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MEMO
DT: 9/10/88
TO: All First-Year Residents
FM: Dr. David Lindstrom, Chief of Surgery
RE: Welcome

As Chief of Surgery, I would like to extend my heartfelt welcome to each of you. While you are probably anxious to begin your duties, please take a moment to examine the orientation materials enclosed:

1. The "Operating Procedures Manual" explaining how to get started.

2. The "New Resident Orientation" (rev. 9/88) handout (attached to this memo), detailing basic hospital procedures of patient admittance, diagnosis and the use of message pagers.

3. A copy of Chapters IV, V and Appendix A of Merl and Newman's classic text, "Anatomy and the Surgical Technique" (Copyright 1938, 1956, 1987, reprinted with permission of STW Medical Press). While our medical center is a general admitting facility, we take special pride in our Department of Abdominal Surgery, founded in 1943 by Drs. Robert Merl and Simon Newman. Due to our expertise, many patients with abdominal complaints are transferred to TGH and — even as a resident — you can expect to see many such cases. This reprint should help refresh your memory regarding the techniques and terminology of abdominal surgery.

4. A history of surgery. It has long been the belief of the hospital Board of Directors that modern medical instruction, with its emphasis on technique, neglects the more human aspects of the healing arts. This document is intended, in small measure, to correct this oversight.

During the day, you can often find me in the classroom where I give daily lectures. I will be more than happy to respond to any problems you may be having with diagnosis or surgical techniques. Once again, welcome to Toolworks General.

Toolworks General Hospital
New Resident Orientation
(Rev. 9/88)

Welcome to Toolworks General

We know that the first few days as a surgical resident can be difficult, so we have put together this orientation handout. Use it to familiarize yourself with the layout of TGH and the procedures you will be expected to follow. Refer to the "Operating Procedures Manual" (enclosed) in any instances that you feel more specific instructions are required. Good luck!

Your Responsibilities

You will be working on the eighth floor, under the auspices of the Department of Abdominal Surgery. This is a separate unit with its own personnel staffing, record keeping and teaching facilities. As you know, your job is to diagnose patients (after ordering any necessary tests), prescribe treatments or drugs and — when appropriate — operate.

In short, you have all the privileges and responsibilities of any other surgeon in the hospital. About the only difference is that Dr. Lindstrom will be tracking your progress and offering guidance when needed.

Upon Arrival

When you arrive at the start of your shift, the first thing you should do is check in at the Nurse's Station. Hospital policy requires that all residents sign in before cases will be assigned. Monica Pierce, the Charge Nurse, keeps track of the sign-in list. Once you sign in with Monica, she will make sure you receive any messages and let you know if you have patients waiting. .

Hospital Paging System

The Board of Directors has installed, at great expense, a hospital message paging system. The paging system assures that all physicians can be located immediately so that test results, medical histories and other critical information can be passed to you quickly and efficiently. All physicians (except when in surgery) are required to carry their beepers and to respond as soon as possible to a page.

Failure to respond in a timely manner will result in dismissal from the staff and termination of your hospital privileges.

When your beeper goes off, return as soon as possible to the Nurse's Station. Nurse Pierce will relay the message and make a phone available so you can return the call. If you are uncertain how to operate your beeper, please see the more detailed instructions located in your "Operating Procedures Manual," also found in this information packet.

The Floor Plan

Aside from the Nurse's Station, there are several other areas with which you should become familiar. Across the hall from the Nurse's Station is the Classroom, where Dr. Lindstrom holds daily lectures (along with special sessions for residents needing extra instruction). The Classroom is fully equipped for audio-visual presentations and will become an integral part of your continuing education in abdominal surgery.

Patient Rooms

The numbered doors at the end of the hall lead to patient's rooms. While on duty, you are the attending physician for all patients on the floor. It is your responsibility to look in on the patients and check their progress. An up-to-date medical history for each patient may be found on the clipboard at the base of the patient's bed. If you feel additional tests, medication or surgical prep is indicated, mark the appropriate action on the clipboard. See the "Operating Procedures Manual" for more specific instructions on surgery as well as ordering medication and tests.

The Personnel Office

Shelly Marks administers the personnel office. We recommend that you visit Shelly to select your surgical team. You will find that, while each staff member is skilled and competent, all have slightly different educational backgrounds, experience and personalities. It may take a while to discover the combination of talent and personality with which you feel most comfortable while in the operating theater.

The Operating Theater

The double doors to the left of **the** Nurse's Station lead to the Operating Theater. After surgical prep is ordered, the patient will be brought to the OR when ready.

We have found that diagnostic and treatment methods among first year residents sometimes differ. To ensure that everyone here at Toolworks General works under the same guidelines, we have included the following excerpt from "Anatomy and the Surgical Technique," by Drs. Robert Merl and Simon Newman (Copyright 1938, 1956, 1987, reprinted with permission of STW Medical Press).

FROM THE DESK OF:
DR. DAVID LINDSTROM

(Rev. 9/88)

Table_of Contents

Chapter Four: Some Pathology and Treatment

Appendicitis

Indications:

Appendicitis is the infection and inflammation of the vermiform appendix, a superfluous, finger-sized appendage to the cecum at the junction of the small and large intestine. Appendicitis can be marked by any combination of loss-of-appetite, nausea, vomiting, diarrhea, high fever and acute abdominal pain.

Treatment:

Surgery is indicated in cases of appendicitis.

Bacterial Infection

Indications:

Bacterial infection is the assault upon the body by a bacteria or germ. As the body's defenses attempt to expel the bacteria, certain symptoms manifest themselves. These can include abdominal discomfort, vomiting, diarrhea, high fever and runny nose.

Treatment:

Bed rest and medication are required.

Intestinal Gas

Indications:

Symptoms include abdominal pain, generalized weakness and dizziness.

Treatment: Observation and bed rest.

Kidney Stones

Indications: Small precipitates composed of mineral salts extracted from urine sometimes become lodged in the ducts of the kidneys. These renal calculi can cause extreme discomfort in the lower back and flank area. The stones, while rarely fatal, are extremely painful and should be treated immediately. Kidney stones will appear on an X-ray as small dots above the pelvis.

Treatment: Kidney-stone patients should be referred to a urologist.

Aneurysms

Indications: When a blood vessel wall becomes diseased or begins to weaken, the blood vessel begins to dilate (stretch), forming what is known as an aneurysm. Should the artery walls become rough from deterioration, the blood within may clot and form an embolism, further stretching the aneurysm. If the aneurysm occurs in a large artery, the potential bursting of the artery is life-threatening. A particularly dangerous aneurysm occurs in the aorta, the main blood-carrying artery. Aneurysms of the descending, or abdominal, aorta can often be felt as a pulsating mass in the abdomen. The most common symptom is abdominal pain.

Ultrasonic scans reveal aneurysms as solid white lumps.

Treatment: If an aneurysm swells to a dangerous level, 5 to 6 cm in diameter, the blood vessel's walls must be supported with a dacron graft. Since aneurysms commonly occur in older patients who have less stable systems, surgeons must take care to avoid needless surgery.

Arthritis

Indications: Arthritis is the erosion of joints and their surrounding tissues. Arthritis is often found among older patients and can be extremely painful.

Treatment: Arthritis is very difficult to treat. The most successful treatments include cautious exercise and pain-relief medication.

Diagnosis

Definition: Diagnosis is the study of symptoms in an effort to discover the ailment causing a patient's discomfort. This process involves gathering as much information as possible about the patient and his or her symptoms before proceeding with treatment. Some of the tools found to be most useful are the patient's own report of symptoms, the abdominal exam, the X-ray and the ultrasonic scan.

Reported Symptoms: Symptoms reported by the patient provide a starting point for diagnosis. These symptoms are often written on a clipboard at the foot of the patient's bed.

Abdominal Exam: The abdominal exam is often an extension of the patient's report of symptoms. By palpating the abdomen and listening to the patient, the tending physician can gain a more detailed understanding of the symptoms. To perform an abdominal exam, palpate various locations on the patient's abdomen and note the responses. (For more information on examinations, refer to your Operating Procedures Manual.)

X-ray: An X-ray is the image of electromagnetic radiation passed through a body and then captured on film. Before it reaches the film below, this radiation passes through porous material, such as skin and muscle, but is absorbed by solid masses, especially bone. X-rays, therefore, show solid masses such as bone but ignore less dense cartilage.

Ultrasonic Scan: An ultrasonic scan is similar to sonar. During an ultrasonic scan, sound waves are focused on a body and scanned by a computer. The recorded wave-forms are translated into images of the masses off of which the sound bounced. Ultrasonic scans show the more porous cartilage that is ignored by X-rays.

In Conclusion: After the initial evaluation, the physician uses the clipboard at the foot of the patient's bed to request treatment or additional diagnostic options. A hospital staff is not allowed to carry out a physician's requests that do not include his or her initials.

Surgery

Orientation: Before a surgeon enters the operating room, he or she must consider the following aspects of surgical procedure: First, he or she must be mentally prepared to finish the operation once it has begun. A mental checklist of the steps involved is often used as preparation. Second, the surgeon must constantly monitor the patient's vital signs. Even though the surgical team will help, the main responsibility for the patient's well-being is that of the surgeon in charge. Third, every surgeon must be very familiar with the medical instruments he or she must utilize.

