We dedicate this book to...

Our Patients

Our Teachers

Our Colleagues, Families & Friends
This introductory work on “Brain Surgery,” as it applies to our lives, is motivated by two important reasons.

Its primary goal is to introduce, in straightforward terms, the fascinating area of surgery involving the brain. Just as scientists have been able to successfully write children’s books about our universe, ancient history, and religion in understandable terms, a goal of this work is to communicate a straightforward message without unnecessary complexity.

An important need for understanding the matters discussed in this book can also arise when a family member or friend is a patient undergoing such brain-related surgery. Reading this source may be of help in familiarizing a person with the entire experience, from a brief overview of this area of medicine and types of disease encountered, to the actual operation, the operating room, the people involved, post-operative intensive care, and new advances in the field. As doctors we notice that many of our patients’ families and friends have important, very reasonable questions, and to this extent we hope this work is a source of useful knowledge. Hence, although this book started as an idea to introduce the youth of our generation to this fascinating area, it may be interesting and useful to persons of all ages who desire to learn more.
Notice

The contents of this book are based upon valid, generalized information (to the best of our knowledge) during the time of writing. As medicine is an ever-changing field and each patient is treated according to his or her specific needs, differences between the content of this book and actual treatment may occur. The contributors to this book cannot be held responsible for its content, should some disparity or inaccuracy arise.

The intent of this book is to attempt an introduction of the field of surgery relating to the brain, in a straightforward manner which may be more easily understood. This book is intended to complement other medical information, and by no means substitute it.

We hope you find this book informative and helpful.
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Who was the first person in the world to have brain surgery? Why did this person need brain surgery? Who was the person who did this surgery?

The answers to these questions are not easy, but the earliest recorded evidence of brain surgery comes from the skull (shown at right) which had a smooth hole cut into it. The hole’s shape suggests use of an instrument such as a rock, and that the hole wasn’t made by accident.

Why would someone do this? At that time people used this technique, called *trephination*, to “ward off spirits which possessed the body.” The entire operation was probably done by a religious official similar to a “witch doctor.”
The Brain

What it does

The brain lets us:

- Watch Monday night football
- Skateboard
- Play chess
- Smell the difference between a rose and garlic
- Feel sad when a close family member dies
- Sleep and eat
- Appreciate music
- Enjoy the spirit of Christmas
- Think actively about our own brains and how we think…
- Celebrate life
- Dream
- Do millions of other things

... and IMAGINE doing anything in the world
The Brain

What it looks like

What does the brain look like from the outside?
An actual human brain is shown at the right. It is made up of millions of little wires (called neurons or nerve cells) which are mixed with other cells of the brain, all folded to look like the brain you see. Coming off the brain is the spinal cord.

What does the brain look like from the inside?
The brain is hollow. There are four chambers in the brain (called ventricles) which hold a clear fluid: this fluid flows inside and around the brain and spinal cord. That's why it's called cerebro-spinal fluid. A picture of the inside of a brain is shown in the bottom picture.

Other interesting facts about the brain:
The brain pulsates with each heartbeat. It needs blood to keep it alive. Blood vessels from the heart branch many times and reach the brain, supplying it with important oxygen and energy resources.

The brain is surrounded by a thick covering called dura. Finally, both the brain and dura are surrounded by the skull, which protects the brain. Attached to the skull is the face -- which we use to recognize each other.

The brain is also divided into regions called “lobes” as shown in the diagram at the bottom right. This diagram shows certain areas mainly associated with certain functions; in reality, a given function may involve many different parts of the brain.
The different layers covering the brain.

- Skull
- Dura Mater
- Scalp
- Hair
- Brain
- Blood vessels

Regions of brain:

- **Frontal lobe**
  (behavior control, movement, Speech output)
- **Temporal lobe**
  (memory, Comprehension & hearing)
- **Parietal lobe**
  (sensation)
- **Occipital lobe**
  (vision)
- **Cerebellum**
  (coordination)

Brainstem & Spinal cord
The brain’s different parts control different functions. Some of these functions are described here, and the brain parts involved are shown on the opposite page.

**Fine touch**
Suppose you close your eyes, and your friend taps your second finger. How do you know which finger was tapped? ...

-- The brain has a map of your body. The picture on the opposite page shows an unusually shaped person with big hands and lips. As this picture shows, the brain pays more attention to sensation from your lips and hands than, for example, your back. That’s why hands and lips are more sensitive to being touched than your back. If someone were to electrically stimulate that part of your brain which maps your lip, then you’d feel like someone were really touching your lip.

