Medical Surgeries and Diagnostic Procedures

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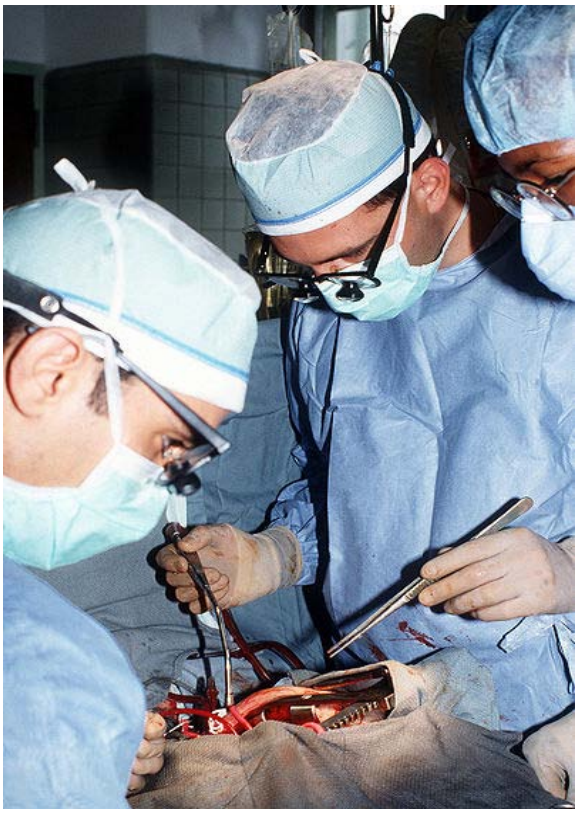
Chapter 1

Surgery



A cardiothoracic surgeon performs a mitral valve replacement at the Fitzsimons Army Medical Center.

Surgery (from the Greek: χειρουργική *cheirourgikē*, via Latin: *chirurgiae*, meaning "hand work") is an ancient medical specialty that uses operative manual and instrumental techniques on a patient to investigate and/or treat a pathological condition such as disease or injury, to help improve bodily function or appearance, and sometimes for religious reasons. An act of performing surgery may be called a **surgical procedure**, **operation**, or simply **surgery**. In this context, the verb **operate** means performing surgery. The adjective **surgical** means pertaining to surgery; e.g. surgical instruments or surgical nurse. The patient or subject on which the surgery is performed can be a person or an animal. A surgeon is a person who performs operations on patients. In rare cases,

surgeons may operate on themselves. Persons described as surgeons are commonly physicians, but the term is also applied to podiatric physicians, dentists (or known as oral and maxillofacial surgeon) and veterinarians. Surgery can last from minutes to hours, but is typically not an ongoing or periodic type of treatment.

The term *surgery* can also refer to the place where surgery is performed, or simply the office of a physician, dentist / oral and maxillofacial surgeon, or veterinarian.

Definitions of surgery

Surgery is a technology consisting of a physical intervention on tissues.

As a general rule, a procedure is considered surgical when it involves cutting of a patient's tissues or closure of a previously sustained wound. Other procedures that do not necessarily fall under this rubric, such as angioplasty or endoscopy, may be considered surgery if they involve "common" surgical procedure or settings, such as use of a sterile environment, anesthesia, antiseptic conditions, typical surgical instruments, and suturing or stapling. All forms of surgery are considered invasive procedures; so-called "noninvasive surgery" usually refers to an excision that does not penetrate the structure being excised (e.g. laser ablation of the cornea) or to a radiosurgical procedure (e.g. irradiation of a tumor).

Types of surgery

Surgical procedures are the commonly categorized by urgency, type of procedure, body system involved, degree of invasiveness, and special instrumentation.

- Based on timing: Elective surgery is done to correct a non-life-threatening condition, and is carried out at the patient's request, subject to the surgeon's and the surgical facility's availability. Emergency surgery is surgery which must be done promptly to save life, limb, or functional capacity. A semi-elective surgery is one that must be done to avoid permanently disability or death, but can be postponed for a short time.
- Based on purpose: Exploratory surgery is performed to aid or confirm a diagnosis. Therapeutic surgery treats a previously diagnosed condition.
- By type of procedure: Amputation involves cutting off a body part, usually a limb or digit. Replantation involves reattaching a severed body part. Reconstructive surgery involves reconstruction of an injured, mutilated, or deformed part of the body. Cosmetic surgery is done to improve the appearance of an otherwise normal structure. Excision is the cutting out of an organ, tissue, or other body part from the patient. Transplant surgery is the replacement of an organ or body part by insertion of another from different human (or animal) into the patient. Removing an organ or body part from a live human or animal for use in transplant is also a type of surgery.
- By body part: When surgery is performed on one organ system or structure, it may be classed by the organ, organ system or tissue involved. Examples include

cardiac surgery (performed on the heart), gastrointestinal surgery (performed within the digestive tract and its accessory organs), and orthopedic surgery (performed on bones and/or muscles).

- By degree of invasiveness: Minimally invasive surgery involves smaller outer incision(s) to insert miniaturized instruments within a body cavity or structure, as in laparoscopic surgery or angioplasty. By contrast, an open surgical procedure or laparotomy requires a large incision to access the area of interest.
- By equipment used: Laser surgery involves use of a laser for cutting tissue instead of a scalpel or similar surgical instruments. Microsurgery involves the use of an operating microscope for the surgeon to see small structures. Robotic surgery makes use of a surgical robot, such as the Da Vinci or the Zeus surgical systems, to control the instrumentation under the direction of the surgeon.

Terminology

- Excision surgery names often start with a name for the organ to be excised (cut out) and end in **-ectomy**.
- Procedures involving cutting into an organ or tissue end in **-otomy**. A surgical procedure cutting through the abdominal wall to gain access to the abdominal cavity is a laparotomy.
- Minimally invasive procedures involving small incisions through which an endoscope is inserted end in **-oscopy**. For example, such surgery in the abdominal cavity is called laparoscopy.
- Procedures for formation of a permanent or semi-permanent opening called a stoma in the body end in **-ostomy**.
- Reconstruction, plastic or cosmetic surgery of a body part starts with a name for the body part to be reconstructed and ends in **-oplasty**. *Rhino* is used as a prefix for "nose", so *rhinoplasty* is basically reconstructive or cosmetic surgery for the nose.
- Reparation of damaged or congenital abnormal structure ends in **-rraphy**. Herniorraphy is the reparation of a hernia, while perineorraphy is the reparation of perineum.

Description of surgical procedure

At a hospital, modern surgery is often done in an operating theater using surgical instruments, an operating table for the patient, and other equipment. The environment and procedures used in surgery are governed by the principles of aseptic technique: the strict separation of "sterile" (free of microorganisms) things from "unsterile" or "contaminated" things. All surgical instruments must be sterilized, and an instrument must be replaced or re-sterilized if it becomes contaminated (i.e. handled in an unsterile manner, or allowed to touch an unsterile surface). Operating room staff must wear sterile attire (scrubs, a scrub cap, a sterile surgical gown, sterile latex or non-latex polymer gloves and a surgical mask), and they must scrub hands and arms with an approved disinfectant agent before each procedure.

Prior to surgery, the patient is given a medical examination, certain pre-operative tests, and their physical status is rated according to the ASA physical status classification system. If these results are satisfactory, the patient signs a consent form and is given a surgical clearance. If the procedure is expected to result in significant blood loss, an autologous blood donation may be made some weeks prior to surgery. If the surgery involves the digestive system, the patient may be instructed to perform a bowel prep by drinking a solution of polyethylene glycol the night before the procedure. Patients are also instructed to abstain from food or drink (an NPO order after midnight on the night before the procedure, to minimize the effect of stomach contents on pre-operative medications and reduce the risk of aspiration if the patient vomits during or after the procedure.

In the pre-operative holding area, the patient changes out of his or her street clothes and is asked to confirm the details of his or her surgery. A set of vital signs are recorded, a peripheral IV line is placed, and pre-operative medications (antibiotics, sedatives, etc.) are given. When the patient enters the operating room, the skin surface to be operated on, called the operating field, is cleaned and prepared by applying an antiseptic such as chlorhexidine gluconate or povidone-iodine to reduce the possibility of infection. If hair is present at the surgical site, it is clipped off prior to prep application. The patient is assisted by an anesthesiologist or resident to make a specific surgical position, then sterile drapes are used to cover all of the patient's body except for the head and the surgical site or at least a wide area surrounding the operating field; the drapes are clipped to a pair of poles near the head of the bed to form an "ether screen", which separates the anesthetist/anesthesiologist's working area (unsterile) from the surgical site (sterile).

Anesthesia is administered to prevent pain from incision, tissue manipulation and suturing. Based on the procedure, anesthesia may be provided locally or as general anesthesia. Spinal anesthesia may be used when the surgical site is too large or deep for a local block, but general anesthesia may not be desirable. With local and spinal anesthesia, the surgical site is anesthetized, but the patient can remain conscious or minimally sedated. In contrast, general anesthesia renders the patient unconscious and paralyzed during surgery. The patient is intubated and is placed on a mechanical ventilator, and anesthesia is produced by a combination of injected and inhaled agents.

An incision is made to access the surgical site. Blood vessels may be clamped to prevent bleeding, and retractors may be used to expose the site or keep the incision open. The approach to the surgical site may involve several layers of incision and dissection, as in abdominal surgery, where the incision must traverse skin, subcutaneous tissue, three layers of muscle and then peritoneum. In certain cases, bone may be cut to further access the interior of the body; for example, cutting the skull for brain surgery or cutting the sternum for thoracic (chest) surgery to open up the rib cage.