Vital Signs

Introduction: Several devices constantly report the patient's vital statistics during an operation. The electrocardiogram (EKG), clock and blood pressure gauge display the primary information. The IV bottle and anesthetic dial display secondary information.

The EKG: The EKG is an electronic representation of a heart beat and is used to monitor abnormalities in heart operation. Conditions for which surgeons must be on the alert are Premature Ventricular Contraction (PVC) and Bradycardia.

PVC: PVC is thought to arise from an imbalance in the electrical system of the heart and is characterized by a drop in the EKG line. If not medicated, PVC may lead to Ventricular Fibrillation, characterized by a rapidly modulating EKG line, absent of normal heart rhythm. This condition is usually fatal.

Bradycardia: Bradycardia occurs when the heart becomes weak or tired and slows or skips beats. If proper medication is administered, the normal heart rhythm is usually restored. If not, the heart can lose strength and stop beating.

Blood Pressure: The blood pressure gauge describes the measure of pressure the heart exerts on the blood vessel walls as it pushes blood against them. It is expressed in two numbers, the systolic pressure and the diastolic pressure. The systolic pressure, the peak level, measures the maximum pressure of the blood exerted against the vessel walls as the heart contracts. The diastolic pressure represents the force of blood exerted against the walls as the heart relaxes. Blood pressure can drop from prolonged anesthesia or blood loss.

Surgical Clock: The clock displays elapsed time from the start of the surgery. Surgeons always work carefully, while trying to avoid unnecessarily prolonging an operation.

The IV Bottle: The IV bottle shows the type and remaining quantity of fluid being infused into the patient. IV bottles should not be allowed to empty, since the injection point may become clotted and hinder further IV administration. A steady flow of glucose solution should be administered to the patient even when a specific transfusion is unnecessary.

Anesthetic: The anesthetic dial displays the status of the anesthetic valve. Generally, if the dial points to "on," the valve is open, and the patient is being anesthetized. If the dial points to "off," the valve is closed, anesthetic is not being introduced into the respiration chamber, and the patient is breathing only oxygen-rich air. Making sure the patient is fully anesthetized before commencing the operation is intensely important to any surgeon. The alternative is quite uncomfortable for the patient.

Chapter Five: Basic Surgical Techniques and The Abdominal Area

In this chapter, we will look at the basic structure of the abdominal cavity and the organs and muscle groups found there. Then, we will discuss the general procedure for surgery in the abdominal area, around which specific operations can be built. Finally, we will look at two surgeries that take place in the abdominal area: the appendectomy and the aneurysm graft. Both surgeries make use of the general procedure as a frame for the particular techniques involved.

Basics of the Abdomen

The human body has several layers of tissue surrounding the skeleton and internal organs. The outermost layer, known commonly as the skin, protects the body from viral and bacterial infections. The fatty layers underneath store excess nutrients for later use. Muscles provide strength and structure.

Tissue Layers

Skin: The inner vascular, sensitive dermis and dead outer epidermis comprise the skin layer. The skin provides a protective cover that holds the body together.

Subcutaneous Fat: Fat is adipose tissue, containing cells distended with oil, that stores excess nutrients for use by the body.

The subcutaneous fat layer covers the lower frontal abdomen just below the skin.

Muscle Groups

Rectus Abdominus: The rectus abdominus is a muscle group just below the subcutaneous fat layer. Known as the stomach muscles by laypersons, the rectus abdominus is characterized by the rippling effect visible across the abdomen.

Linea Alba: The thin connective tissue between the left and right halves of the rectus abdominus is called the linea alba. It is often incised vertically to provide access through the rectus abdominus to the abdomen.

External Oblique: These muscle groups, one on the right and one on the left, cover the sides of the abdominal wall from the bottom of the ribs to the top of the pelvis.

Transversus Abdominus: Lying just, below the external oblique, the transversus muscle tissue connects at the top of the pelvis and the side of the stomach. The muscle cells run at right angles to those of the external oblique.

Preperitoneum: The preperitoneum is a delicate opaque membranous tissue separating the abdominal muscle layers and the organs of the abdomen.

Postperitoneum: This thin membranous tissue, located just below the intestines, covers and protects the kidneys and aorta.

Organs

Intestines: One of the major organs of the abdomen, the intestines are responsible for the digestion of food and compacting of waste. The small intestine secretes gastric juices to break down food particles into valuable nutrients. The large intestine compacts waste food material for expulsion.

Aorta: The aorta is the largest artery in the body. It is the major vessel carrying blood to the abdomen and legs. Just below the umbilicus or "belly button," the aorta splits into the left and right iliac arteries which transport the blood to the legs.

Basic Surgical Techniques

The initial and final steps of most surgeries follow a standardized regimen. This procedure can be used as the start and end of most abdominal surgeries.

Surface Preparation

Thorough cleansing and proper attire are required in an operating theater. The surgeon must scrub with sterile, antiseptic cleanser, then dress in an approved, sterile surgical gown. The face must be covered with a sterile mask, and a fresh pair of surgical latex gloves must be worn.

The patient's skin must be similarly prepared. Scrub the uncovered skin with antiseptic and then cover the unaffected regions with a sterile drape.

Initial Medications

When you are ready, add anesthetic to the patient's air mixture. Before incising, inject antibiotics to prevent infection after the operation begins. Keep a steady glucose IV dripping to balance fluid loss.

Incising

Introduction:

The most basic procedure in an operation is the incision and retraction of the top tissue layer. To remove or manipulate an offending organ or appendage, the surgeon must first sever the protective tissue layers which cover it. Since there are numerous levels of tissues, the surgeon must make incisions long enough to allow ample space in which to operate after pulling back the tissue layers.

Procedure:

The first step in this process is to incise the tissue layer. Generally, this is done with the scalpel. Applying moderate pressure, draw the scalpel downward across the layer. Always incise parallel to the muscle cells to insure proper healing.

If the layer is an especially thin or delicate one such as the peritoneal layer, do not use the scalpel to incise. Instead, raise a bit of the tissue with forceps and nick it carefully with the scalpel. Then use the scissors to continue the incision from the nicking point. This method protects the peritoneal layer as well as the sensitive organs below.

Controlling Bleeders

Introduction:

If the layer is vascular (containing veins and arteries), it will bleed. The point at which an incision crosses a vein or artery is called a bleeder. These bleeding vessels must be sealed to prevent traumatic blood loss. Use forceps to clamp the bleeders off and temporarily stop the bleeding. Then use either a cauterizer or a ligator to permanently seal each bleeder.

Cauterizer:

To use a cauterizer, place the tip of the cauterizer on the clamped end of the vessel and coagulate. (For specific instructions, consult your Operating Procedures Manual)

Ligator:

To use a ligator, encircle the tip of the clamped bleeder with the ligation string and tie off the bleeder tautly. (For specific instructions, consult your Operating Procedures Manual)

Retracting

Once the tissue layer is free of bleeders, it may be retracted. Use the retractors to pull back the incised layer. Slip the blade ends of the retractor into the wound and stretch the tissue apart near the incision.

Be sure your incision is long enough before you attempt to retract. If the incision is not long enough, the wound cannot be retracted without damaging the tissue layer.

The incise-ligate/cauterize-retract sequence is repeated until the necessary organs or appendages are exposed. Some layers, of course, do not contain blood vessels or arteries, so the ligate/cauterize step is unnecessary.

The actual corrective phase of the operation continues at this point.

Closing the Patient

After the operation is complete and you are ready to close the patient, gently release the retractor blades. You must unretract the tissue layers by sliding the retractor blades together and then removing the retractor (Refer to your Operating Procedures Manual for specific instrument procedure). At this point, carefully suture the incision closed so the patient's wounds will heal. If you place a suture in an incorrect area, it can be removed with the scissors. You must use enough sutures or the wound will not heal. Too many, however, and the tissue may be too corrupted to heal. At the skin level, use adhesive skin strips to close the wound rather than sutures. This helps reduce scarring.

Special Techniques

In addition to the general surgical techniques described above, each operation requires the mastery of specific techniques to bring it to completion. The rest of this chapter is devoted to discussions of the appendectomy and aneurysm grafting techniques.

Appendectomy

Introduction:

The vermiform appendix is located in the lower-right quadrant of the patient's abdomen. Due to its placement and the form of the musculature in this area, you must use diagonal muscle-split incisions to reach it.

Procedure:

Incise from the patient's upper right to lower left, using what is called a McBurney's Incision, through most of the layers. However, take care not to use McBurney's incisions where it may cause incisions to cross muscle tissue. Make certain when incising the peritoneum that the colon is not accidentally punctured.

After incising and retracting the peritoneum, take a sample of the abdominal fluids; analysis of this specimen will help you prescribe proper medication during the patient's recuperation. Use suction to remove the abdominal fluid. Gently lift the cecum from the abdominal cavity until the appendix is free. The appendix is just underneath the cecum. To elevate, clamp the appendix at its tip.

The mesoappendix membrane must be incised, and the artery running parallel to the appendix must be tied off and severed before the appendix can be removed. Nick the membrane with the scalpel near the cecum alongside the mesenteric artery. Then tie off the mesenteric artery with a suture through the nick you've just made. Carefully sever the mesenteric artery from the appendix with the scalpel at the tip of the clamp.