**Pain & Temperature**
Suppose you touch something hot or painful, like fire. Your brain will know this in less than 1 second, from the special “wires” called nerves which run from the tips of your fingers to the brain through the spinal cord.

**Special Sensation**
Seeing, hearing, smelling, and tasting are called “special senses.” Once again, different parts of the brain do each of these.
Touching a flame sends a signal through nerves from the finger, up the arm, up the spinal cord, and to the brain, as shown here. [The brain sends a signal back which moves the muscles of the arm away from the flame.]
What normally happens: Movement & Balance

Movement
How do we walk? -- Our brain puts one foot in front of the other, plants that foot, and puts the other foot ahead of the first foot. How does it know which foot is which, and how to move the foot (and not a hand or the face)? Once again, the brain has a map (as shown in the picture). Almost identical to the map for sensation, this “movement” map is just in front of the “sensation map.” In fact, if you were to touch that part of the brain where movement of the leg is mapped, the leg would actually move.

Balance
The reason a person can bring fingers together to pick up a fork, or can walk without losing balance, is because of the cerebellum (shown in the second picture). If the cerebellum weren’t working properly, a person may have to stand with feet spread wide apart for balance, and walk in that manner to avoid falling. Also, this person would be very uncoordinated in many activities.
What normally happens: Speech, Memory, and Thought

Speech
Some people understand ideas well, but can’t speak properly. Some people speak proper words, but can’t understand ideas, or just don’t make sense with their words. The areas of brain responsible for understanding, processing, and then saying the proper words, are shown in the second picture.

Memory
Who was the first president of the United States? The brain has stored this information in a special region known as “the hippocampus” (see picture on prior frame). That’s where long-term memory is probably stored.

Recent memory (such as remembering what you had for dinner) is also stored within the brain. Where is recent memory stored? Nobody really knows.

Thought
Thinking about ideas, solving difficult problems, and recognizing and understanding another person are all functions of the brain. Although we think that the brain’s cerebral cortex part controls such functions, nobody knows exactly which parts within the cortex are involved.

The brain obviously does quite a lot, and it usually does all of it very well when it’s normal.
The Brain

What Abnormally happens

We’ve thought about the way the brain should normally function. But now let’s answer the questions:

What are some things that can go wrong with the brain?

And how can we help to correct what’s wrong with the brain?
**Stroke**

The brain needs continuous blood supply to stay alive. Without blood (for example, if a blood vessel carrying blood were blocked off) parts of the brain can be severely injured or die.

What can block a blood vessel? It may be a blood clot -- either inside of the vessel, preventing flow, or outside, pressing the vessel shut. Usually, the blockage is a large cholesterol-related piece of tissue attached to the inside of the blood vessel, which can cause a blood clot to form and narrow a blood vessel (as shown in the first picture). This clot can then break off and cut off blood supply to the brain further downstream. That’s one of the reasons why each of us should eat a healthful, low cholesterol diet -- to help keep us from having a stroke later on.
How is a stroke treated?

First, the cause of the stroke must be decided.

** If a stroke resulted from a bleed around or into the brain, this may due to a blood vessel expanding (like a balloon) and then bursting -- called an aneurysm. This is treated either by clipping the ballooned part of the blood vessel, known as “clipping the aneurysm” or filling up the weakened ballooned part with small coils. Sometimes bleeding can result from “vascular malformations” or abnormal tangles of blood vessels which are present from birth -- these can be treated either by surgical removal or radiation. Bleeding in the brain can also be due to high blood pressure, or getting hit in the head -- in some of these cases, the blood (which then clots) must be removed before it presses and kills the brain. In some cases the risk of surgery is more than its benefit, and in these cases surgery should not be performed.

** If a stroke results from a blood clot inside a blood vessel, this can be treated using blood clot-breaking medication or inserting a thin balloon into the vessel and blowing up the balloon to break up the clot (known as “balloon angioplasty”). In some cases, blood thinning medicine helps prevent a blood clot from building up in the first place.

** If a stroke results from a clot breaking off from a cholesterol-lined blood vessel supplying the brain (as in the first picture), then this blood vessel must be cleared. Usually, the risk of such a stroke is reduced by a procedure called “carotid endarterectomy,” where pieces of fatty, cholesterol-containing material are surgically removed or “unclogged” from a blood vessel supplying the brain. Balloon angioplasty may also be an option in such cases.
The Brain

What Abnormally happens: BRAIN TUMORS

Nearly all things that are alive are made up of tiny living cells -- the brain is made up of millions of cells, and so are the bones, the muscles, skin, and so forth....