Work to correct the problem in body then proceeds. This work may involve:

- excision - cutting out an organ, tumor, or other tissue.
- resection - partial removal of an organ or other bodily structure.

- reconnection of organs, tissues, etc., particularly if severed. Resection of organs such as intestines involves reconnection. Internal suturing or stapling may be used. Surgical connection between blood vessels or other tubular or hollow structures such as loops of intestine is called anastomosis.
- ligation - tying off blood vessels, ducts, or "tubes".
- grafts - may be severed pieces of tissue cut from the same (or different) body or flaps of tissue still partly connected to the body but resewn for rearranging or restructuring of the area of the body in question. Although grafting is often used in cosmetic surgery, it is also used in other surgery. Grafts may be taken from one area of the patient's body and inserted to another area of the body. An example is bypass surgery, where clogged blood vessels are bypassed with a graft from another part of the body. Alternatively, grafts may be from other persons, cadavers, or animals.
- insertion of prosthetic parts when needed. Pins or screws to set and hold bones may be used. Sections of bone may be replaced with prosthetic rods or other parts. Sometime a plate is inserted to replace a damaged area of skull. Artificial hip replacement has become more common. Heart pacemakers or valves may be inserted. Many other types of prostheses are used.
- creation of a stoma, a permanent or semi-permanent opening in the body
- in transplant surgery, the donor organ (taken out of the donor's body) is inserted into the recipient's body and reconnected to the recipient in all necessary ways (blood vessels, ducts, etc.).
- arthrodesis - surgical connection of adjacent bones so the bones can grow together into one. Spinal fusion is an example of adjacent vertebrae connected allowing them to grow together into one piece.
- modifying the digestive tract in bariatric surgery for weight loss.
- repair of a fistula, hernia, or prolapse
- other procedures, including:
    - clearing clogged ducts, blood or other vessels
    - removal of calculi (stones)
    - draining of accumulated fluids
    - debridement- removal of dead, damaged, or diseased tissue
- Surgery has also been conducted to separate conjoined twins.
- Sex change operations

Blood or blood expanders may be administered to compensate for blood lost during surgery. Once the procedure is complete, sutures or staples are used to close the incision. Once the incision is closed, the anesthetic agents are stopped and/or reversed, and the patient is taken off ventilation and extubated (if general anesthesia was administered).

After completion of surgery, the patient is transferred to the post anesthesia care unit and closely monitored. When the patient is judged to have recovered from the anesthesia, he/she is either transferred to a surgical ward elsewhere in the hospital or discharged home. During the post-operative period, the patient's general function is assessed, the

outcome of the procedure is assessed, and the surgical site is checked for signs of infection. There are several risk factors associated with post operative complications, such as immune deficienty and obesity. Obesity has long been considered a risk factor for adverse post-surgical outcomes. It has been linked to many disorders such as obesity hypoventilation syndrome, atelectasis and pulmonary embolism, adverse cardiovascular affects, and wound healing complications. If removable skin closures are used, they are removed after 7 to 10 days post-operatively, or after healing of the incision is well under way.

Post-operative therapy may include adjuvant treatment such as chemotherapy, radiation therapy, or administration of medication such as anti-rejection medication for transplants. Other follow-up studies or rehabilitation may be prescribed during and after the recovery period.

In special populations

Elderly people

Older adults have widely varying physical health. Frail elderly people are at significant risk of post-surgical complications and the need for extended care. Assessment of older patients before elective surgeries can accurately predict the patients' recovery trajectories. One frailty scale uses five items: unintentional weight loss, muscle weakness, exhaustion, low physical activity, and slowed walking speed. A healthy person scores 0; a very frail person scores 5. Compared to non-frail elderly people, people with intermediate frailty scores (2 or 3) are twice as likely to have post-surgical complications, spend 50% more time in the hospital, and are three times as likely to be discharged to a skilled nursing facility instead of to their own homes. Frail elderly patients (score of 4 or 5) have even worse outcomes, with the risk of being discharged to a nursing home rising to twenty times the rate for non-frail elderly people.

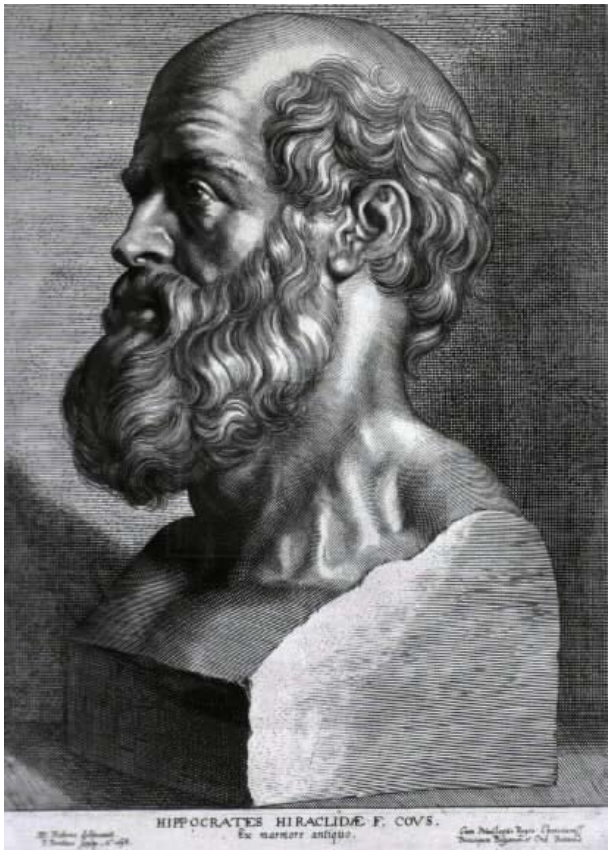
History

At least two prehistoric cultures had developed forms of surgery. The oldest for which there is evidence is trepanation, in which a hole is drilled or scraped into the skull, thus exposing the dura mater in order to treat health problems related to intra cranial pressure and other diseases. Evidence has been found in prehistoric human remains from Neolithic times, in cave paintings, and the procedure continued in use well into recorded history. Surprisingly, many prehistoric and premodern patients had signs of their skull structure healing; suggesting that many survived the operation. Remains from the early Harappan periods of the Indus Valley Civilization (c. 3300 BCE) show evidence of teeth having been drilled dating back 9,000 years. A final candidate for prehistoric surgical techniques is Ancient Egypt, where a mandible dated to approximately 2650 BCE shows two perforations just below the root of the first molar, indicating the draining of an abscessed tooth.

The oldest known surgical texts date back to ancient Egypt about 3500 years ago. Surgical operations were performed by priests, specialized in medical treatments similar to today. The procedures were documented on papyrus and were the first to describe patient case files; the Edwin Smith Papyrus (held in the New York Academy of Medicine) documents surgical procedures based on anatomy and physiology, while the Ebers Papyrus describes healing based on magic. Their medical expertise was later documented by Herodotus: "The practice of medicine is very specialized among them. Each physician treats just one disease. The country is full of physicians, some treat the eye, some the teeth, some of what belongs to the abdomen, and others internal diseases."

Other ancient cultures to have surgical knowledge include India, China and Greece.

Sushruta (also spelled Susruta or Sushrutha), c. 6th century BCE,is known as the Father of Surgery. He was a renowned surgeon of Ancient India and the author of the book *Sushruta Samhita*. In his book written in Sanskrit, he described over 120 surgical instruments, 300 surgical procedures and classifies human surgery into 8 categories. He performed Plastic Surgeries, Cataract operations and Cesarean. He used to give a kind of herbal juice equivalent to anesthetics. He was a surgeon from the Dhanvantari school of Ayurveda.



Hippocrates stated in the oath (c. 400 BC) that general physicians must never practice surgery and that surgical procedures are to be conducted by specialists.

In ancient Greece, temples dedicated to the healer-god Asclepius, known as *Asclepieia* (Greek: Ασκληπιεία, sing. *Asclepieion Ασκληπιείον*), functioned as centers of medical advice, prognosis, and healing. At these shrines, patients would enter a dream-like state of induced sleep known as "enkoimesis" (Greek: ενκοίμησις) not unlike anesthesia, in which they either received guidance from the deity in a dream or were cured by surgery. In the Asclepieion of Epidaurus, three large marble boards dated to 350 BCE preserve the names, case histories, complaints, and cures of about 70 patients who came to the temple with a problem and shed it there. Some of the surgical cures listed, such as the opening of an abdominal abscess or the removal of traumatic foreign material, are realistic enough to have taken place, but with the patient in a state of enkoimesis induced with the help of soporific substances such as opium.

The Greek Galen was one of the greatest surgeons of the ancient world and performed many audacious operations — including brain and eye surgery — that were not tried again for almost two millennia.

In China, Hua Tuo was a famous Chinese physician during the Eastern Han and Three Kingdoms era who performed surgery with the aid of anesthesia.

In the Middle Ages, surgery was developed to a high degree in the Islamic world. Abulcasis (Abu al-Qasim Khalaf ibn al-Abbas Al-Zahrawi), an Andalusian-Arab physician and scientist who practised in the Zahra suburb of Córdoba, wrote medical texts that shaped European surgical procedures up until the Renaissance.