Because the infected appendix is filled with offensive fluid, it should be clamped off. To do so, place a clamp at the base of the appendix and another slightly higher. Then, sew a draw-string suture between the clamps and sever the appendix. To ensure proper healing of the stump, invert it with your hand and suture the end of the cecum closed. After, replace the cecum into the abdomen and close the patient. If the appendix ruptures during the surgery, immediately insert a drain hose into the appendix and allow it to drain.

Aneurysm Grafting

Introduction:

Grafting the aorta is a highly sensitive operation. The aorta is the major blood-carrying vessel in the body. To remove the clot forming the dilation and graft the vessel walls, the aorta must be clamped off, stopping precious blood flow to the legs. As the aorta remains closed longer, the probability of abnormal heart rhythms increases dramatically.

Procedure:

Begin the operation using standard incisions and retractions. The incision at the rectus abdominus must be made on the linea alba. Be sure not to incise the intestines when cutting the preperitoneum. The intestines must be lifted from the abdomen and stabilized with an intestinal bag so that the postperitoneum can be incised. Use extreme caution when incising the postperitoneum because the aorta underneath could be pierced.

There should be ample room to mobilize the aorta past the postperitoneum. Lay rubber tubing under the aorta with your hand. An injection of heparin at this stage will keep the blood from clotting and causing embolisms. Carefully clamp the left and right iliac arteries below the aneurysm and the mesenteric artery in the middle of the aorta. Finally, stop the blood flow through the aneurysm by applying a clamp just above the aneurysm. Cut the mesenteric artery dose to the aorta and ligate it.

The aortal incision should be made along the center of the vessel. This incision must be long enough to remove the clot and insert a graft. Lift the clot from the artery with your hand and insert the dacron graft. Suture the graft ends to the aorta walls, close the aortal incision and suture.

The aorta must next be checked for leaks. Release the iliac clamps first and then the aorta clamp to examine the area for bleeding. If the graft leaks, it will need to be resutured. Finish by demobilizing the aorta and closing the patient.

Appendix A: Glossary

Anesthesia: A general anesthetic produces a total lack of bodily sensation and consciousness. A local anesthetic blocks the nerves surrounding an area to be operated on so that the sensation of pain cannot reach the brain.

Aneurysm : Local dilation or stretching of a blood vessel due to deterioration, injury or disease of the vessel wall. This condition creates a pulsating mass over which a "murmur" sound can be heard.

Antibiotic : Antibacterial material, of which penicillin is perhaps the best known, obtained from fungi and bacteria.

Antiseptic : A material that is destructive to microorganisms that lead to disease, fermentation or putrefaction.

Aorta : The major artery that emanates from the left ventricle of the heart.

Artery : A vessel that transports blood from the heart to various tissues in the body.

Arthritis : Inflammation of joints and/or the surrounding tissues.

Atropine : A drug introduced prior to anesthetic to lessen the secretion in both bronchial and salivary systems and to prevent cardiac depression by quickening the heartbeat.

Bacteria: Bacteria are a group of microorganisms. The average size of these small cells is approximately one micron in transverse diameter. Some are pathogenic (disease-producing) to humans.

Blood Plasma: The part of the blood that is composed of liquid, of which 90 percent is water.

Blood Pressure: The blood pressure is the measure of pressure the heart exerts on the blood vessel walls as it pushes blood through them. It is expressed in two numbers, the systolic pressure and the diastolic pressure. The systolic pressure, the peak level, measures the maximum pressure of the blood exerted against the vessel walls as the heart contracts. The diastolic pressure represents the force of blood exerted against the vessel walls as the heart relaxes.

Bradycardia: A retarded rate of heart contraction producing a slowed pulse rate.

Calculus (calculi) : An abnormal cohesion of mineral substances that can form in the passageways that transmit the body's secretions, or in the organs that serve as reservoirs for them. **Renal calculi** are those located within the kidney.

Cauterizer: An instrument that uses a heated filament to burn or scar tissues and thus coagulate bleeding blood vessels.

Cecum : The roughly 6 cm cul-de-sac that lies below the terminal ileum forming the first part of the large intestine.

Clamp: An instrument used in surgery to grasp, join, compress or support an organ, tissue or vessel.

Coagulate : Changing a substance from a fluid to a gel, to clot.

Dacron Graft : A smooth, pliable plastic tube that is placed within the aorta in order to stabilize the artery wall.

Dopamine: Dopamine is a stimulant used to reverse radical drops in blood pressure.

Drain: The drain is used to siphon offensive fluid from a wound, or in the case of an appendectomy, the appendix. Insert the end of the drain into the incision and let the fluid drain out. Remove the drain when the fluid has been removed.

Electrocardiogram: The record (also referred to as an EKG) made by an electrocardiograph, an instrument that receives the electrical current produced by a heart's contraction and records it on a moving drum of graph paper or L.E.D. display.

Embolism : A solid mass, clot or bubble obstructing a blood vessel.

Fluid Vial : A receptacle used to hold a patient's bodily fluids often taken during an operation.

Forceps : An instrument used for holding, seizing or retracting.

Gauze : **A** thin, meshed material used in a multitude of surgical procedures.

Glucose : Dextrose, blood sugar, corn sugar, grape sugar or starch sugar. In this form, carbohydrates are absorbed through the intestinal tract and carried by the blood throughout the body.

Heparin : A fast-acting anticoagulant drug.

Intestinal Bag : A receptacle, sometimes called a "gut" bag, used during an operation to hold the intestines out of the way of the surgeon as he or she operates.

Intravenous catheter : A hollow tube of variable length used to introduce fluids into the body, by way of the veins.

IV Bottle : A container for fluid that is fed into the body intravenously (through **a** vein).

Kidney Stones : Small precipitates, calculi, composed of mineral salts extracted from urine. These "stones" often become lodged in the ducts of the kidneys.

Lidocaine : A local anesthetic recognized as effective as an antiarhythmic agent.

Ligator : An instrument used to bind or tie vessels that are deep or nearly inaccessible.

Lumen : The smooth interior of a tube such as an artery or intestine.

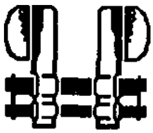
Palpate : To feel or examine by touch.

Pelvis : The bony, saucer-shaped cavity that protects the bladder, rectum and reproductive organs.

Precipitate : A Deposit of solid matter that has separated or settled from a solution.

Premature Ventricular Contraction : Also known as PVC, results from the premature contraction of the ventricles (lower chambers of the heart). This "early" or "weak" beat of the heart causes an irregular pulse.

Retractors : An instrument for drawing aside the edges of a wound.



Saline : Relating to or containing salt, salty.

Scalpel : A pointed knife with a convex edge.

Scissors: Very delicate layers of tissue are cut using scissors. This instrument is often used instead of a scalpel because scissors can cut tissues without applying pressure to the tender organs underneath.

Skin Clips : Small plastic adhesive clips used to hold the skin layer closed after incising.

Suction: The suction is a small vacuum hose for removing bodily fluids. Deposits of blood or infected fluid can be removed by applying the suction tip to the affected area.

Suture : The material, often nylon or cat gut, used to unite two surfaces of tissue by means a stitch.

Thrombosis : The formation of a blood clot or clots within the chambers of the heart or in a blood vessel.

Ultrasonic Scan: Sound Vibrations of a high frequency focused into a beam whose echoes provide diagnostic information about the body's different physical properties.

Ventricular Fibrillation An uncoordinated quivering, as opposed to any kind of synchronized beat, of the heart's ventricles (the two lower chambers of the heart). This condition is usually fatal.

Vermiform Slender and worm-like in structure.

X-ray: Short rays of the electromagnetic spectrum that are passed through the body and then captured on photographic film. X-rays are often used to examine irregularities in skeletal formation.

A Brief, Bloody History of Surgery

The Dawn of Surgery

Surgery is a surprisingly ancient art, older by far than the earliest recorded history.

There is physical evidence from many different parts of the world that at least one surgical specialty was practiced as far back as the stone age. Strangely enough, that specialty was brain surgery, or at least skull surgery. In the middle of the 19th century, paleontologists began digging up what looked like neolithic skulls that bore unmistakable evidence of trepanning — the act of sawing or drilling a hole through the cranium and removing a plug of bone.

Trepanned skulls began turning up in prehistoric excavations in France, Denmark, Asia Minor, North Africa and many other parts of the world. They caused quite a stir. Was it magic or medicine? Were the victims living or dead at the time of the operation? Did knowledge of this operation spread secretly among civilizations not known to have any cultural contact? Or — equally strange — is brain surgery a universal human trait?

The great French physician and anthropologist, Paul Broca, demonstrated in the 19th century that the operations had been performed on living human beings. He further found that the people who received these operations lived for years, even decades, after the removal of a plug of headbone — often the size of a hen's egg. In fact, it looked as if about half of the patients survived.

Whatever their reasons, people all over the world managed to cut holes in the skulls of living patients without killing them, scores of centuries before the first written records of surgery.

Trepanned skulls became a wonderful mystery for archaeologists, paleontologists and surgeons. Theories abounded as to why these operations might have been performed — to cure epilepsy, migraines, or madness; or as ritual sacrifice to unknown deities — but nobody proved one theory well enough to rule out the others. And because the skulls were discovered before the era of precise radioactive dating, many experts even remained doubtful that the skulls actually dated back to prehistoric times.

But those doubts were dispelled when the mummies of Peru were discovered.