Where do these cells come from? From old cells -- which divide to make new cells. So, if you cut your skin (and leave a small hole in your skin in the process), your body has to make new cells to fill this hole. So old cells divide to make new cells, until the hole is filled -- and then old cells should stop dividing. But what if they keep dividing, to make new cells? Then you have a tumor. If the cells which can’t stop dividing involve the brain, you have a brain tumor. A brain tumor is basically made up of cells which are growing out of control. These cells then push and hurt normal brain. If they hurt the part which the brain uses to move, a person wouldn’t be able to move properly. If they hurt the part which the brain uses to speak, a person wouldn’t either understand or be able to properly speak words. In other words, a brain tumor can hurt any normal function of the brain we discussed earlier -- sensation, movement, speech, balance, the ability to taste, see, hear, smell, and also the ability to remember or think.
How is a brain tumor treated?

Today, there are at least three main ways of treating a brain tumor. These include medications (steroids, chemotherapy), radiation (whole brain, focused beam, Gamma Knife [see “New Advances” section]), and surgery. If the tumor is large and/or is hurting the brain or body, then surgery may be done to remove as much of the tumor as possible without hurting normal brain. Because brain tumors can be in difficult-to-reach or very important regions of the brain, different “approaches” to the tumor -- including through the nose, mouth, and ear -- have been used (see picture panel below). In rare cases, the tumor may not be treated either because the risk is too high for any form of treatment, or the tumor is not worrisome enough at the present time to require treatment. Sometimes, a biopsy, or small piece of the tumor is removed and identified using a microscope, to decide the best treatment plan. (Many different types of tumors exist, and some are better treatable than others, depending on the the type of tumor).
As described earlier, a brain can start a function such as moving a hand, and can then stop it. But what if it is able to start but not stop a function -- for example, what if your brain began moving your hand, but couldn't stop? Or what if it couldn't control a motion properly? One cause of this may be a seizure -- an uncontrollable, usually repetitive movement caused by the brain. Of course, seizures can involve any of the brain’s functions -- sensation, thought, etc. But usually the most obvious seizures involve repetitive movement. Other than being obviously occurring, seizures can be detected electrically by using a test called an EEG (electroencephalogram). Electrodes placed on the scalp record the waveforms shown on this page, which indicate a seizure.

What causes seizures? Although some seizures can be caused by tumors or bleeds, the majority of them may be related to problems within the brain’s circuitry or chemical balance. When a person has continuing seizures, this condition may be called epilepsy.

How is a seizure treated?

Medications alone are able to treat the majority of patients suffering from epilepsy. However, some patients with a tumor, bleed, or other (sometimes unknown) cause for their seizures are not helped by medications alone. After trying different medications for many years, some of these patients continue to have seizures. The goal of surgery in these patients is to find the region of the brain which causes these seizures. Special electrodes can be used, either placed on the scalp, on top of the brain directly, or within the brain, to record where the seizure starts from. After this region is found, surgery is performed to remove the seizure-causing region or “seizure focus” from the brain, with the hope that normal brain function is not damaged in any way. Some patients are cured of seizure activity after this seizure-causing part of their brain is removed. If no specific “focus” of seizure activity can be found, other options such as brain stimulation through a nerve can be tried.
A person affected by Parkinson’s disease may shuffle while walking, may continually move the thumb and index finger as if rolling a pill between them (known as a tremor), and can have stiff movements overall, along with other problems.

Why? Normally, certain chemicals in the brain cause movement and other chemicals prevent movement. If the brain has more of the chemicals to start movement or not enough to stop it, then parts of the body may continue this unusual movement. Many patients suffering from Parkinson’s disease may not have enough of a chemical called dopamine, and so may continue to have symptoms of this disease.
How is Parkinson’s disease treated?

Parkinson’s disease, like many other diseases, is treated by using medications first. However, there are some patients who are not successfully treated by medications, and these patients may be helped by surgery. One example of a newer form of surgery is for treating “the tremor of Parkinson’s disease.” In this type of surgery, a small recording electrode is inserted in the brain to find the proper region to stimulate for stopping this tremor. Other symptoms of Parkinson’s disease, as well as other movement disorders, may be treated by such electrode methods also.

More recently, devices such as “thalamic stimulators” have been implanted in the brain to stop tremors from specific causes, and these devices can be turned on by waving a small magnet over the skin when a tremor starts.
A “brain surgeon” is otherwise known as a *neurosurgeon*. This is probably a better name, since the neurosurgeon operates not only on the brain, but on the spinal cord *and* nervous system-related structures throughout the body.