In Europe, the demand grew for surgeons to formally study for many years before practicing; universities such as Montpellier, Padua and Bologna were particularly renowned. According to Peter Elmer and Ole Peter Grell, "Guy de Chauliac (1298-1368) was one of the most eminent surgeons of the Middle Ages. His *Chirurgia Magna* or *Great Surgery* (1363) was a standard text for surgeons until well into the seventeenth century." By the fifteenth century at the latest, surgery had split away from physic as its own subject, of a lesser status than pure medicine, and initially took the form of a craft tradition until Rogerius Salernitanus composed his *Chirurgia*, laying the foundation for modern Western surgical manuals up to the modern time. Late in the nineteenth century, Bachelor of Surgery degrees (usually ChB) began to be awarded with the (MB), and the mastership became a higher degree, usually abbreviated ChM or MS in London, where the first degree was MB, BS.

Barber-surgeons generally had a bad reputation that was not to improve until the development of academic surgery as a specialty of medicine, rather than an accessory field. Basic surgical principles for asepsis etc., are known as Halsteads principles

Modern surgery

Modern surgery developed rapidly with the scientific era. Ambroise Paré (sometimes spelled "Ambrose") pioneered the treatment of gunshot wounds, and the first modern surgeons were battlefield doctors in the Napoleonic Wars. Naval surgeons were often

barber surgeons, who combined surgery with their main jobs as barbers. Three main developments permitted the transition to modern surgical approaches - control of bleeding, control of infection and control of pain (anaesthesia).

Bleeding

Before modern surgical developments, there was a very real threat that a patient would bleed to death before treatment, or during the operation. Cauterization (fusing a wound closed with extreme heat) was successful but limited - it was destructive, painful and in the long term had very poor outcomes. Ligatures, or material used to tie off severed blood vessels, originated as early as ancient Rome, and were improved by Ambroise Paré in the 16th century. Though this method was a significant improvement over the method of cauterization, it was still dangerous until infection risk was brought under control - at the time of its discovery, the concept of infection was not fully understood. Finally, early 20th century research into blood groups allowed the first effective blood transfusions.

Pain

Modern pain control through anesthesia was discovered by two American dental surgeons, Horace Wells (1815–1848) and William T. G. Morton. Before the advent of anesthesia, surgery was a traumatically painful procedure and surgeons were encouraged to be as swift as possible to minimize patient suffering. This also meant that operations were largely restricted to amputations and external growth removals. Beginning in the 1840s, surgery began to change dramatically in character with the discovery of effective and practical anaesthetic chemicals such as ether and chloroform, later pioneered in Britain by John Snow. In addition to relieving patient suffering, anaesthesia allowed more intricate operations in the internal regions of the human body. In addition, the discovery of muscle relaxants such as curare allowed for safer applications.

Infection

Unfortunately, the introduction of anesthetics encouraged more surgery, which inadvertently caused more dangerous patient post-operative infections. The concept of infection was unknown until relatively modern times. The first progress in combating infection was made in 1847 by the Hungarian doctor Ignaz Semmelweis who noticed that medical students fresh from the dissecting room were causing excess maternal death compared to midwives. Semmelweis, despite ridicule and opposition, introduced compulsory handwashing for everyone entering the maternal wards and was rewarded with a plunge in maternal and fetal deaths, however the Royal Society in the UK still dismissed his advice. Significant progress came following the work of Louis Pasteur and his advances in microbiology, when the British surgeon Joseph Lister began experimenting with using phenol during surgery to prevent infections. Lister was able to quickly reduce infection rates, a reduction that was further helped by his subsequent introduction of the techniques of Robert Koch (such as the Steam Steriliser, which proved more successful than the carbolic acid spray that Lister had been using previously) to sterilize equipment, have rigorous hand washing and a later implementation of rubber gloves. Lister published his work as a series of articles in The Lancet (March 1867) under the title *Antiseptic Principle of the Practice of*

Surgery. The work was groundbreaking and laid the foundations for a rapid advance in infection control that saw modern aseptic operating theatres widely used within 50 years (Lister himself went on to make further strides in antisepsis and asepsis throughout his lifetime).

Surgical specialties and sub-specialties

- General surgery
  - Cardiothoracic surgery
  - Colorectal surgery
  - Paediatric surgery
  - Plastic surgery
  - Vascular surgery
  - Transplant surgery
  - Trauma surgery
  - Breast surgery
  - Surgical oncology
  - Endocrine surgery
  - Skin surgery
- Otolaryngology
- Gynecology
- Oral and maxillofacial surgery
- Orthopaedic surgery
- Neurosurgery
- Ophthalmology
- Podiatric surgery
- Urology

Some other specialties involve some forms of surgical intervention, especially gynaecology. Also, some people consider invasive methods of treatment/diagnosis, such as cardiac catheterization, endoscopy, and placing of chest tubes or central lines "surgery". In most parts of the medical field, this view is not shared.

Patronage

The patron saints for surgeons are Saint Luke the Evangelist the physician and disciple of Christ, Saints Cosmas and Damian (3rd century physicians from Syria), Saint Quentin (3rd century saint from France), Saint Foillan (7th century saint from Ireland), and Saint Roch (14th century saint from France).

Chapter 2

General Surgery

A surgeon operating

General surgery, despite its name, is a surgical specialty that focuses on abdominal organs, e.g., intestines including esophagus, stomach, small bowel, colon, liver, pancreas, gallbladder and bile ducts, and often the thyroid gland (depending on the availability of head and neck surgery specialists). They also deal with diseases involving the skin, breast, and hernias. These surgeons deal mainly in the Torso.

Scope

With the prevalent trend for increasing sub-specialization in today's medical practice, General Surgery has lost most of its former glory and scope. Nonetheless, it continues to be a somewhat competitive, rewarding and demanding specialty in its own right. Until recently, all surgeons in the United States were required to be board certified by the American Board of Surgery in order to progress into further sub-specialty training. However, recently, board certification has been delegated into separate sub-branches, whereby successful completion of a Residency in General Surgery is not necessarily required, but may well be desired - depending on the country and area of practice, as well as the individual sub-specialty.

Many sub-specialties are still part of the General Surgical training program. That is, General Surgeons may sub-specialize into one or more of the following disciplines:

Trauma surgery

In the United States and Canada, the overall responsibility for trauma care falls under the auspices of general surgery. Some general surgeons obtain advanced training and specialty certification in this field alone. General surgeons must be able to deal initially with almost any surgical emergency. Often they are the first port of call to critically ill or gravely injured patients, and must perform a variety of procedures to stabilise such patients, such as intubation, burr hole, cricothyroidotomy, and emergency laparotomy or thoracotomy to stanch bleeding.

All General Surgeons are trained in emergency surgery. Bleeding, infections, bowel obstructions and organ perforations are the main problems they deal with. Cholecystectomy, the surgical removal of the gallbladder, is one of the most common surgical procedures done worldwide. This is most often done electively, but the gallbladder can become acutely inflamed and require an emergency operation. Ruptures of the appendix and small bowel obstructions are other common emergencies.

Laparoscopic surgery

Is a relatively new specialty dealing with minimal access techniques using cameras and small instruments inserted through 0.5 to 1 cm incisions. Robotic surgery is now evolving from this concept. Gallbladders, appendices, and colons can all be removed with this technique. Hernias are now repaired mostly laparoscopically. Most bariatric surgery is performed laparoscopically. General surgeons that are trained today are expected to be proficient in laparscopic procedures.

Colorectal surgery

General Surgeons treat a wide variety of minor colon and rectal diseases ranging from inflammatory bowel diseases (such as ulcerative colitis or Crohn's disease)to diverticulitis, gastrointestinal bleeding, hemorrhoids, etc.

Breast surgery

General surgeons perform a majority of all non-cosmetic breast surgery from lumpectomy to mastectomy, especially pertaining to the evaluation and diagnosis, of breast cancer

Vascular surgery

General Surgeons can perform vascular surgery if they receive special training and certification in vascular surgery. Otherwise, these procedures are performed by vascular

surgery specialists. However, general surgeons are capable of treating minor vascular disorders.

Endocrine surgery

General Surgeons are trained to remove all or part of the thyroid and parathyroid glands in the neck and the adrenal glands just above each kidney in the abdomen. In many communities, they are the only surgeon trained to do this. In communities that have a number of subspecialists other subspecialty surgeons may assume responsibility for these procedures.

Dermatological Surgery

General Surgeons perform a wide variety of skin-related surgeries ranging from removing suspicious moles to treating major burns. General Surgeons also remove tumors that often grow just below the skin such as fatty tumors or tumors that arise in muscles or other soft tissues. General Surgeons also treat more complex skin or subcutaneous infections including necrotizing fasciitis and will often employ skin grafts to cover defects in the skin resulting from burns, trauma, or infections.

Trends

In the last few years minimally invasive surgery has become more prevalent. Considerable enthusiasm has built around robotic surgery (also known as *robotic-assisted surgery*), despite a lack of data suggesting it has significant benefits that justify its cost.

Training

In Canada, Australia, New Zealand, and the United States general surgery is a five to seven year residency and follows completion of medical school, either MD, MBBS, MBChB, or DO degrees. In Australia and New Zealand, a residency leads to eligibility for Fellowship of the Royal Australasian College of Surgeons. In Canada, residency leads to eligibility for Certification by and Fellowship of the Royal College of Physicians and Surgeons of Canada, while in the United States, completion of a residency in general surgery leads to eligibility for board certification by the American Board of Surgery which is also required upon completion of training for a general surgeon to have operating privileges at most hospitals in the United States.