The Mochican brain-surgeons of prehistoric Peru were busy people, whatever their purpose might have been. More than 10,000 trepanned skulls were discovered among the silent stacks of mummies discovered in ancient Mochican tombs. Not only did the neatly circular incisions in many cases indicate the use of sophisticated specialized saws, similar to the mechanized versions still in use, but examination of the skulls indicated an incredibly high proportion of survivors. Out of 400 skulls examined by one investigator, there were 250 certain recoveries.

There was no such thing as brain surgery in the 1850s, when these artifacts were discovered. How could the ancients accomplish a feat that contemporary surgeons didn't yet dare try? The most basic problems of hemorrhage and infection in exposing the brain were considered formidable. The Mochican trepannists left a few ceramic depictions of the operation, but no one had thus far discovered evidence of how they dealt with bleeding and infection.

Prehistoric trepanning

The first physical evidence of surgery may have been related to brain surgery, but the earliest pictorial evidence appears to depict something else. Thousands of years after those mysterious neolithic skull plugs, the first surgical operation to be recorded for posterity was a procedure that is still carried out today: circumcision. On the doorjamb of the tomb of a high royal official who lived around 2300 B.C. is a relief depicting two boys being circumcised by men wielding stone instruments. One of the boys is being gripped by an assistant, while the other, his gaze aimed beatifically upward, merely braces his hand on the squatting surgeon's forehead.

The Earliest Surgical Annals: Egypt, Mesopotamia, India

In 1906, James Henry Breasted translated an old papyrus scroll that had been found in a tomb near Thebes. He proved the manuscript itself dated from 1550 B.C. but was most probably a copy of older works. In this collection of specific "instructions" to medical practitioners is considered to be the first written reference to the human brain: "This quivering and fluttering under your fingers comes because the brain of his skull is broken open. Blood flows from his two nostrils." The Egyptian diagnostician offered a poor prognosis for these cases.

Though Breasted's translation may count as the first written documentation of surgical techniques, the first code of surgery was created by the Babylonians long before that old papyrus was pressed and dried.

These first surgical principles were known as the code of Hammurabi.

The code of Hammurabi was chiseled into stone around the 18th century B.C. From the specific laws governing the conduct of surgery, it is obvious that the art had been developing for a while before Hammurabi. The bronze scalpels of the Babylonian surgeons were wielded according to a carefully-regulated schedule of fees — and the rather stiff penalties for malpractice were laid out in no uncertain terms:

> "If a physician operate on a man for a severe wound (or make a severe wound upon a man) with a bronze lancet and save the man's life; or if he opens an abscess (in the eye) of a man with a bronze lancet and save the man's eye, he shall receive ten shekels of silver (as his fee).
> "If a physician shall make a severe wound with the bronze operating knife and kill the patient, or shall open a growth with a bronze operating knife and destroy the eye, his hands shall be cut off."

Despite the rather severe penalties for losing a patient, it appears that Babylonian surgeons flourished, judging by the sheer number of surgical instruments that have been found in Babylonian excavations. Little more is known about the details of Mesopotamian surgical techniques, for no other written records have been discovered.

The most extensive and advanced literature on the specifics of surgery came from India. The ancient medical traditions of the subcontinent probably date back considerably further than even the Egyptians, as far back as 6000 B.C. The main written contributions of Indian surgeons came later, from the period after the Aryan invasions of approximately 2300 B.C. — around the same time Troy was sacked. The Aryan's oldest religious document, the *Rigveda*, speaks of "sages" who accompanied the Aryan tribes in their conquests, caring for the wounded along the way. Just like today, in ancient times the battlefield was one of the most intensive schools for surgeons ever invented.

Whether on the battlefield or not, great teachers and lecturers in various medical fields began to leave written records in India long before scholars codified medicine in the West. One great medical writer, Susruta, lived around the seventh or eighth century B.C. He and other medical writers referred to a medical text that was already ancient in their time, now lost to humanity, known as the *Ayurveda* (in which the earliest anaesthetic, soma, was first mentioned).

Until the translation of the writings of Susruta, Western historians had debated whether the medical traditions of India could have been borrowed somehow from Greek medicine. Susruta, however, described surgical ideas that were unknown to the Greeks or anyone else until at least the Middle Ages.

Susruta made it clear that he, like many of his profession through the centuries, had an exalted view of the place of surgery in the realm of medicine. "Surgery," he wrote, "is the first and highest subdivision of the healing art, and the least susceptible to deception, transparent in itself, most noble in its application, the worthy product of heaven, the sure source of prestige upon earth."

Susruta described an operation for correcting cataract in excruciating detail. (Those readers who feel uncomfortable about graphic descriptions of surgery should probably skip the following quote):

> "After he has warmed the patient's eye with the breath of his mouth, rubbed it with his thumb, and detected the uncleanness which has formed in the pupil, he orders the patient to look down at his nose. Then, while the patient's head is held firmly, he takes the lancet between his forefinger, middle finger, and thumb, and introduces it into the eye, toward the pupil, on the side, half a finger's breadth from the black of the eye and a quarter of a finger's breadth from the outer comer of the eye. He moves it back and forth and upward. Have him operate on the left eye with the right hand or on the right with the left hand. If he has probed correctly, there is a sound, and a drop of water comes out painlessly."

Susruta also wrote detailed descriptions of plastic surgery, including an operation for reconstructing a severed nose. One of the popular customs on the subcontinent was the punishment of cutting off the nose and ears, which evidently furnished a stimulus for plastic surgical technique. Susruta's drawings and text instructed the surgeon to use a template cut from a leaf to mark a piece of the patient's cheek the same size as the missing nose, then to cut a flap of skin, leaving one end attached to the cheek. First the surgeon scrapes the ends of the stump, then wraps the fresh flap of skin around it and sews the edges, leaving two thin pipes where the nostrils belong. After the skin grows onto the nose, the connection with the cheek is severed. Use of such "skin flaps," however more refined, is still used in plastic surgery today.

"Cutting of the stone" at the cemetery of St. Severin

Susruta also turns out to be the earliest source of description of the urological operation known for centuries as "the cutting of the stone." The specific procedure for surgical removal of cystic calculi, a.k.a. bladder stones, is known as lithotomy. Samuel Pepys wrote in his famous diary with grateful relief of the day he was "cut for stone," and wandering specialists known for lithotomies had existed as long as anybody could remember. This specialty had been traced back to Rome and Greece, but Susruta described the operation in characteristic detail at least two thousand years before Giovanni de Romanis, the late 15th-century founder of modern lithotomy.

The ancient Chinese did not leave an extensive written record of surgical lore. In the second millennium B.C., the Chinese emperor Hwang Ti turned to medicine, legend has it, after his wife died of a baffling ailment. He is worth a mention here because his famous book about medicine, *Nei Ching,* contains a theory about the circulation of blood that puts the flow of blood through the body under control of the heart, history's first mention of the fact. Because of strong dissection taboos, however, anatomy was strictly a theoretical subject in China, and never developed in an empirical direction. In the West, it took a few thousand years more to rediscover this principle, so fundamental to the work of a surgeon.

Hua To, a renowned Chinese surgeon of the second century A.D., was known for his use of a potion that put his patients to sleep before he operated — the first recorded use of surgical anaesthesia, since the soma of ancient Hindu writings was not specifically associated with surgery. Hua To's mixture was said to consist of a mixture of monkshood and hemp (also known as cannibus sativa or marijuana) in an alcohol solution. Legend also has it that Hua To's last patient was the Chinese prince Tsao Tsao, who suffered extreme headache pain. Hua To suggested trepanning. Tsao Tsao, however, balked and immediately condemned China's most famous surgeon to execution. Hua To's notes and medical writings were destroyed after his death, at his request.

Surgery in the West: From Classical Greece to the Renaissance

Around the time of the Aryan invaders, another wave of invasions came from approximately the same direction and moved south through Macedonia and the Peloponessian peninsula, conquering the indigenous, agricultural societies huddled for centuries in those isolated mountains and seaside shores. To judge from oral traditions, the ancestors of the invaders who came to be known as the Hellenic Greeks seemed to be skilled in field surgery.

The *Iliad* and the *Odyssey,* epic poems of these invaders' great bard, Homer, include realistic descriptions of 140 different wounds and injuries and, according to one scholar, the mortality rate of these injuries was 77.6 percent. In the *Mad,* Patroclus operates open the thigh of his friend, Eurypylus, which has been pierced by arrows:

"Patroclus, with his dagger,
from the thigh
Cut out the biting shaft; and
from the wound
With tepid water cleans'd the
clotted blood;
Then pounded in his hands, a
root applied

Astringent, anodyne, which all
his pain
Allay'd; the wound was dried,
and stanch'd with blood."

And in the *Odyssey*, Ulysses was gored by a wild boar and tended by a band of healers who, rather charmingly, sang while they operated:

"With bandage firm Ulysses'
knee they bound;
Then, chanting mystic lays, the
closing wound
Of sacred melody confessed the
force:
The tides of life regained their
azure course."

The next milestone in the history of surgery in Greece was the work and teaching of Hippocrates, a wandering healer and teacher of the fifth century B.C. He left precise accounts of case histories, counseled physicians on ethics, laid down the rules for the arrangement of surgery and prescribed methods for postoperative dressing of surgical wounds. He (or his pupils) wrote volumes on treating fractures. And Hippocrates was the author of the oath every doctor of medicine then affirmed upon receiving his degree — a custom that is still followed today.