A general neurosurgeon usually undergoes 15 years of training after high school graduation -- 4 years of undergraduate college, 4 years of medical school, one year of general surgical training called “internship,” and 6 years of specialized neurosurgical training called “residency.” Neurosurgeons are usually trained to do many different procedures in general Neurosurgery, and some neurosurgeons specialize further in mainly treating one of the problems we have discussed.

As with any medical problem, a *Neurosurgeon* knowledgeable and skilled in the latest and past available techniques in a particular field, as well as knowledgeable of non-Neurosurgical treatments available, is in the best position to offer optimal care to the patient.
There are three main parts to any brain-related or other surgical operation:

1. The Patient;
2. Surgeons, Anesthesiologists, and Nurses;
3. The Procedure.

The interaction between each of these is very important. Each group has a specific role, with the ultimate goal being the patient’s benefit (since the patient is always the most important person in medicine).

(1) The Patient

The patient is the most important member of the operation. Prior to the operation, details of the need for operation, the risks and benefits, and answers to questions are addressed by the neurosurgeon. Only after determining that the benefits outweigh risks, and that the patient is agreeable to proceed, is the operation begun. Great care is taken by the nurses, anesthesiologists, and surgeons, to ensure comfort and best possible outcome. When awake, each important step is usually described to the patient to keep him or her informed. The patient’s family and loved ones are also notified regarding progress of the operation in many cases, as well along with the results and findings following the operation.

(2) Surgeons, Anesthesiologists, and Nurses

Upon arrival to the operating room, the surgeons, anesthesiologists, and nurses help position the patient on the operating room table. Depending upon what part of the body needs an operation, the patient’s back, front, or side are placed on the table. The patient is then “put to sleep” by the anesthesiologist, who gives numbing medicine (so the patient doesn’t feel any pain), sleeping medicine (so the patient doesn’t wake up during the operation), and sometimes, medicine to paralyze the muscles temporarily (so the patient doesn’t move), with medicine which may help forget the actual operation. After the patient is put to sleep, the surgeons begin the actual operation, and the patient is carefully watched or monitored by the anesthesiologist.
The Procedure

The first steps of the surgical procedure include positioning and putting the patient to sleep, as described above. At this point, the surgical instruments have already been heated and/or chemically treated to make them germ-free, or sterile. All people handling these instruments (including the surgeons and nurses) must make themselves sterile as well, by washing their hands and forearms for up to 10 minutes with a special soap and water; then, a special sterile gown must be worn by each of them. The patient’s skin is also sterilized using a special iodine solution, and then sterile sheets are placed upon the patient. After all of these steps, the surgeon is ready to begin.

**STEP 1**: After the patient is asleep and feels nothing, a head-holder keeps the head in place. After sterilizing the skin, an incision is made on the scalp.

**STEP 2**: A “craniotomy” or skull opening is made using a specialized drill.

**STEP 3**: After the bone is removed, the dura, or covering of the brain, is exposed.

**STEP 4**: Opening of the dura, in this case, revealed the blood clot between the brain and dura which was compressing the brain. This blood clot can be removed to help against life-threatening brain damage.
Steps of an operation are shown in the previous picture. Usually, the first instrument used is the knife (or the scalpel), and this is used to cut through the skin. The skin is peeled apart using retractors. Bleeding is controlled by a special electric instrument called a “Bovie” which heats a tiny portion of body tissue to stop bleeding. The skin and muscle, along with layers underneath these structures are cut through, and the bone of the skull is exposed. To cut through the skull, two or more holes may be drilled, and these “dots are connected” to remove a piece of bone known as a “bone flap.” This reveals the covering of the brain, known as the dura. Finally, cutting through the dura with scissors shows the brain. Once the brain is seen, a microscope is used to guide the surgeon to the specific region which requires surgery. For example, if a tumor needs to be removed from between the hemispheres of the brain, then the two halves of the brain must be carefully moved apart to access the tumor. If an aneurysm needs to be clipped along the bottom of the brain, then part of the brain must be carefully lifted without injuring the delicate brain. Small, precise instruments are used for these tasks, and the surgery can last well over 4 hours at times.

A sample set-up of instruments used for a typical operation.

After the goal of the operation has been achieved, then the patient’s brain must be properly covered, and the dura, skull, muscle, and skin must be properly aligned and stitched into place. After all of these steps, the anesthesiologist must wake the patient up. During the surgery, a special machine breathes for the patient; this must be turned off after surgery, when the patient will hopefully resume his or her own breathing. The most critical parts of surgery are not complete until the goals of surgery have been achieved -- that the patient is alive, awake, and better in comparison to before surgery.