In the United Kingdom, surgical trainees enter training after five years of medical school and two years of the Foundation Programme. During the two to three-year core training programme, doctors will sit the Membership of the Royal College of Surgeons (MRCS) examination. On award of the MRCS examination, surgeons may hold the title 'Mister' or 'Miss/Ms' rather than doctor. This is a tradition dating back hundreds of years in the United Kingdom that is still in use today. Trainees will then go onto Higher Surgical Training (HST), lasting a further four to five years. During this time they may choose to subspecialise. Before the end of HST, the examination of Fellow of the Royal College of

Surgeons (FRCS) must be taken in General Surgery plus the subspeciality. Upon completion of training the surgeon will become a Consultant Surgeon and will be eligible for entry on the GMC Specialist Register and may work both in the NHS and independent sector as a Consultant General Surgeon. However, with the implementation of the European Working Time Directive limiting UK surgical residents to a 48-hour working week there are concerns that upon completion of training UK surgeons will not be confident enough to work independently. The introduction of a sub-consultant grade to enable those who have recently received a UK Certificate of Completion of Training may be necessary.

Subspecialization

In many countries general surgery is a prerequisite for subspecialization in:

- vascular surgery
- thoracic surgery
- cardiac surgery
- plastic surgery
- Surgical Critical Care

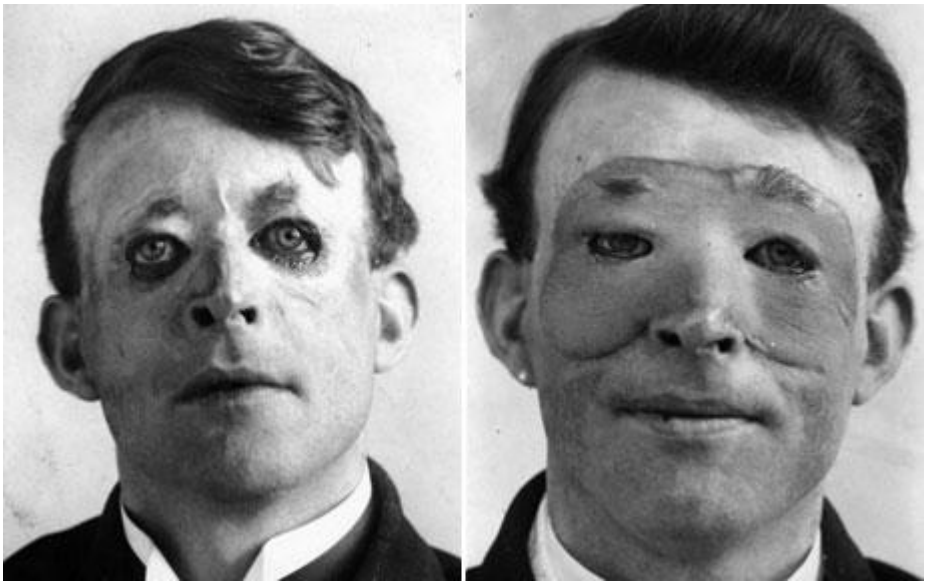
Chapter 3

Plastic Surgery

Plastic surgeon	
Occupation	
Names	Doctor, Medical Specialist
Type	Specialty
Activity sectors	Surgery
Description	
Education required	**MD or MBBS or DO-US**
Fields of employment	Hospitals, Clinics

Plastic Surgery is a medical specialty concerned with the correction or restoration of form and function. While famous for aesthetic surgery, plastic surgery also includes many types of reconstructive surgery, hand surgery, microsurgery, and the treatment of burns. The word "plastic" derives from the Greek *plastikos* (πλαστικός) meaning to mold or to shape, thus plastic surgery means "molding or shaping surgery" – its use here has no connection with plastics in the sense of synthetic polymer material. While the majority of cosmetic surgery comes under plastic surgery, most plastic surgery is not cosmetic surgery.

History



Walter Yeo, a British soldier, is often cited as the first known person to have benefited from plastic surgery. The photograph shows him before the procedure (left) and after (right) receiving a skin graft performed by Sir Harold Gillies in 1917.

Reconstructive surgery techniques were being carried out in India by 800 BC. Sushruta, the father of Indian surgery, made important contributions to the field of plastic and cataract surgery in 6th century BC. The medical works of both Sushruta and Charak originally in Sanskrit were translated into Arabic language during the Abbasid Caliphate in 750 AD. The Arabic translations made their way into Europe via intermediaries. In Italy the Branca family of Sicily and Gaspare Tagliacozzi (Bologna) became familiar with the techniques of Sushruta.

British physicians traveled to India to see rhinoplasties being performed by native methods. Reports on Indian rhinoplasty performed by a Kumhar vaidya were published in the *Gentleman's Magazine* by 1794. Joseph Constantine Carpue spent 20 years in India studying local plastic surgery methods. Carpue was able to perform the first major surgery in the Western world by 1815. Instruments described in the *Sushruta Samhita* were further modified in the Western world.

Aulus Cornelius Celsus, who lived in the first century AD, described plastic surgery of the face, using skin from other parts of the body.

The ancient Egyptians and Romans also performed plastic cosmetic surgery. The Romans were able to perform simple techniques, such as repairing damaged ears from around the 1st century BC. For religious reasons, they did not dissect either human beings or animals, thus their knowledge was based in its entirety on the texts of their Greek predecessors. Notwithstanding, Aulus Cornelius Celsus left some surprisingly accurate anatomical descriptions, some of which — for instance, his studies on the genitalia and the skeleton — are of special interest to plastic surgery.

In 1465, Sabuncuoglu's book, description, and classification of hypospadias was more informative and up to date. Localization of urethral meatus was described in detail. Sabuncuoglu also detailed the description and classification of ambiguous genitalia. In mid-15th century Europe, Heinrich von Pfolspeundt described a process "to make a new nose for one who lacks it entirely, and the dogs have devoured it" by removing skin from the back of the arm and suturing it in place. However, because of the dangers associated with surgery in any form, especially that involving the head or face, it was not until the 19th and 20th centuries that such surgery became common.

Up until the techniques of anesthesia became established, surgeries involving healthy tissues involved great pain. Infection from surgery was reduced by the introduction of sterile techniques and disinfectants. The invention and use of antibiotics, beginning with sulfa drugs and penicillin, was another step in making elective surgery possible.

In 1792, Chopart performed operative procedure on a lip using a flap from the neck. In 1814, Joseph Carpue successfully performed operative procedure on a British military officer who had lost his nose to the toxic effects of mercury treatments. In 1818, German surgeon Carl Ferdinand von Graefe published his major work entitled *Rhinoplastik*. Von Graefe modified the Italian method using a free skin graft from the arm instead of the original delayed pedicle flap.

The first American plastic surgeon was John Peter Mettauer, who, in 1827, performed the first cleft palate operation with instruments that he designed himself. In 1845, Johann Friedrich Dieffenbach wrote a comprehensive text on rhinoplasty, entitled *Operative Chirurgie*, and introduced the concept of reoperation to improve the cosmetic appearance of the reconstructed nose.

In 1891, American otorhinolaryngologist John Roe presented an example of his work, a young woman on whom he reduced a dorsal nasal hump for cosmetic indications. In 1892, Robert Weir experimented unsuccessfully with xenografts (duck sternum) in the reconstruction of sunken noses. In 1896, James Israel, a urological surgeon from Germany, and in 1889 George Monks of the United States each described the successful use of heterogeneous free-bone grafting to reconstruct saddle nose defects. In 1898, Jacques Joseph, the German orthopaedic-trained surgeon, published his first account of reduction rhinoplasty. In 1928, Jacques Joseph published *Nasenplastik und Sonstige Gesichtsplastik*.

20th century

In World War I, a New Zealand otolaryngologist working in London, Harold Gillies, developed many of the techniques of modern plastic surgery in caring for soldiers suffering from disfiguring facial injuries. His work was expanded upon during World War II by his cousin and former student Archibald McIndoe, who pioneered treatments for RAF aircrew suffering from severe burns. McIndoe's radical, experimental treatments, led to the formation of the Guinea Pig Club. In 1946, Gillies carried out the first female-to-male sex reassignment surgery.

Plastic surgery, as a specialty, evolved remarkably during the 18th century in the United States. One of the founders of the specialty, Vilray Blair, was the first chief of the Division of Plastic and Reconstructive Surgery at Washington University in St. Louis, Missouri. In one of his many areas of clinical expertise, Blair treated World War I soldiers with complex maxillofacial injuries, and his paper on "Reconstructive Surgery of the Face" set the standard for craniofacial reconstruction.

Techniques and procedures

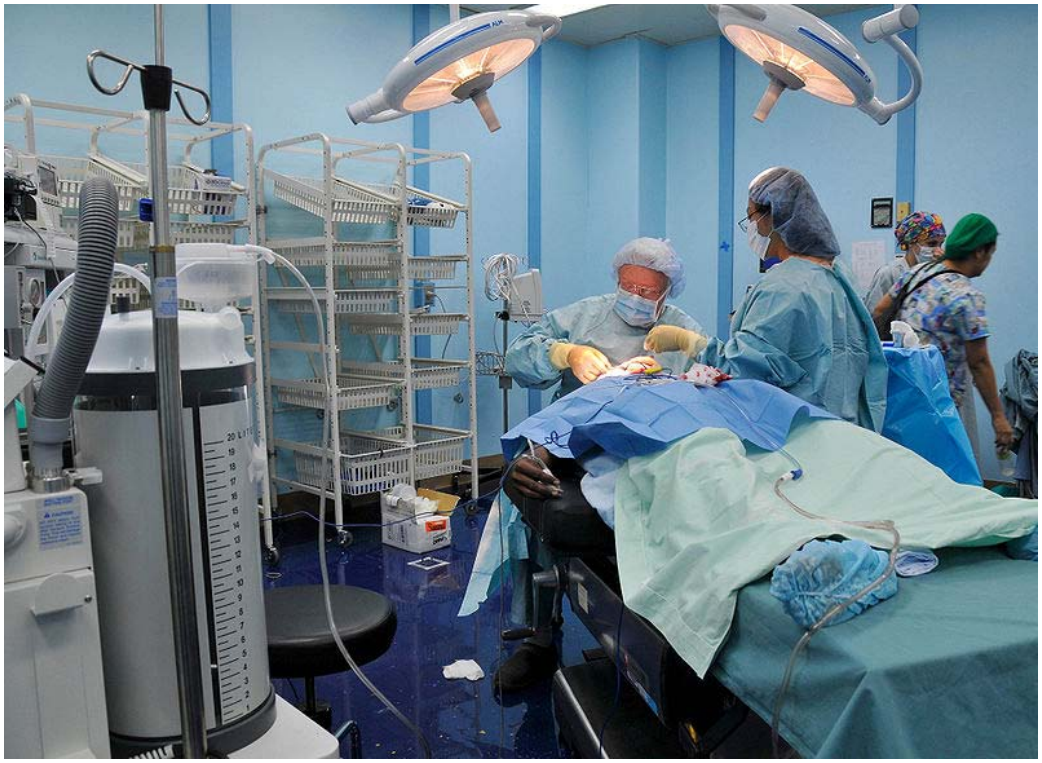
In plastic surgery, the transfer of skin tissue (skin grafting) is a very common procedure. Skin grafts can be taken from the recipient or donors:

- Autografts are taken from the recipient. If absent or deficient of natural tissue, alternatives can be cultured sheets of epithelial cells *in vitro* or synthetic compounds, such as integra, which consists of silicone and bovine tendon collagen with glycosaminoglycans.
- Allografts are taken from a donor of the same species.
- Xenografts are taken from a donor of a different species.

Usually, good results are expected from plastic surgery that emphasizes careful planning of incisions so that they fall in the line of natural skin folds or lines, appropriate choice of wound closure, use of best available suture materials, and early removal of exposed sutures so that the wound is held closed by buried sutures.

Reconstructive surgery

Reconstructive plastic surgery is performed to correct functional impairments caused by burns; traumatic injuries, such as facial bone fractures and breaks; congenital abnormalities, such as cleft palates or cleft lips; developmental abnormalities; infection and disease; and cancer or tumors. Reconstructive plastic surgery is usually performed to improve function, but it may be done to approximate a normal appearance.



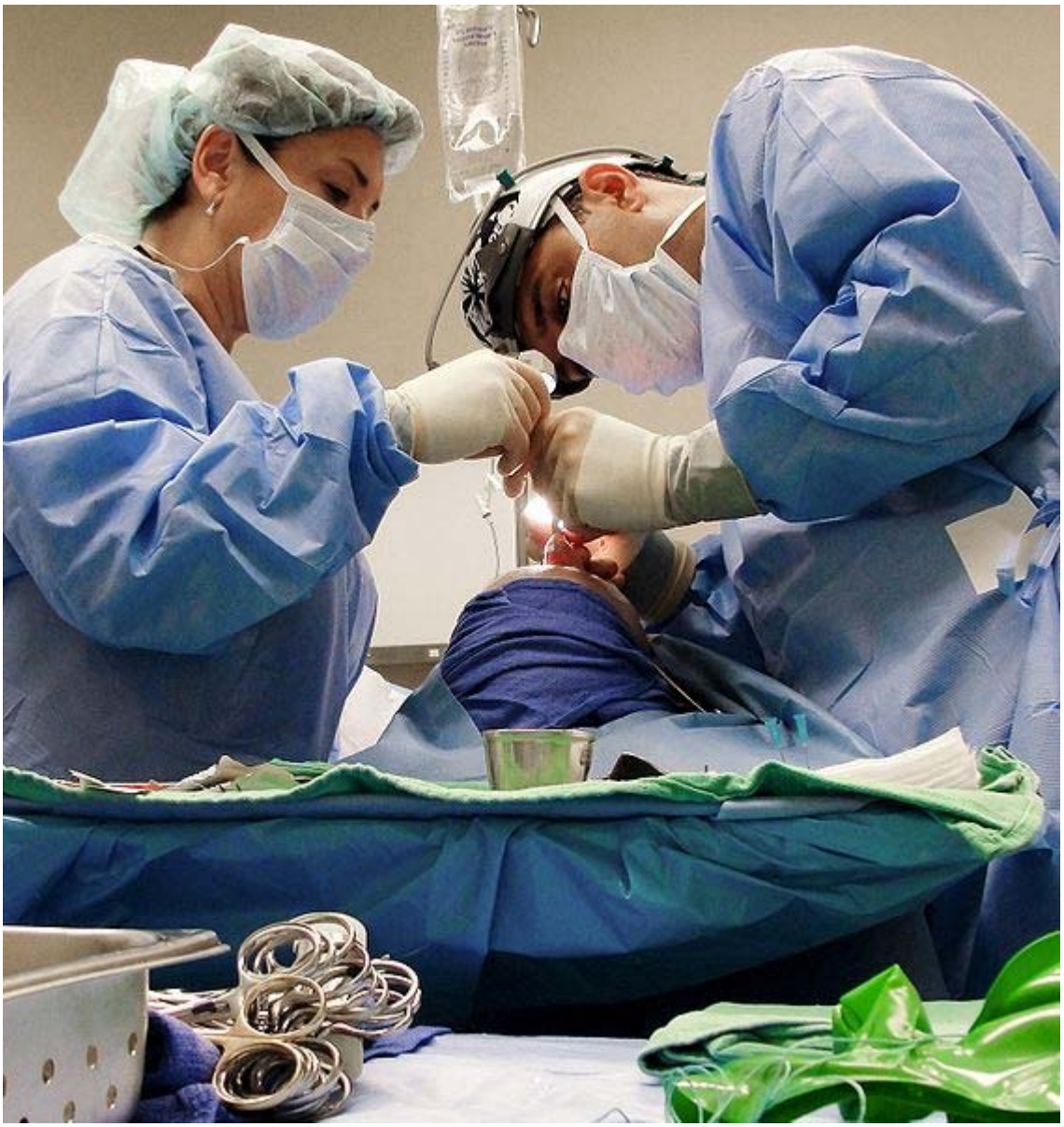
Navy doctors perform reconstructive surgery on a 21-year-old patient

The most common reconstructive procedures are tumor removal, laceration repair, scar repair, hand surgery, and breast reduction. According to the American Society of Plastic Surgeons, the number of reconstructive breast reductions for women increased in 2007 by

2 percent from the year before. Breast reduction in men also increased in 2007 by 7 percent. Some other common reconstructive surgical procedures include breast reconstruction after a mastectomy, cleft lip and palate surgery, contracture surgery for burn survivors, and creating a new outer ear when one is congenitally absent.

Plastic surgeons use microsurgery to transfer tissue for coverage of a defect when no local tissue is available. Free flaps of skin, muscle, bone, fat, or a combination may be removed from the body, moved to another site on the body, and reconnected to a blood supply by suturing arteries and veins as small as 1 to 2 millimeters in diameter.

Cosmetic surgery



Rhinoplasty or Nose Surgery

Blepharoplasty or Cosmetic Eyelid Surgery

Aesthetic plastic surgery involves techniques intended for the "enhancement" of appearance through surgical and medical techniques, and is specifically concerned with maintaining normal appearance, restoring it, or enhancing it beyond the average level toward some aesthetic ideal.

In 2006, nearly 11 million cosmetic procedures were performed in the United States alone. The number of cosmetic procedures performed in the United States has increased over 50 percent since the start of the century. Nearly 12 million cosmetic procedures were performed in 2007, with the five most common surgeries being breast augmentation, liposuction, nasal surgery, eyelid surgery and abdominoplasty. The increased use of cosmetic procedures crosses racial and ethnic lines in the U.S., with

increases seen among African-Americans and Hispanic Americans as well as Caucasian Americans. In Europe, the second largest market for cosmetic procedures, cosmetic surgery is a $2.2 billion business. Cosmetic surgery is now very common in countries such as the United Kingdom, France, and Germany. In Asia, cosmetic surgery has become an accepted practice; currently most widely prevalent and normal in China where it is currently Asia's biggest comestic surgery market. Children undergoing cosmetic eye surgery can be seen in Japan and South Korea.