The greatest individual surgeon of the Roman era was Celsus, who left voluminous writings in Latin around 30 A. D. Celsus added to the older knowledge of Hippocrates the previously unknown cardinal signs of inflammation that are important to surgeons and still learned by every medical student — heat, pain, redness and swelling. With this crucial piece of knowledge, Celsus began the long battle against postoperative complications. He also recommended surgical removal for cancer of the breast, and described a method of removing the tonsils that is still in use. Like Susruta, a millennium before him and half a hemisphere away, Celsus described plastic surgery techniques for replacing severed noses. The gladiatorial combat at Rome's Coliseum was as instructive as battlefield medicine for plastic surgeons of Celsus' time.

The following centuries yielded very slow advance in the application of surgery to the cure of internal illness. The extreme pain of surgery put enormous pressure on surgeons to do their work as quickly as possible. Those patients who didn't die from excessive bleeding often died anyway, usually after mysterious postoperative fevers. The Church prohibited dissection absolutely and the practice of medicine was forbidden to the priesthood, who were virtually the only people in Europe through the Middle Ages who knew how to read or write. Hence, for a thousand years after the fall of Rome, there were no medical schools and very few physicians in Christian Europe.

The Moslem physicians of North Africa, Spain, the Middle East and India kept Greek knowledge alive and preserved Greek surgical texts in Arabic translation until they were translated into Latin during the Renaissance.

The dissection taboo in the Islamic world was also very strong. While great doctors in Baghdad, Damascus, Alexandria and Granada advanced the state of medical knowledge in other directions, they were neither great anatomists nor surgeons. For century after century, those few learned men in Europe who managed to study medicine were taught almost universally from the writings of Galen, a Greek physician who lived under Roman rule around 100 A. D. Galen, like the Church, frowned on experimentation and considered dissection of humans out of the question.

From Barbers To Surgeons

At a time when experimental science of all kind languished in Christian Europe and the role of the priest was considered far more important than the role of the healer, the ancient skills of surgeons, passed down orally from the time of Susruta, were not the domain of the upper classes but of the serving class. The kind of surgery previously performed by itinerants and mountebanks — lithotomists, cataract specialists and others — was claimed by the barbers' guilds in British cities and elsewhere. The first barbers' and surgeons' guilds were organized in the early 1300s.

Minor surgery such as blood letting and tooth-pulling had long been the domain of barbers, whose traditional red-and-white striped poles date back to the drying bandages found outside barber shops during the days when inducing bleeding in less-than-fatal amounts was thought to be beneficial.

Andre Wesel, more popularly known as Vesalius, was the man who broke through one of the most powerful and destructive taboos in history. He revealed the facts of human anatomy and thus elevated surgery to a science. He lived in the early 16th century, studied anatomy in Paris and taught in Padua. Having risen to some prominence as a lecturer, he urged the judges of the criminal courts to arrange their times of execution and to employ less mutilating forms of death in order to provide him with fresh, legitimate dissecting material. Condemned criminals were the only way he could legally obtain fresh human cadavers for dissection.

Like other anatomists before and after him, Vesalius was forced to deal with that ghastly, but necessary partner to the scientific explorer — the graverobber.

Blood letting: 14th Century state-of-the-art medicine

Vesalius began to do what no one had done publicly in more than a thousand years: he began to find errors in Galen's texts by checking the words of the ancient medical classics against his observations of actual human specimens. Just as Copernicus set off a ruckus when his astronomical observations challenged the authority of Ptolemy, and Galileo's physics experiments challenged Aristotle, Vesalius found that his corrections of Galen caused an uproar in the colleges of his time. His biographers wrote that the audience at his lectures were akin to "excited mobs," prone to "stormy objections, stormy applause." In 1543, Vesalius set the stage for the next developments in surgery by publishing *De Humani Corporis Fabrica,* an event which some historians use to mark the birth of modern medicine in the West.

With the beginning of a science of human anatomy based on direct observation, surgeons at last had a map to use in their campaigns against their age-old enemies, of which the loss of blood was the most immediate.

Patients who bleed to death aren't prone to infection, so the battle against infection couldn't get underway before the practice of ligature (suturing or clamping blood vessels during surgery) became commonplace.

One contemporary of Vesalius, Ambroise Pare, helped elevate the art of surgery to a higher level by mastering the use of ligature during amputation and by focusing attention on the use of medicinal dressings to repair operative wounds. Pare took a different route to Paris than the rather more well-off Vesalius. Legend has it that Pare's early education came by way of a parish priest who gave him lessons in exchange for labor in his garden. While Vesalius was out finding specimens and carefully taking them apart, Pare was experiencing his apprenticeship in the Hotel Dieu, a huge, stinking, filthy, humid hospital on the Left Bank, not far from the Cathedral of Notre Dame.

From the hellhole of a Parisian hospital before anesthetics were used or antiseptics or even basic cleanliness were understood, Pare went to war. He began to experiment with salves for healing gunshot wounds. Firearms of that period were notoriously inaccurate, so they were often used at point-blank range, which blasted and burned a fairly large hole in a person. The traditional dressing of Pare's time was to scald the wound with hot oil. In an emergency, unable to procure oil, he mixed egg yolk, oil of roses and turpentine, which turned out to work rather better than boiling oil. He began to experiment with healing salves, and one story has it that he courted an old doctor for years, trying to persuade him to part with his own secret formula for healing salve.

The formula he eventually purchased directed him to boil two newborn puppies alive in oil of lilies, add one pound of worms after they have been drowned in white wine and mix the resulting brew with sixteen ounces of turpentine.

And while Pare did not greatly advance scientific thinking as he dragged himself through gory field surgeries and dank hospital corridors stacked with the howling wounded, he did bring something vitally important to the advancement of surgery. Pare invented tools and techniques for stemming the gushers of blood that had heretofore limited the scope and success of major operations.

During the wars, Pare started to wonder whether there might be better ways to deal with the most common procedure of the battlefield surgeon — amputations. Traditional medical practice was to prevent the patient from bleeding to death by cauterization — burning the raw stump with a heated iron or boiling oil. The pain associated with such a procedure was considerable, and the wound often started to hemorrhage again when the scab from the first cauterization broke loose, a few days later, requiring a repeat performance of the whole horrifying procedure! Pare began to experiment with the technique of holding blood vessels with forceps and tying them shut with ligatures as he amputated. He applied the technique at the siege of Danvilliers, succeeded, and surgeons began to use the technique of clamp and ligature that is still used today.

Today, the battle against gross loss of blood owes as much to technology as to technique, with the introduction of transfusions, heart-lung machines and laser cautery. But Pare's routine of cutting, clamping and suturing, carefully repairing the scalpel's damage along the way as it progresses deeper into flesh, is still a major part of every operation. Both technique and technology are based on a firm knowledge of physiology (an understanding of the functions of the body) as well as anatomy (an understanding of the structures of the body). Surgeons couldn't hope to control hemorrhage without a firm knowledge of how the blood circulates in the body.

Twelve years after Pare died, William Harvey was born in England, during the reign of Queen Elizabeth. Shakespeare was furiously dashing off plays for the Globe theater around the time Harvey went off to one of the penitentiary-like boys' schools the British upper classes traditionally use to educate their young. Early in his schooling, Harvey became

Leg amputation - 1897. Still from one of first medical films.

fascinated with one thing he noticed in his dissections, an important fact that seemed to have gone unnoticed by the great scientists and physicians of the ages (save, perhaps, our Chinese emperor of thirty centuries before): the heart seems to do the same thing in every different animal.

Hearts beat. Hearts pump blood. Harvey founded the science of comparative anatomy.

Unlike some other major discoveries, Harvey's insights did not come in a great flash of illumination, but followed years of careful observation. He worked as a not-terribly-distinguished physician while he pursued his research. Harvey discovered that the heart drives the blood and that it is a muscle which alternates rhythmically between spasm and relaxation. He observed the blood driven through the arteries and returned through the veins in a continuously repeating cycle. He never did find out how the blood travelled through the tissues and returned to the veins — capillaries weren't revealed for years afterward, when microscopes came into use. Harvey's surgical lecture notes of 1615 are considered to be the first written description of the theory of the circulation of blood.

Like other major discoveries before and since, Harvey's theory was not easily accepted by the old guard. The controversy raged throughout his lifetime. But he had made a. major step in transforming surgery into a science, more closely allied to biology than barbering. Pare had introduced the technique of ligature, and now surgeons understood, thanks to Harvey, exactly how and why it worked. This close linkage between advances in theoretical understanding and improvements in surgical techniques served to accelerate the evolution of surgery. And surgeons, having gained major victories against hemorrhage, were able to deal with two of their other age-old enemies — infection and pain.

The Invisible Enemy: The Battle Against Infection

In the middle of the 17th century, bubonic plague killed a lot of people. The people who were left were wealthier than they would have been otherwise, and more concerned with the medical profession — and how it might prolong their lives. After the fire of London in 1666 (which put a swift end to the plague by killing the rats that harbored the fleas that transmitted the disease), existing hospitals were expanded and new ones constructed. Instead of dying at home or on the streets, people went to hospitals, in hopes of a cure or alleviation of pain. The hospital boom was a boon for surgeons.

It took them another two centuries to realize it was a mixed blessing.

