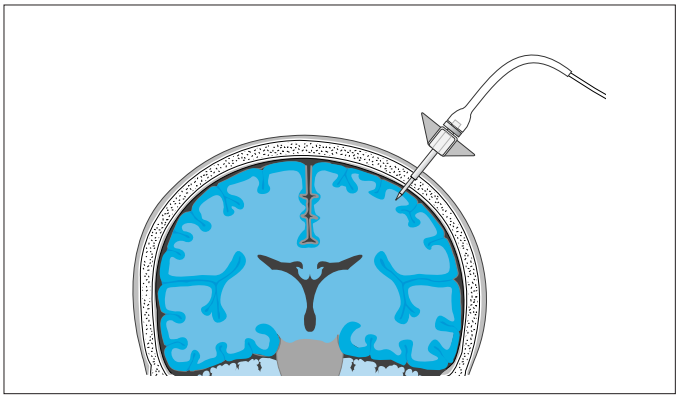


Illustration showing the insertion of an ICP monitoring device.

Intracranial Pressure Monitoring

Patients who might require intracranial pressure monitoring are those who have experienced intracranial injuries or diseases of the brain which have caused intracranial pressure to rise above normal. Intracranial pressure monitoring allows the healthcare team to accurately observe and measure changes in the intracranial pressure of a patient. Knowing the ICP of a patient gives the team valuable information to make a more thorough assessment of a patient's neurological status. Advances in technology and a wide variety of ICP monitoring systems have made ICP monitoring relatively commonplace.

Inserting an ICP Monitoring Device

Before the procedure begins, medication may be given to help the patient relax. First, the head is shaved around the insertion site. The site is then scrubbed with an antibacterial solution and a local anesthetic is applied to numb the area.

The ICP monitoring device is implanted by the doctor. This involves drilling a small hole into the skull and inserting the monitoring device into the subarachnoid space (see illustration on page 12), the ventricles or into the brain itself. The device is then connected to a monitor that shows a picture of the pressure waveforms on the monitor screen. These pressure waveforms indicate changes in intracranial pressure. Careful observation of the pressure waveforms allows the healthcare team to immediately treat changes in pressure.

The insertion procedure is not painful to the patient, as the brain and skull have no pain receptors.

Treating Increased Intracranial Pressure

Ventricular Drainage

Sometimes a doctor will want to reduce the intracranial pressure. This involves drilling a small hole in the skull and inserting a catheter into the ventricles. Placing a catheter into the ventricles is called a **ventriculostomy**. The catheter is then connected to a drainage collection system at the bedside. Increased intracranial pressure is relieved by draining excess fluid from the ventricles into the collection system.

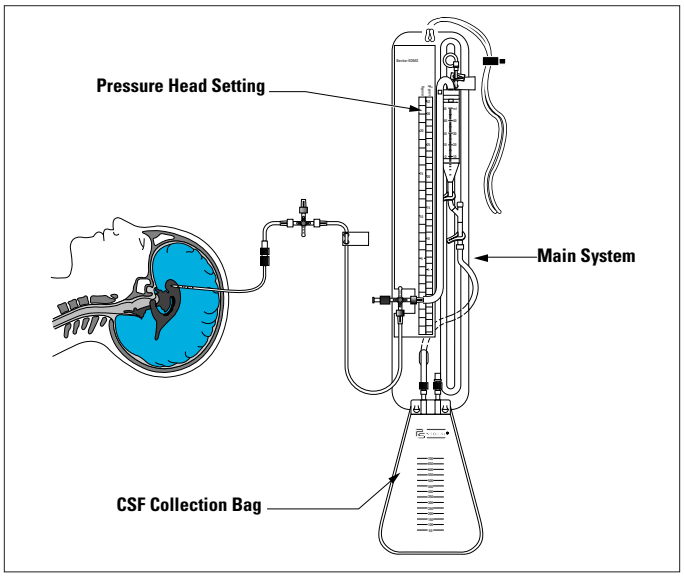


Illustration of an external drainage and monitoring system used to monitor and collect excess cerebrospinal fluid.

During the time that the ventricular drain is in place, a nurse will observe the patient closely to prevent any further brain injury. The nurse will measure the amount of fluid coming through the ventricular drain into the collection bag. The nurse will report any changes in the patient's condition or in the amount or quality of the fluid being drained. The nurse may also administer other treatments intended to decrease the patient's intracranial pressure.

As the patient's condition improves, the patient may feel an itching sensation, usually from the stitches keeping the drain in place or from the tape holding the dressing down.