The most prevalent aesthetic/cosmetic procedures include:

- Abdominoplasty ("tummy tuck"): reshaping and firming of the abdomen
- Blepharoplasty ("eyelid surgery"): reshaping of the eyelids or the application of permanent eyeliner, including Asian blepharoplasty
- Phalloplasty
- Mammoplasty:
    - Breast augmentations ("breast implant" or "boob job"): augmentation of the breasts by means of fat grafting, saline, or silicone gel prosthetics, which was initially performed to women with micromastia
    - Reduction mammoplasty ("breast reduction"): removal of skin and glandular tissue, which is done to reduce back and shoulder pain in women with gigantomastia and/or for psychological benefit men with gynecomastia
    - Mastopexy ("breast lift"): Lifting or reshaping of breasts to make them less saggy, often after weight loss (after a pregnancy, for example). It involves removal of breast skin as opposed to glandular tissue
- Buttock augmentation ("butt implant"): enhancement of the buttocks using silicone implants or fat grafting ("Brazilian butt lift") and transfer from other areas of the body
    - Buttock lift: lifting, and tightening of the buttocks by excision of redundant skin
- Chemical peel: minimizing the appearance of acne, chicken pox, and other scars as well as wrinkles (depending on concentration and type of agent used, except for deep furrows), solar lentigines (age spots, freckles), and photodamage in general. Chemical peels commonly involve carbolic acid (Phenol), trichloroacetic acid (TCA), glycolic acid (AHA), or salicylic acid (BHA) as the active agent.
- Labiaplasty: surgical reduction and reshaping of the labia
- Lip enhancement: surgical improvement of lips' fullness through enlargement
- Rhinoplasty ("nose job"): reshaping of the nose
- Otoplasty ("ear surgery"/"ear pinning"): reshaping of the ear, most often done by pinning the protruding ear closer to the head.
- Rhytidectomy ("face lift"): removal of wrinkles and signs of aging from the face
    - Browplasty ("brow lift" or "forehead lift"): elevates eyebrows, smooths forehead skin
    - Midface lift ("cheek lift"): tightening of the cheeks
- Suction-assisted lipectomy ("liposuction"): removal of fat from the body

- Chin augmentation ("chin implant"): augmentation of the chin with an implant, usually silicone, by sliding genioplasty of the jawbone or by suture of the soft tissue
- Cheek augmentation ("cheek implant"): implants to the cheek
- Orthognathic Surgery: manipulation of the facial bones through controlled fracturing
- Fillers injections: collagen, fat, and other tissue filler injections, such as hyaluronic acid
- Laser skin resurfacing

Sub-specialties

Plastic surgery is a broad field, and may be subdivided further. Plastic surgery training and approval by the American Board of Plastic Surgery includes mastery of the following as well:

Burn

Burn surgery generally takes place in two phases. Acute burn surgery is the treatment immediately after a burn. Reconstructive burn surgery takes place after the burn wounds have healed. Reconstructive surgery generally involves plastic surgery.

Cosmetic

Aesthetic surgery is an essential component of plastic surgery. Plastic surgeons use cosmetic surgical principles in all reconstructive surgical procedures as well as isolated operations to improve overall appearance.

Craniofacial

Craniofacial surgery is divided into pediatric and adult craniofacial surgery. Pediatric craniofacial surgery mostly revolves around the treatment of congenital anomalies of the craniofacial skeleton and soft tissues, such as cleft lip and palate, craniosynostosis, and pediatric fractures. Adult craniofacial surgery deals mostly with fractures and secondary surgeries (such as orbital reconstruction) along with orthognathic surgery. Craniofacial surgery is an important part of all plastic surgery training programs, further training and subspecialisation is obtained via a craniofacial fellowship.

Hand

Hand surgery is concerned with acute injuries and chronic diseases of the hand and wrist, correction of congenital malformations of the upper extremities, and peripheral nerve problems (such as brachial plexus injuries or carpal tunnel syndrome). Hand surgery is an important part of training in plastic surgery, as well as microsurgery, which is necessary to replant an amputated extremity. The Hand surgery field is also practiced by orthopedic

surgeons and general surgeons. Scar tissue formation after surgery can be problematic on the delicate hand, causing loss of dexterity and digit function if severe enough.

Micro

Microsurgery is generally concerned with the reconstruction of missing tissues by transferring a piece of tissue to the reconstruction site and reconnecting blood vessels. Popular subspecialty areas are breast reconstruction, head and neck reconstruction, hand surgery/replantation, and brachial plexus surgery.

Pediatric

Children often face medical issues very different from the experiences of an adult patient. Many birth defects or syndromes present at birth are best treated in childhood, and pediatric plastic surgeons specialize in treating these conditions in children. Conditions commonly treated by pediatric plastic surgeons include craniofacial anomalies, cleft lip and palate and congenital hand deformities.

Plastic surgery obsession

With increased media attention on beauty and perfection, celebrities and those alike are turning to plastic surgery more and more. Some take out loans for this purpose; one woman spent over $83,000 for 14 surgeries.

Though media and advertising do play a large role in influencing many people's lives, researchers believe that plastic surgery obsession is linked to psychological disorders. Body dysmorphic disorder is seen as playing a large role in the lives of those who are obsessed with going under the knife in order to achieve physical perfection. People with this disorder are so preoccupied with their appearance that it can dominate their lives.

In some cases, people whose doctors refuse to perform any further surgeries, have turned to "do it yourself" plastic surgery, injecting themselves and running extreme safety risks.

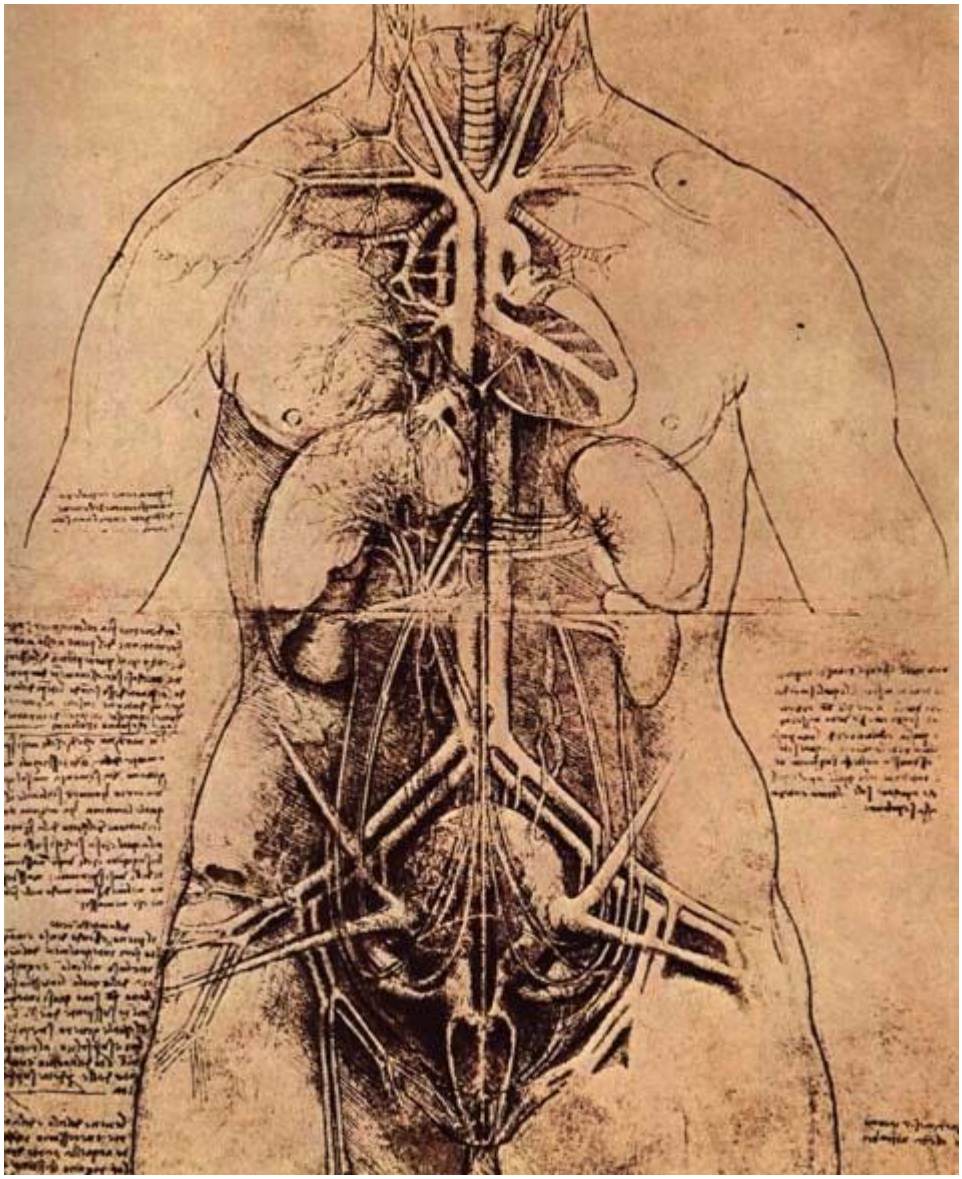
Chapter 4

Vascular Surgery

Vascular Surgeon	
Occupation	
Names	Doctor, Medical Specialist
Type	Specialty
Activity sectors	Medicine
Description	
Fields of employment	Hospitals, Clinics

Vascular surgery is a specialty of surgery in which diseases of the vascular system, or arteries and veins, are managed by medical therapy, minimally-invasive catheter procedures, and surgical reconstruction. The specialty evolved from general and cardiac surgery. Early pioneers of the field include Russian surgeon Nikolai Korotkov, noted for developing early surgical techniques, and Robert Paton, one of the first Australian vascular surgeons and often credited with helping the field achieve recognition as a speciality. Edwin Wylie of San Francisco was one of the early American pioneers who developed and fostered advanced training in vascular surgery and pushed for its recognition as a specialty in the United States in the 1970s. The vascular surgeon is trained in the diagnosis and management of diseases affecting all parts of the vascular system except that of the heart and brain. Cardiothoracic surgeons manage surgical disease of the heart and its vessels. Neurosurgeons manage surgical disease of the vessels in the brain (e.g. intracranial aneurysms).

The Evolution of Endovascular Surgery



Medical science has advanced significantly since 1507, when Leonardo da Vinci drew this diagram of the internal organs and vascular systems of a woman.

The specialty continues to be based on operative arterial and venous surgery but since the early 1990s has evolved greatly. There is now considerable emphasis on minimally invasive alternatives to surgery. This area of vascular surgery is called Endovascular Surgery, a term that some in the specialty append to their primary qualification as Vascular Surgeon. Endovascular and endovenous procedures can now form the bulk of a vascular surgeons practice.