For two hundred years, between the fire of London in 1666 and the discoveries of Joseph Lister in the middle of the 19th century, hospital surgeons were able to perform dissections on cadavers, conduct surgery and attend to births on thousands of patients — all without washing their hands or their instruments. The result of the new hospital construction was that they were places where gravely ill people could go to seek surgical relief of their ailments. Their chances of walking out alive after an operation, however, were even worse than the days of Pare. The hospitals themselves became the breeding grounds for horrendous and fatal illnesses, particularly among surgery patients.

"Hospital diseases" as the mysterious postoperative infections were known, are among the most unpleasant ways to die ever observed. In one form of blood poisoning, the area around the wound fills with pus and becomes red, swollen and extremely painful; the fever spikes, the infected limb swells to frightening proportions and the unfortunate patient begins to waste away. Another form, now known as "hospital gangrene," begins with a kind of greyish mush that forms around the wound, then slowly eats into the flesh, exposing, then destroying skin, flesh and muscle until gaping holes appear in the infected area.

No miraculous technique or wonder drug was needed to abate this hideous problem. Ironically, nothing more than some knowledge of bacteriology and access to soap and water would have done the trick. Strange as it sounds today, century after century of brilliant surgeons failed to make the connection between filth and infection. And when a brave soul or two did begin to pick up clues, they found that not only were their contemporaries less than eager to listen, but often found themselves under attack for suggesting a connection between cleanliness and infection. And even when the debates were concluded and the principles of antiseptics were theoretically well-established, many hospitals simply did not implement them.

In the mid-1800s, an Austrian named Ignaz Semmelweis had been concerned about the high mortality rate in the maternity ward of his hospital. A terrible danger of hospital childbirth in those days was puerperal fever, which turns out to be related to the other "hospital diseases" attendant upon surgical wounds. Semmelweis was thinking about the reason why midwives had a lower mortality rate than doctors when one of his colleagues did science a big favor by accidentally cutting himself while dissecting a patient who had succumbed to the disease. A few days later, the unfortunate colleague was dead of a mysterious illness that resembled puerperal fever. Semmelweis got it into his head that the mortality rate might be cut drastically if he could only convince students and doctors to wash their hands after leaving the dissecting room and before they entered the surgical theater.

The man who has come to be known as "the saviour of mothers" did not actually discover anything new. As early as 1795, two British physicians published a paper demonstrating that puerperal fever and wound fever were identical, but the paper attracted little attention. In 1829, Robert Collins demonstrated that fumigation and scrubbing with chlorine solutions could cut the mortality rate in maternity wards, but nobody paid much attention. In 1843, no less a personage than Oliver Wendell Holmes wrote a paper pointing out the evidence for contagion as the causative agent in puerperal fever. Amazingly, these measures never caught on. Semmelweis, however, raised such a stink, personally and zealously inflaming debate in medical circles, that he ultimately got his point across.

Semmelweis had, however, no specific explanation for why handwashing should reduce mortality. He had empirically stumbled across a good bit of medical practice that saved many lives, but he had not provided a theory, a scientific explanation for this phenomenon. He made a good observation and did his best to get surgeons to put it into practice. But neither he nor any other surgeon of the day had the least idea about invisible organisms travelling on hands and even in the air and capable of attacking and destroying flesh. Before the application of the newly-invented microscope to biomedical research, the notion of nasty lifeforms too small for the eye to see was preposterous.

The name of Joseph Lister, the crusading British surgeon, is closely associated with the antiseptic revolution. Lister's findings, though, were dependent upon Louis Pasteur's discoveries in France regarding the role of microbes in disease. Another obstacle to the evolution of surgery was the poor state of scientific communications. If Lister had only known about the more or less contemporaneous crusade of Semmelweis in Austria, he might have not had such a hard time convincing his colleagues. Ironically, Lister honeymooned in Vienna when Semmelweis was lecturing about the necessity for hand-washing in maternity wards.

Before Lister was able to conceive his crusade for antiseptic technique in

Bellevue Hospital, New York City. Notice filthy operating conditions.

surgery, he needed a crucial bit of knowledge about microbes, those invisible organisms that microscopes were beginning to reveal. The French researcher Louis Pasteur created the science of bacteriology, which led to a true understanding of the causes of infection. This knowledge from outside the immediate domain of surgery, like Harvey's discovery of the circulation of the blood, was to set off another surgical revolution.

Pasteur would be remembered with great reverence if his only accomplishment had been to demonstrate the role of microscopic organisms in disease. He also, however, happened to save the entire French wine and silk industries, discovered an immunization for sheep anthrax and chicken cholera and developed the treatment for rabies that is still used around the world. When Pasteur told the grateful vintners of France that their wine was under attack by bacteria, which could be killed by warming the wine to 50-60 degrees Celsius — the simple but life-saving procedure now known as pasteurization — he was also setting forth an important clue to any surgeon interested in combatting wound infection.

Lister was looking at the whole field of surgery-related infections. He had noticed that simple fractures rarely led to wound fever, but compound fractures in which the skin was broken almost always led to infection. And he saw the connection with the inflammation associated with surgical wounds. Something in the air was getting into the body when the skin was breached, but he had no idea what could be causing the damage.

In 1865, the year after Pasteur had saved the wine industry, one of Lister's colleagues directed the surgeon to Pasteur's writings. Noting the similarities between the vegetable putrefaction Pasteur had discovered with the flesh-rotting process of gangrene, Lister made the correct leap of logic. Microbes in the air were the source of infection.

Lister happened to walk by a riverbank sewage works one afternoon and noted that the sewage stank considerably less aggressively after it was treated with carbolic acid. Perhaps the carbolic acid was killing some of the microorganisms that caused putrefaction in sewage. He took his theory into the tricky arena of practice and brought carbolic acid into the operating room — a moment of significant breakthrough in the long battle against infection. Just as Harvey's anatomical discoveries boosted the power of surgical techniques like Pares ligation, Lister's application of antibacterial chemicals to the problem of surgical infection set off a co-evolution of theory and practice.

By introducing an entirely new set of hygienic procedures into the traditionally casual if not outright funky operating theaters and making liberal use of carbolic acid solution, the frightful toll of postoperative infection could be reduced. Lister proved it with the statistics from his own hospital. He also enlisted an assistant to run a small engine for spraying a two-percent solution of carbolic acid into the air of the operating theater. As usual, the tenets of "Listerism" as the advocacy of antiseptic surgical technique came to be called, were firmly resisted by the surgical establishment.

Not until Lister's technique was successfully applied to Queen Victoria's underarm abscess did hospitals begin to smell of chemical disinfectants rather than blood and pus and putrefying flesh — the odor that had been known for centuries as "surgical stink."

First operation using carbolic spray.

Several different technologies emerged in response to the basic knowledge of the causes of surgical infection. The use of biological agents as antibiotics was the next such breakthrough, and ironically it was right under Lister's eyes. Penicillin was discovered accidentally in 1928 when Alexander Fleming noticed that a mold spore had blown in the window and contaminated one of his culture dishes; upon closer examination, he further noted that no bacteria were growing around the airborne spores These spores turned out to be Penicillin glaucum.

Ironically, Lister himself had once noted the role of the penicillin mold in the death of bacteria in an urine specimen, but he failed to follow up on his own research.

The now-traditional custom of "scrubbing" for surgery, sterilizing instruments, cleansing wounds, and wearing sterile caps, gowns and masks set the stage for multiple breakthroughs in abdominal surgery and other operations deep in the body. Surgeons at Johns Hopkins Hospital began using sterile rubber gloves early in the 20th century and the practice soon became universal. Mortality rates dropped dramatically and swiftly.

The conquest of infection was a tremendous step, but surgery could not have advanced without major breakthroughs in the battle against pain. The wacky history of anaesthesia in 19th century Britain and America, combined with the antiseptic revolution that happened at approximately the same time, set the stage for 20th century technological medicine.

The Zany History of Anaesthesia

If the whole raucous story of anaesthesia weren't so painful, it would be funny.

When you look into the exact circumstances by which people were, for the first time, "numbed" during surgery, it is easy to see that these great 19th century victories against surgical pain weren't exactly orthodox advancements. By the time the Story of Modern Anaesthesia is told, an amazing series of coincidences, stupidities, venalities, weird characters, wild parties, public performances, lawsuits and command performances pass across the stage.

The problem of pain is an ancient one. For uncounted generations of surgeons, however, it was an unfortunate but not immediate obstacle. Hemorrhage was more formidable. When the use of ligature enabled surgeons to control bleeding, surgery made a leap forward, only to find further progress blocked by the pain problem. Deep surgery causes agony. Such extreme pain limits the amount of time a surgeon can spend operating. That limits the scope of operations surgeons can dare.

At the beginning of the 19th century, just before the discoveries of the uses of nitrous oxide, ether and chloroform ushered in the age of anaesthesia, the very best surgeons prided themselves on their ability to remove a bladder stone or cut a leg off at the hip joint in less than a minute. Anyone born since the discovery of anaesthesia, who has had most any operation, should at least once pay homage to the discoveries that distinguish their operations from the shrieking torture of old.