Risks of Intracranial Monitoring and Ventricular Drainage

There are risks to ICP monitoring as for any invasive technique. Infection, hemorrhage, increase in brain swelling, overdrainage and collapse of the ventricles and occlusion of the catheter or monitoring device are possible complications. The use of antibiotics, diverting the catheter away from the original incision area and the use of sterile techniques help to reduce the rate of infection.

Neurosurgeons might limit the duration of an indwelling placement to avoid infection. However, in life-threatening situations, where the potential benefits outweigh the risks, intracranial pressure monitoring should be done.

What You Can Do

The brain works continuously, but stimulation of any kind causes the brain to work harder. As the brain works harder, the intracranial pressure will rise. Keeping the patient's intracranial pressure within normal limits after an intracranial injury is the goal of the healthcare team. Symptoms that will alert the healthcare team will vary depending upon how high the pressure is and what part of the brain is being affected.

Diagnostic testing, intracranial pressure monitoring and the use of a ventriculostomy drainage device which you have read about in this pamphlet are significant tools in the management of intracranial pressure of the patient with an intracranial injury.

As a family member or friend, you can contribute to the well-being of the patient during their recovery period in the following ways:

- Keep the patient's room dark and quiet.
- Discuss visiting limitations with the healthcare team prior to entering the patient's room and follow their instructions as they are acting in the patient's best interest.
- Speak softly and limit conversations with and around the patient. Keep discussions light and pleasant.

- Ask the healthcare team for assistance if the patient needs something. The team will safely provide comfort measures such as turning and positioning the patient, temperature control and toileting.
- Let the healthcare team know if the patient is hungry or thirsty. The team will provide for nutritional needs of the patient; this is another safety measure in caring for the patient.

The most important contribution you can make to the patient's recovery is to be there.

Glossary

Anesthesiologist A physician with specialized training in administering anesthesia before surgery or other procedures. The anesthesiologist will usually meet with patients and family members before surgery.

Aneurysm An aneurysm is an abnormal, blood-filled swelling of an artery or vein caused by a weakness or disease of the vessel wall.

Anosmia Loss or impairment of the sense of smell; also known as "smell blindness."

Anoxia (*see also, Hypoxia*) Anoxia is from the Greek, meaning "lack of oxygen." Damage occurs when the body's circulation is interrupted, since blood carries oxygen throughout the body. Lack of oxygen can damage the brain as well as vital organs. The body's oxygen supply can be cut off by a traumatic injury which causes a great loss of blood, drowning, heart attack, stroke or serious infections.

Arachnoid Granulations Arachnoid granulations arise from the pia mater and the arachnoid membrane and serve to transfer cerebrospinal fluid from the subarachnoid space to the venous system.

Arachnoid Membrane The arachnoid membrane is a delicate fibrous membrane which forms the middle of the three coverings of the bran, the other two being the pia mater and the dura mater.

Barbiturate Coma In selected cases, a coma is induced by the administrering of barbiturates (drugs which depress the nervous system) to decrease the space taken up by blood volume in the brain, which decreases the energy requirements of the brain, thus decreasing ICP.

Brain Tumor A group of abnormal cells growing inside the brain. The cells may be benign (noncancerous) or malignant (cancerous). The cell group enlarges and presses against normal brain cells, causing symptoms ranging from headache to coma.

Brain Scan An imaging technique in which a radioactive liquid is injected into the bloodstream so that pictures of the brain can reveal tumors, blood clots, hemorrhages or abnormal anatomy.

Catheter A flexible tube, made of silicone or polyurethane (plastic), varying in size, which can be used to withdraw fluids from or introduce fluids into body cavities.

Cerebrospinal Fluid (CSF) The protective, cushioning fluid originating in the lateral ventricles of the brain which also surrounds the brain and spinal cord.

CAT; CT or Computed Tomography Scan Abbreviation for computerized axial tomography. A special x-ray technique which outlines the ventricles and other structures of the brain in cross sections.

Cerebral Angiography A technique of taking several x-rays at once to visualize the brain's blood vessels after they have been injected with a radiopaque (visible on x-ray) substance.

Choroid Plexus The choroid plexus regulates the intraventricular pressure by secreting or absorbing cerebrospinal fluid.

Closed Head Injury Trauma to the head that damages the brain but does not penetrate or fracture the skull.

Cognition A conscious function of the mind such as general awareness, conceiving, judging, sensing, reasoning and imagining.