The development of endovascular surgery has been accompanied by a gradual separation of vascular surgery from its origin in general surgery. Most vascular surgeons would now

confine their practice to vascular surgery and similarly general surgeons would not be trained or practice the larger vascular surgery operations or most endovascular procedures. More recently, professional vascular surgery societies and their training programme have formally separated "Vascular Surgery" into a separate specialty with its own training program, meetings, accreditation. Notable societies are Society of Vascular Surgery (SVS), USA; Australia and New Zealand Society of Vascular Surgeons (ANZ SVS). Local societies also exist e.g. Melbounrne Society of Vascular Surgeons (MVSA). Larger societies of surgery actively separate and encourage specialty surgical societies under their umbrella e.g. Royal Australasian College of Surgeons (RACS). Big text

Common Professional Associations

Associated areas of interest and operative surgical practice for vascular surgeons are access surgery for hemodialysis and peritoneal dialysis, organ harvesting for transplantation, renal transplantation, pancreatic solid organ transplantation Organ transplant.

Vascular surgeons will frequently have close associations with specialist vascular radiology clinics for a combined treatment of certain conditions. The radiologists contribute to endovascular cases management, sometimes with angioplasty and stenting, but more often in specific areas of expertise e.g. sclerotherapy for vascular anomalies and arteriovenous malformations (AVMs), coil embolisation of bleeding visceral arteries in trauma or for occlusion of tumour supplying arteries as a prelude to operation, CT-guided procedures such as lumbar chemical sympathectomy.

Common medical associations are the involvement providing surgical opinions and treatment for a multidisciplinary clinic with vascular surgeons, vascular nurses, wound management nurses, podiatrists, prosthetists, rehabilition physicians, vascular physicians, endocrinologists, etc. to manage high risk foot disease patients.

Less common operative surgical associations are: sympathectomy (ETS, Endoscopic thoracic sympathectomy), lumbar sympathectomy, Hyperhidrosis surgery); vascular access for chemotherapy etc. patients; dialysis/ECMO (extra-corporeal membrane oxygenation) for patients in Intensive Care Wards; vascular mobilisation for access associated with other specialist operations e.g. extensive orthopaedic spinal and pelvic surgery, retroperitoneal cancer dissections, renal tumour surgery.

Vascular Surgery in the Third Millennium

Arterial and venous disease treatment by angiography, stenting, and non-operative varicose vein treatment sclerotherapy, endovenous laser treatment are rapidly replacing major surgery in many first world countries. These newer procedures provide reasonable outcomes that are comparable to surgery with the advantage of short hospital stay (day or overnight for most cases) with lower morbidity and mortality rates. The durability of endovascular arterial procedures is generally good especially when viewed in the context of their common clinical usage i.e. arterial disease occurring in elderly patients and

usually associated with concurrent significant patient comorbidities especially ischaemic heart disease. The cost savings from shorter hospital stays and less morbidity are considerable but are somewhat balanced by the high cost of imaging equipment, construction and staffing of dedicated procedural suites, and of the implant devices themselves. The benefits for younger patients and in venous disease are less persuasive but there are strong trends towards nonoperative treatment options driven by patient preference, health insurance company costs, trial demonstrating comparable efficacy at least in the medium term.

A recent trend in the USA is the stand-alone day angiography facility associated with a private vascular surgery clinic, thus allowing treatment of most arterial endovascular cases conveniently and possibly with lesser overall community cost. Similar non-hospital treatment facilities for non-operative vein treatment have existed for some years and are now widespread in many countries.

An emerging trend based on such venous clinics is the treatment of varicose veins by non-vascular surgeons e.g. cosmetic physicians, phlebologists, radiologists, etc. These practices aim to offer a complete varicose and surface vein treatment without surgery.

Breadth of discipline

- Arterial diseases (especially in Diabetics)
    - Aneurysms
    - Ischemia
        - Limb ischemia
            - Acute limb ischemia
                - Thrombectomies
                - Embolectomies
                - Anti-coagulation and Thrombolysis
            - Chronic limb ischemia
                - Diabetic foot ulcers
        - Mesenteric ischemia
        - Renal ischemia
    - Extracranial cerebrovascular disease
        - Carotid Endarterectomy and other carotid surgery
        - Surgery of the vertebral system
- Venous disease
    - Deep Vein Thrombosis
    - Thrombophlebitis
    - Varicose Veins and Varicosities
    - Venous malformations
- Lymphatic disease
    - Lymphoedema

- Vascular Medicine
    - Medical disorders with a significant vascular component, for example:

- Raynaud's syndrome
- Scleroderma
- Hyperhidrosis

Training

Previously considered a field within general surgery, it is now considered a specialty in its own right. As a result, there are two pathways for training in the United States. Traditionally, a five year general surgery residency is followed by a 1-2 year (typically 2 years) vascular surgery fellowship. An alternative path is to perform a five or six year vascular surgery residency.

Programs of training are slightly different depending on the region of the world one is in.

Country	Standards body	Professional representation	Minimum Length of training (post intern)
Australia and New Zealand	Royal Australasian College of Surgeons	Australian & New Zealand Society of Vascular Surgery (ANZSVS)	6 years
United Kingdom	Royal College of Surgeons of England, Royal College of Surgeons of Edinburgh	Vascular Society of Great Britain and Ireland	8 years
USA	Accreditation Council for Graduate Medical Education (ACGME), American Board of Surgery	American College of Surgeons Multiple vascular societies	5 years (4 via 5-year integrated Vascular Surgery Residency)

Research

Research in treating vascular disease is exploring new areas, such as minimally invasive techniques which are less risky and speed a patient's recovery time. Vascular surgeon Kenneth Ouriel studied methods like these as part of a National Institute of Health grant to study thrombosis; results from this large, multicenter randomized trial of clot busting therapy treatments were published in the New England Journal of Medicine in 1998.

Surgical procedures

By no means exhaustive, but below are a number of common procedures and indications for vascular surgeons.

Indication/disease	Procedure
Abdominal aortic aneurysm	Open AAA repair
	Endoluminal AAA repair (EVAR)
Carotid stenosis	Carotid endarterectomy
	Carotid stenting
Varicose veins	Vein stripping
	Sclerotherapy and Foam sclerotherapy or Endovenous Laser Treatment, radiofrequency vein ablation
	Ambulatory phlebectomy
Peripheral arterial occlusive disease	Angioplasty with/out Stenting
	Bypass surgery Endarterectomy Atherectomy
	Balloon embolectomy
Acute limb ischaemia	Thrombectomy
	Bypass surgery
Aortic dissection	Open repair
	Thoracic stent graft

Major Trials in Vascular Surgery

- **Edinburgh Artery Study**. *Highwire results for Edinburgh Artery Study

- **Netherland Vascular Study**.

- **Framingham heart study**. Highwire results for Framingham heart Study

- **MASS Trial**. – the Multicentre Aneurysm Screening Study (MASS) trial. Four centres (about 7000 men); screening (and treatment) vs. control group. AAA-related mortality in the screening arm reduced by about 40%; emergency ruptured AAA reducted by about 70%; disruption to elective work was reduced; and better management of risk factors and ITU/HDU beds. The overall survival benefits remain difficult to estimate, nevertheless, screening for AAA is recommended [level of recommendation: B].

- **UK Small Aneurysm Trial**: 1090 patients; AAA 4-5.5 cm; Immediate surgery vs. ultrasound surveillance (and treatment for rapid expansion or AAA >5.5); 30-day mortality after elective AAA repair is 5.8%. No difference in survival.

- **ADAM VA Cooperative Group Trial**. 73451 VA patients screened with no known hx of aneurysm; Age 50-79; AAA 4.0-5.4 cm; similar conclusion to Uk Small Aneurysm Trial.

- **Joint Vascular Research Group Trial**. 284 patients; Study the relationship between intraoperative intravenous heparinisation, blood loss during surgery and thrombotic complications. Conclusion: Intraoperative heparin, given before aortic cross clamping, is an important prophylaxic against perioperative MI in aortic aneurysm surgery.

- **HOPE (Heart Outcomes Prevention Evaluation) study** - 4046 patients with PAD. In this subgroup, there was a 22% risk reduction in patients randomized to ramipril compared with placebo,which was independent of lowering of blood pressure.

Chapter 5

Intersex Surgery

Intersex surgery is one of several terms referring to surgery performed to correct birth defects or early injuries of the genitalia, primarily for the purposes of making the appearance more normal and to reduce the likelihood of future problems. The recent history of intersex surgery has been characterized by controversy after publicized reports that surgery failed to achieve the desired outcomes in many cases. Timing of surgery (infancy, adolescence or adult age) has also been controversial.

Intersex surgery is a form of genital reconstructive surgery, which also includes surgery performed for the purpose of transforming normal adult genitalia of one sex to that of the other (discussed elsewhere as sex reassignment surgery).

Purposes of genital reconstructive surgery

The goals of surgery vary with the type of abnormality but usually include one or more of the following:

1. to improve the potential for fertility
2. to provide an outlet for menstruation
3. to prevent or reduce urinary tract infections or obstruction
4. to reduce risk of cancer in abnormal gonads.
5. to close open wounds or exposed internal organs
6. to improve urinary or fecal continence.
7. to alleviate parental distress over the atypical genital appearance.
8. to make the appearance more normal for the person's sex of rearing
9. to reduce effects of abnormal genitalia on psychosexual development and gender identity
10. to improve the potential for adult sexual relationships

Types of surgery

Genital reconstructive surgery can be divided into ***masculinizing surgical procedures*** intended to make the genitalia more like those of typical males, and ***feminizing surgical procedures*** intended to make the genitalia more like those of typical females.