Hua To, the ancient Chinese surgeon, was not the only Chinese medical writer who referred to the use of a hemp (marijuana) infusion in dulling the pain of surgery. Liquor or other intoxicants, however, merely serve to dull pain. Even people who have passed out drunk tend to wake up a bit when somebody hacks off a limb or cuts open their abdomen. The most common method of short-term anaesthesia in ancient China and elsewhere was a swift blow to the jaw, a technique used often in preparation for the quick, but shocking operation that was performed by the thousands at certain times: castration.

Roman surgeons put pressure on the carotid artery, thus temporarily interrupting blood flow to the brain, to knock patients unconscious — a procedure that was extremely dangerous in itself. In the first century A.D., a Greek surgeon in the Roman army, Dioskorides, was the first to use the word "anaesthesia" in reference to the use of wine of mandragora to alleviate surgical pain. When entrepreneurs, aristocrats, mountebanks and crusading dentists were knocking around America and Britain with their gases in the 19th century, Oliver Wendell Holmes suggested reviving this ancient word to describe the state of insensibility attendant upon inhalation.

In the Middle Ages, the Roman pressure method was widely used, and various herbals mentioned the use of opium, hemp, alcohol and other substances to kill pain. A 12th century manuscript mentioned the "sleeping sponge," which was soaked in herbal infusions and held to the nostrils of patients. The effectiveness of the sponge varied with the formula used and didn't seem to have much effect on the progress of surgery. (Indeed, when one modern investigator experimented with some of the old formulae for sleeping sponges, he reported that most of them "wouldn't even make a guinea pig nod.") But the largest obstacle to overcome in the field of pain relief ultimately was theological rather than medical.

When surgical hospitals proliferated in the 17th century, both the Catholic and Protestant churches stepped in and declared that suffering was the will of God. "Pain is something visited upon us from above, and not to accept it is sinful," they declared. For a physician to attempt to thwart God's will was blasphemous. Pain in childbirth in particular was judged to be "naturally" painful because of scriptural interpretation of Genesis, and midwives were burned at the stake for attempting to relieve the suffering of a woman in labor.

In the years preceding the French revolution, toward the end of the 18th century, a dramatic character by the name of Franz Anton Mesmer announced his miraculous discovery of a "Final Cure for Pain and Suffering." Although he thrust himself onto the stage of medical history and had an indirect but significant influence on the birth of psychoanalysis a century later, Mesmer had no significant influence on the way the evolution of surgery turned out. It was the sheer power of Mesmer's ideas, the audacity of his public performances,and the widespread popular acclaim he managed to stir up that earned him a place in any history of anaesthesia.

Mesmer claimed that he had found a way of healing people by means of a power, unique to him, of controlling "animal magnetism." By making certain gestures (passes) with his hands around the bodies of patients, he was able to render them insensible to pain. Almost universally denounced by the medical establishment, Mesmer became the plaything of the European aristocracy.

However, it was actually one of his ardent followers, Count de Puysegur, who discovered the hypnotism that was probably the unconscious ingredient in Mesmer's success. And while hypnotism played a certain role in the development of painless surgery, the next breakthroughs on the pain front were to come from chemistry rather than psychology.

The curious history of anaesthetic gas inhalation begins with young Humphry Davy, in the year 1798. Davy was working at an unusual and amusing-sounding place known as the "Pneumatic Institution" where people were able to avail themselves of various scientific, not-so-scientific and would-be cures. The Institution specialized in the inhalation of various gases, among which was nitrous oxide.

Davy, just 21 at the time, was quick to notice that nitrous oxide seemed to render people insensitive to pain. He experimented with it personally and found that it made him want to laugh before he fell into insensibility. In 1800, he published a book about his findings in which he wrote the words that might have relieved immeasurable agony in the following decades, had they been heeded soon after they were written, "As nitrous oxide... appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place."

Unfortunately, virtually nobody in the medical establishment — not even a maverick — took up Davy's challenge and tried to experiment with nitrous oxide in surgery. It took decades for his observation to be rediscovered. And ironically, the one person who seemed to take an interest, years after Davy's initial discovery, was thwarted in his own research by Davy himself! Henry Hill Hickman, a country surgeon a few decades younger than Davy, had been experimenting with carbon dioxide inhalation in animal surgery. He applied for support for further research, but the president of the Royal Society — Sir Humphry Davy — ignored him. Nitrous oxide then temporarily exited the medical drama in Britain and entered America by way of—what else? — show business.

One of the popular forms of entertainment in the early decades of the 19th century in America were travelling shows that included hands-on demonstrations as well as lectures. An 18-year-old entrepreneur by the name of Samuel Colt, who was trying to raise money to promote his own invention, the revolver, dubbed himself "Dr. Colt of New York, London and Paris," then set out across America in 1832 with a homemade apparatus for producing and inhaling nitrous oxide. Colt soon left the laughing gas business and got into the more lucrative firearm industry, but the inhalation demonstrations caught on with certain segments of the public, and by the 1840s, had become the craze.

Like bootleg liquor in the 1920s and 30s and marijuana in the 1960s and 70s, nitrous oxide appealed primarily to young people, who took to gathering in parties for "inhalation frolics." In their experimental zeal, these enthusiasts began to use other inhalable substances at their gatherings, ether among them. One of the consequences of unregulated inhalation was that more than a few people reeled and rocked and fell flat on their faces without feeling any pain. Sooner or later, someone was bound to notice the medical possibilities, as Davy had. Unfortunately, once again the progress of anaesthetic research was thwarted because the first man to actually test the efficacy of ether inhalation for surgery decided to keep his discovery to himself for years!

A physician by the name of Dr. Crawford Williamson Long in Jefferson, Georgia, a habitue of ether frolics, noticed that he came home with large bruises on his body and no recollection of having fallen painfully. It happened that one of Long's patients had two small tumors on the back of his neck, and the patient, James M. Venable, had also attended several ether frolics and didn't need to be convinced to try an experiment when the time came for excising the tumors. On March 30, 1842 - a date which might have been far more significant if Dr. Long had been half the promoter that were several of the characters who will soon enter the story - Long performed a successful surgery. He put his patient to sleep with ether, removed the tumors on his neck, and when Venable awoke, the doctor had to show him the tumors to convince him they had actually been removed.

Years later, Long said the reason he didn't publish his results or attempt to patent them or contact medical researchers was that he was waiting to see if any other medical authority made the same discovery. He continued to use ether in his own practice until rumor spread that it was dangerous and the townspeople of Jefferson threatened to shut him down. It was up to a young dentist in Hartford, Connecticut to move the story forward. Horace Wells attended one of the public demonstrations of nitrous oxide. During this particular demonstration, a man from the audience went briefly amok and flailed into the seats near Wells, quite insensible to the severe bruises he was inflicting on himself. Wells asked the owner of the show, a man by the name of Gardner Quincy Colton, whether he thought a tooth might be pulled under the influence of the gas.

"A Radical Cure" by Daumier

The next day, Colton took a bag of the gas to Wells' office and administered it to Wells himself, while another dentist pulled one of his teeth. Wells was elated. He was sure they could make medical history — and fortunes for themselves. He looked up an old partner in Boston, William Morton. Morton convinced Wells to see yet a third doctor, Charles Thomas Jackson. The cast of characters suddenly expanded, and the antics of Wells, Colton, Morton and Jackson took decades to play out.

Jackson was a strange fellow, and not entirely to be trusted. At key moments in this history, he was to give other characters important pieces of information, but he was also capable of misinforming them as well. At the first meeting, Jackson tried to convince Morton and Wells to abandon their quest. Wells didn't take his advice. In fact, he convinced a distinguished group of physicians to attend a demonstration at Massachusetts General Hospital.

In 1845, in full view of skeptical surgeons and medical students, Wells attempted to extract a tooth from a student volunteer. Something went wrong with the anaesthetics and the student leaped up, howling with pain. Although it would simply have been a mistake in private research, it was quite a disaster as a public demonstration and Wells slinked back to Hartford. Morton, however, was unshaken in his obsession with making a name and fortune for himself in the field of anaesthesia.

None of these people was a great scientist, and their motives in many instances seemed to be more for profit than humanitarian, but somehow in their plots and plans and conspiracies, they managed to move anaesthesia research forward. Morton went back to Jackson to ask him whether he thought ether might be a better substance to use. Jackson was partially helpful, partially irascible.

Morton experimented with ether on his family dog and goldfish at his summer home until his family convinced him to leave his pets alone. He then continued to experiment haphazardly by himself but wasn't having enough success to dare a public demonstration. So, he went to Jackson again, who told him to use sulfuric rather than choleric ether — a crucial bit of information, as it turned out. Morton convinced a dentist named Hayden, who had taken over his practice when his obsession began taking up most of his time, to try sulfuric ether. They seized the next patient to walk through the door, a musician by the name of Ebon Frost, and pulled his bicuspid under the effects of sulfuric ether anaesthesia on September 30, 1846.

Morton filed a patent application in October. The time came for Morton to risk his own career the way Wells had done a year before. He found a surgeon, again at Massachusetts General Hospital, who was willing to put Morton's reputation on the line and settle the question of ether anaesthesia once and for all.

The surgeon's name was Dr. John Collins Warren. He had selected a patient by the name of Gilbert Abbot, who was suffering from a tumor on his neck. On the day of the operation, the tiers of spectator seats of the Massachusetts General Hospital were filled. The patient was wheeled in. Dr. Warren lectured briefly, explaining what he and Dr. Morton — who was nowhere to be seen — planned to do. When he was finished speaking, Warren looked around and Morton failed to step forward. The audience grew fidgety, began to jeer, and Dr. Warren announced, "Since Dr. Morton has not appeared, I presume he is otherwise engaged."