The surgeon notifies the family about the patient’s condition following the operation. The patient is carefully monitored in the days following surgery to ensure the best possible recovery to normal life.
The Intensive Care Unit, or I.C.U., is a specialized part of the hospital whose mission is to carefully monitor critically ill patients. These include patients who’ve undergone a major operation, or are being treated for a severe brain injury following an accident. The I.C.U. contains many machines and devices, which perform many functions -- from breathing for the patient to measuring the patient’s heart rate, blood pressure, output from the heart, pressure in the blood vessels, and pressure in and around the brain. All of this is important since the patient is not always awake enough after a major operation or severe injury, and all of these numbers help in deciding whether this patient is “doing well.” The skilled nurses and doctors in the I.C.U. work towards recovery from the patient’s critical status, so that the patient can then move along successfully to less critically monitored areas of the hospital, such as the wards, rehabilitation units, and finally, home.
A patient in the neurosurgical ICU may need the treatment shown here:
- Vital signs monitor (A) - enlarged in other picture;
- IV fluids (B) to prevent dehydration
- Ventilator (C) to help a patient breathe
- Ventriculostomy (D), or a thin tube which removes cerebrospinal fluid and relieves pressure on the brain.
The field of brain surgery is always advancing at a tremendous rate. Some of these more interesting advancements are very briefly discussed here.

(1) **Medications**
Some surgical treatment has been avoided because of medicines. These include steroids for certain brain tumors, and L-DOPA, a dopamine derivative, for Parkinson’s disease. Still, several surgical procedures involving the brain are necessary and cannot be simply substituted by medicine alone.

(2) **Instruments**
Aside of the usual instruments, technological advances have introduced new instruments. These include the stereoscopic microscope, which actually projects images into the microscope’s field, so that it helps guide the surgeon even when a deep tumor is not seen from outside. There are many, many new instruments other than these, and the technical aspects of all instruments may be quite complex. Also, certain instruments may only be useful for specific disease processes, and cannot always substitute the need for the appropriate open operation.
This machine, the BrainLab Novalis linear accelerator, is used for brain tumors. For certain tumors, radiation treatment can be done without surgery. Many different “radiation doses” are given in different directions which focus on the tumor. Hence surrounding brain is not as affected by the radiation, and the tumor receives the maximum of the dose. An actual machine (top left) with a conceptual diagram of the process (bottom right) are shown. (Courtesy BrainLab, Inc., 2001)

An example of recent advances is the navigational system for brain surgery, a sort of “GPS” for the brain – it allows planning trajectory for approaches within the head prior to making a skin incision and also during operations. (Courtesy Brainlab, Inc., 2001)
Less than 100 years ago some regions of the brain were considered “impossible to reach,” because of the delicate structures which would be disturbed in trying to reach them. Today, surgical procedures may reach such difficult regions through the nose, mouth, ear, and/or forehead, or by swinging the jaw to one side. Such procedures have made the impossible more possible.

Other techniques, such as the gamma knife or linear accelerator instruments, are able to perform brain surgery without a single cut (by using radiation which is concentrated at one area in the brain). This treatment is reserved for only specific types of tumors, but can be performed without a single surgical incision. These treat mostly certain brain tumors and vascular malformations, which must be relatively small and be in locations favorable for this treatment.

Many neurosurgeons and scientists in other fields continue to invent ways to reach difficult regions of and around the brain, and in doing so, help in solving some life-threatening problems.

One very important area of Brain Surgery is research. Research involves finding out more about how the brain works, how treatment of the nervous system (including brain surgery) can be improved, and how past experience can lead to a better future. All of brain surgery, just like any field in science, is advanced significantly because of the building blocks of research.
It is important, after introducing the field of brain surgery, to take away some important concepts.

Brain surgery is only used when all other treatment will not give better results, and only when the risks of surgery are less than the risks of not having surgery. Also, a competent patient must agree to having a specific operation, since this decision is first and foremost.

The final satisfaction from all of the collective technological advances, critical procedures, and logical research is the treatment of a patient with success. Success in today’s medical world should be measured by restoring not only a life, but also the good quality of that life.
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Ravish Vinay Patwardhan, M.D., Neurosurgeon, is Founder & Director of The Comprehensive Neurosurgery Network, LLC, based in Shreveport, Louisiana. A graduate of UCLA School of Medicine, he practices all aspects of brain, spine, and peripheral nerve related surgery, while specializing in epilepsy and functional neurosurgery. In addition, he participates in numerous research projects to further field, along with community activities to educate and promote philanthropy. With the writing of this book commenced in 1996, this book is the culmination of over 10 years of experience in the field, an effort to introduce the general public to a few aspects of a rapidly expanding field.