Coma A state of deep unconsciousness from which a person cannot be awakened; lasting from a few days to several months. A patient in a coma may be expected to wake suddenly as from a deep sleep, but very often the process is a gradual one of increasing responsiveness and awareness. Individuals will progress at their own rate—it cannot be predicted how any one individual will recover.

Cortex (Cerebral) The 1 to 4 mm-thick, gray surface layer of the cerebrum

Electroencephalogram (EEG) The tracing made by an electroencephalograph which records the electrical waves in the brain (brain waves) as the brain sends messages from one lobe to another.

Epidural Space Literally, upon (or outside) the dura mater. The space between the dura mater and the skull.

Hyperventilation Often one of the first things a doctor will prescribe is that the patient be made to breathe quickly and shallowly. This "hyper" or overventilation causes a decrease in the pressure of carbon dioxide in the body which in turn decreases ICP.

Hypoxia (*see also, Anoxia*) A decreased amount of oxygen in the blood.

Intracranial Pressure (ICP) The relationship of the contents of the brain. Normally the contents of the brain are in balance and do not create pressure in the skull. For this reason, normal pressure is measured at zero millimeters of mercury (mm Hg). In the case of

injury or a tumor, expansion of the contents can increase the pressure inside the brain.

Lasix Used as a method of decreasing intracranial pressure. A medication which helps rid the body of excess water (diuretic) by increasing the excretion of sodium through the body's urinary system.

Lumbar Puncture Also called a spinal tap. During this test, a needle placed into the spinal column draws out fluid for testing.

Magnetic Resonance Imaging (MRI) A diagnostic procedure in which a scan is made using magnetic energy to create images of the soft tissue structures of the brain. An MRI scan shows more detail of the brain than a CAT scan.

Mannitol Medication that can decrease the swelling in the brain by helping the body to eliminate water. When the body gets rid of excess water, pressure on the brain can be reduced.

Neurological Relates to the study and treatment of the body's nervous system (specifically the brain, spinal cord and nerves).

Neurologist A physician specializing in the diagnosis and treatment of diseases and disorders of the nervous system.

Neurosurgeon A physician specializing in surgery for diseases and disorders of the brain, spinal cord and the nerves.

Pia Mater Pia mater is Latin for "tender, affectionate mother." It is the delicate, fibrous membrane which closely covers the brain.

Pressure Waveform A pressure waveform is the increase or decrease of fluid in the cranial space which is recorded and monitored.

Radiopaque A quality of being opaque (non-transparent) to various forms of radiation; visible on x-ray.

Seizure A convulsive state in which cells in the brain fire off random impulses, causing the patient to lose consciousness. A seizure is caused by irritation to the brain or lack of oxygen to certain areas of the brain. During a seizure, patients will often lose consciousness and their bodies will shake and thrash about uncontrollably. Seizures greatly increase the pressure within the brain; for this reason the patient is often given anticonvulsant medication.

Seizure Precautions Procedures that either prevent a seizure from happening, or keep the patient safe during a seizure. Medications, padded side rails and limb holders are common precautions.

Shunt/Shunting Shunting is a procedure which employs a surgically placed shunt (usually valves and catheters) to divert fluid from one part of the body to another. Shunting often means moving excess fluid from the brain's ventricles to the abdominal cavity or heart.

Spinal Cord The cord of nervous tissue, protected by the vertebrae, which begins at the base of the brain and progresses down the back. The spinal cord carries impulses to and from the brain and is a center for starting and coordinating many of the body's reflex acts.

Steroids The administration of steroids is used to regulate ICP, usually when it is associated with brain tumors.

Subarachnoid Space The space underneath the arachnoid membrane. It lies between the arachnoid membrane and the pia mater.

Subdural Space Subdural means "beneath the dura." The space beneath the dura mater or between it and the arachnoid membrane.

Ventricles (Cerebral) The four communicating cavities inside the brain that are continuous with the central canal of the spinasl cord and which produce and circulate CSF.

Ventriculostomy Inserting a small catheter into the ventricles to allow measurement of intracranial pressure and drainage of excess CSF.

Ventricular Drain Drains the excess CSF into a collection bag.

Medtronic

Medtronic Neurosurgery
125 Cremona Drive
Goleta, CA 93117-5500 USA
(800) 468-9710 USA/Canada
(901) 344-0645 International
(800) 468-9713 FAX USA/Canada
(901) 396-2698 FAX International

LIT59059-1B

Printed in USA