At the moment Dr. Warren reached for his scalpel, a breathless Morton burst into the operating theater with a new inhaler, which his instrument-maker had had trouble installing. He also brought Ebon Frost along with him.

Warren announced, sarcasm evident in his tone, "Well, sir, your patient is ready."

Morton stepped up and asked Mr. Abbott if he was afraid, and pointed out Ebon Frost, who was prepared to testify to ether's effectiveness. Mr. Abbott, however, didn't require any convincing. Morton etherized him. Abbott breathed, twitched a couple of times, then slumped. Morton turned to Warren and replied, "Doctor, your patient is ready."

Warren removed the tumor and sutured the wound before Abbott returned to consciousness. The patient had not felt a single twinge of pain. Turning to the assembled gallery, Warren declared to the crowd, his voice trembling with emotion, "Gentlemen, this is no humbug."

Two months later, the British surgeon, Robert Liston, used ether for an amputation, the occasion for another famous operating theater scene. Once again, the gallery was packed and skeptical. Echoing the preoperative sarcasm of his American colleague, Dr. Warren, Liston announced to the gallery, "Gentlemen, we are going to try a Yankee dodge to make men insensible."

The patient, Frederick Churchill, had blood poisoning as the result of a compound fracture and amputation was necessary to save his life. Churchill was strapped to the operating table, a sponge of ether was placed over his mouth and Robert Liston removed the leg at the thigh in twenty-eight seconds. Bleeding was controlled and the stump treated. Churchill finally woke up and asked when they were going to begin. Dr Liston, his voice shaking, announced, "This Yankee dodge, gentlemen, beats mesmerism hollow."

One of the characteristic ironies of this convoluted story is that Joseph Lister was one of the people in the audience the day Dr. Liston performed that historic amputation. The other characters who carried the drama thus far spent the rest of their lives entangled with their roles in the history, one way or another. Horace Wells, the Hartford dentist who had approached Morton, found himself in jail in 1848, accused of throwing acid on two girls. He committed suicide. Jackson spent the rest of his days making sure that he thwarted Morton, finally ruining him financially by successfully petitioning the American Congress for an award of damages in the amount of $100,000. Morton died at 49, a pauper on a park bench. Jackson spent his final years in an insane asylum.

Others went on to experiment with chloroform as a still better anaesthetic agent, and Queen Victoria, the inadvertent patron of surgical innovation who also made carbolic acid antiseptics fashionable, legitimized the procedure in 1853. She gave birth to her eighth child, Prince Leopold, under the influence of chloroform. After that, this anaesthesia became immediately acceptable.

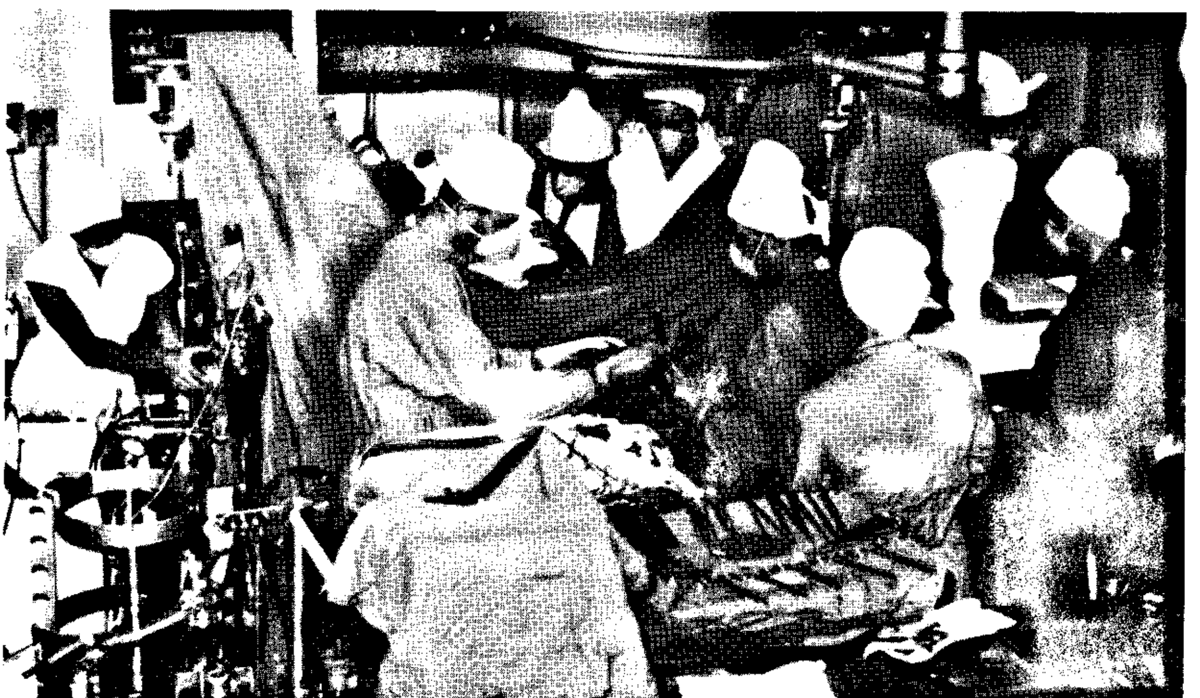
With the conquest of pain and the great breakthroughs against infection, surgeons proliferated and specialized, exploring heretofore forbidden reaches of the human body. At about the same time the antiseptic and anaesthetic revolutions were well established, World War I came along to give the craft of surgery another evolutionary boost. Antibiotics, World War II and transfusion technologies combined to accelerate progress in chest surgery, abdominal surgery, brain surgery and other new fields. Cancerous tumors within lungs or intestines could be removed, prolonging the lives of previously hopeless patients. The heart itself was within reach. After the second world war came the most intense period of scientific and technological development in history. Surgery has evolved more spectacularly in the past four decades than most of previous history. It has become a team operation. And part of that team is technology.

Surgery and Technology: The 20th Century and Beyond

Heart surgery requires tight communication and coordination. In order to repair a human heart by cutting, a surgeon is the focus of a team that has to work together in harmony and precision for hours at a time. Besides the surgeon, open-heart surgery requires a specially trained nursing staff and an anesthetist at hand; and radiologists, physiologists and biochemists who help in the careful planning stages. The first true heart surgery didn't happen until 1938. Just 29 years later, in 1967, the first human heart transplant was accomplished. By the mid-1980s heart transplants weren't commonplace, but success rates were climbing. And in 1982, the first artificial heart implant was accomplished.

The first heart surgery patients were babies. Certain kinds of congenital heart defects meant certain death within days, and these were the first heart conditions to be treated surgically. In 1938, Robert Gross of Boston operated to close a ductus arteriosus, a blood vessel that joins the pulmonary artery to the aorta, diverting blood from the embryo's lungs during gestation. This vessel normally closes after birth; if it doesn't, the infant is in danger. The operation was a success, and doctors began to operate on heart valves and major arteries. One problem with heart surgery, though, was that they were never able to stop the heart and look inside, so all operations in the heart's interior had to be done strictly by feel.

In the early 1950s, hypothermia — lowering the patient's temperature and



Dr. Christian Barnard performs the first heart transplant.

thus slowing vital functions — was introduced. Soon after, the first machines for diverting blood flow from the heart began to envolve into true heart-lung machines. It became possible to stop the heart, open it, and repair it without damaging vital brain tissue. Open-heart surgery left the laboratory and became widespread hospital practice. In the 1960s, another convergence of knowledge, technology and surgical technique occurred. Biological knowledge about the way the immune system rejects foreign tissue combined with a decade of development of open-heart surgery and another milestone was achieved on December 3, 1967.

On that date, a team led by Christaan Barnard at Groote Schuur Hospital in Cape Town, South Africa, transplanted the heart of a twenty-four-year-old girl, dead of head injuries, into the fifty-four-year-old Louis Washkansky. Washkansky's own heart was 90 percent destroyed by repeated heart attacks, and he would have died within hours or days without the operation. After the surgery, he lived for 18 days. In America, Doctors Adrian Kantrowitz and Norman Shumway began to perform heart transplants. Over the years, survival time has been pushed from days to weeks to months to over a year. Due largely to the difficulties of suppressing tissue rejection without damaging the patient's immune system, progress in prolonging postoperative survival of heart transplants has kept it from becoming a standard procedure.

On December 2, 1982, a team at the University of Utah Medical Center, headed by William C. DeVries, implanted an artificial heart, designed by Robert Jarvik, into the chest of Barney Clark, 61. Clark, a retired dentist, died on March 23, 1983.

Computer technology, laser technology and immunosuppressive drugs are already advancing the state of the surgical art. Basic knowledge about the immune system, cellular function and biochemistry is emerging from research laboratories and entering medical clinics in the form of new preoperative imaging techniques, operative monitoring systems and postoperative treatments. The economic cost of highly technologized medicine has become a social issue, but never before in history have surgeons faced such exciting prospects for the future.

With increasingly sophisticated and powerful imaging technologies for peering deeply into the body, laser scalpels for eye surgery and microsurgery, tools for monitoring blood gases, the technological element of the 20th century continues to generate headlines straight out of yesterday's science fiction.

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