- There are several techniques or approaches for each procedure.
- Some of the variations of procedure are needed for varying degrees of severity of the abnormalities.
- Some of the different techniques have been devised to reduce complications associated with earlier techniques.
- Techniques and procedure have evolved over the last 60 years. Some have been considered obsolete for decades.
- Some children need a combination of procedures.
    - For example, a severely undervirilized boy with a pseudovaginal perineoscrotal hypospadias may have midline urogenital closure, third degree hypospadias repair, chordee release and phalloplasty, and orchiopexy performed. A severely virilized girl with congenital adrenal hyperplasia (CAH) may undergo both a clitoral reduction and a vaginoplasty.

Masculinizing surgical procedures

Orchiopexy and hypospadias repair are the most common types of genital corrective surgery performed in infant boys, but most of these boys have no other abnormalities and are not considered to have an intersex condition. Undervirilized boys typically have at least one of these two procedures performed in addition to others described below.

Types of undervirization and malformation for which some type of masculinizing surgery has been performed most often in the last 50 years are:

- the configuration of ambiguous genitalia referred to as pseudovaginal perineoscrotal hypospadias (PPSH)
    - the Reifenstein type of partial androgen insensitivity syndrome
    - gonadal dysgenesis disorders such as mixed gonadal dysgenesis and testicular dysgenesis
    - idiopathic (specific cause not determined)
- birth defects of male genitalia
    - bladder exstrophy and epispadias spectrum
    - chordee (simple or as part of undervirilization)
    - micropenis
    - concealed penis

The disorders above comprised over 90% of reported surgical series from North America and Europe. In a few parts of the world 5-alpha-reductase deficiency or defects of testosterone synthesis, or even rarer forms of intersex account for a significant portion of cases but these are rare in North America and Europe. Masculinizing surgery for completely virilized genetic females with CAH is even rarer.

Orchiopexy for repair of undescended testes (cryptorchidism) is the second most common surgery performed on infant male genitalia (after circumcision). The surgeon

moves one or both testes, with blood vessels, from an abdominal or inguinal position to the scrotum. If the inguinal canal is open it must be closed to prevent hernia.

Potential problems: Maintaining the blood supply is the major challenge. If vessels cannot be stretched into the scrotum, or are separated and cannot be reconnected, a testis will die and atrophy.

Hypospadias repair is a relatively simple single procedure if the hypospadias is first or second degree (urethral opening on glans or shaft respectively) and the penis is otherwise normal. Repair of a third degree hypospadias (urethral opening on perineum or in urogenital opening) is more challenging, may be done in stages, and has a significant rate of complications and unsatisfactory outcomes. (Glassberg, 1999)

Potential problems: For severe hypospadias (3rd degree, on perineum) constructing a urethral tube the length of the phallus is not always successful, leaving an opening (a "fistula") proximal to the intended urethral opening. Sometimes a second operation is successful, but some boys and men have been left with chronic problems with fistulas, scarring and contractures that make urination or erections uncomfortable.

Urogenital closure describes closure of any midline opening at the base of the penis. In severe undervirilization a boy may have a "pseudovaginal pouch" or a single urogenital opening in the midline of the perineum.

Potential problems: The most complicated aspect of closure involves moving the urethra to the phallus if it is not already there (i.e., repairing a perineal hypospadias). Fistulas and scarring are the main risks.

Gonadectomy (also referred to as "orchiectomy") refers to removal of the gonads. This is done in three circumstances. (1) If the gonads are dysgenetic testes or streak gonads and at least some of the boy's cells have a Y chromosome, the gonads or streaks must be removed because they are nonfunctional but have a relatively high risk of developing gonadoblastoma. (2) In rare instances when an XX child with completely virilizing congenital adrenal hyperplasia (Prader stage 5) is being raised as a male, the ovaries must be removed before puberty to prevent breast development and/or menstruation. (3) Gonadectomy would be needed for the equally rare instance of a child with true hermaphrodite virilized enough to raise as male: any ovary or ovotestis would need to be removed. (Manuel, 1976)

Potential problems: Gonadectomy involves little risk beyond that of any abdominal surgery.

Chordee release refers to cutting of ventral penile skin and connective tissue to free and straighten the penis. A mild chordee, manifest as a well-formed penis "bent" downward by subcutaneous connective tissue, may be an isolated birth defect easily repaired by releasing some of the inelastic connective tissue on the ventral side of the shaft. In a complete chordee the phallus is "tethered" downward to the perineum by skin. A more

severe chordee is often accompanied by a hypospadias and sometimes by severe undervirilization: a perineal "pseudovaginal pouch" and bifid ("split") scrotum with an undersized penis. This combination, referred to as pseudovaginal perineoscrotal hypospadias, is in the spectrum of ambiguous genitalia due to a number of conditions.

Potential problems: Scarring and contracture are occasional complications, but most unsatisfactory outcomes occur when a severe hypospadias needs to be repaired as well. Long-term complications can include fistulas between colon or upper rectum and skin or other cavities, or between urethra and perineum.

Cloacal repair is among the most complex of the surgeries described here. Bladder exstrophy or more severe cloacal exstrophy refers to a major birth defect involving inadequate closure and incomplete midline fusion of multiple pelvic and perineal organs as well as the front of the pelvis and lower abdominal wall. The penis and scrotum are often widely bifid (the two embryonic parts unjoined). The penis often cannot be salvaged, although the testes can be retained. Repair may involve closure of the bladder, closure of the anterior abdominal wall, colostomy (temporary or permanent) with reconstruction of the rectum. If the halves of the phallus cannot be joined, they may be removed. The smallest defect in this spectrum is an epispadias. Surgical repair for this is primarily a phalloplasty. (Schober, 2002)

Potential problems: Surgery for the more severe degrees of cloacal exstrophy is extensive and usually multistage. A variety of potential problems and complications can occur, including need for long-term colostomy or vesicostomy. In many cases a functional penis cannot be created. Scarring is often extensive and the lower torso severely disfigured even with fairly good outcomes.

Phalloplasty is a general term for any reconstruction of the penis itself, especially for more unusual types of injuries, deformities, or birth defects. The principal difficulty is that erectile tissue is not easily constructed and this limits the surgeon's ability to make more than minor size changes. Construction of a narrow tube lined with mucosa (a urethra) is a similar challenge.

Potential problems: Minor revisions of the skin are rarely followed by problems. More complicated reconstruction may result in scarring and contracture, which can distort the shape or curvature of the penis, or interfere with erections or make them painful.

Hysterectomy is removal of a uterus. It is rare that a uterus or mullerian duct derivatives would need to be removed from a child being raised as a boy. The most common scenario is accidental discovery of persistent mullerian derivatives or a small uterus during abdominal surgery of a normal boy for cryptorchidism, appendectomy, or bowel disease. Removal would not involve genital surgery. A rarer indication would be that of a completely virilized XX child with congenital adrenal hyperplasia (Prader stage 5) being raised as a male; ovaries and uterus must be removed to prevent breast development and menstruation by early adolescence.

Potential problems: Risks are simply those of abdominal surgery.

Testicular prostheses are saline-filled plastic ovoids implanted in the scrotum. They have no function except to provide the appearance and feel of testes. Several sizes are available, but most are implanted in adolescence to avoid repeated procedures to implant larger sizes at puberty. Prostheses made of silastic are no longer available due to safety and perception-of-safety concerns.

Potential problems: Foreign body reactions, rarely with infection or erosion of scrotal skin, are minimal but constitute the most significant complication.

Penile augmentation surgery is surgery intended to enlarge a small penis. Early attempts in the 1950s and 1960s involved constructing a tube of non-erectile flesh extending a small penis but the penis did not function. In recent years a small number of urologists have been offering an augmenation procedure that involves moving outward some of the buried components of the corpora so that the penis protrudes more. The girth is augmented with transplantation of the patient's fat. This procedure is designed to preserve erectile and sexual function without surgically altering the urethra. This type of surgery is not performed on children and primarily produces a small increase in the size of a normal penis, but would be less likely to produce a major functional change in a severe micropenis.

Potential problems: Reabsorption of the fat is common. Scarring resulting in interference with erectile function is less likely but more damaging.

Concealed penis is the term used to describe a normal penis buried in suprapubic fat. In most cases, when the fat is depressed with the fingers, the penis is seen to be of normal size. This is common in overweight boys before the penile growth of puberty. Surgical techniques have been devised to improve it. (Casale, 1999)

Potential problems: The most common difficulty is recurrence with further weight gain. Scarring can occur.

Feminizing surgical procedures

In the last 50 years, the following procedures were most commonly performed for the following intersex conditions and birth defects in order to make the genitalia more like those of normal females:

- virilization due to congenital adrenal hyperplasia
- malformations of genitalia in genetic females
    - urogenital sinus malformation
    - cloacal exstrophy
- conditions involving severe undervirilization or malformations of genetic males, or infants with mixed genetic sex, to be assigned and raised as girls
    - gonadal dysgenesis (various forms)

- partial and complete androgen insensitivity syndrome
- micropenis
- cloacal and bladder exstrophy

There are rarer causes of virilization of genetic females or undervirililizaton of genetic males, as well as some less easily categorized types of intersex conditions or other malformations of the genitalia. In the last decade, feminizing surgery to support reassignment of genetic males with non-ambiguous micropenis has been largely discontinued, and surgical reassignment of genetic males with exstrophy or other severe malformations or injuries is diminishing.

Clitorectomy describes amputation or removal of most of the clitoris, including glans, erectile tissue, and nerves. This procedure was the most common clitoral surgery performed prior to 1970, but was largely abandoned by 1980 because it usually resulted in loss of clitoral sensation.

Potential problems: The primary effect of this surgery, not surprisingly, is a drastic reduction in ability to experience orgasm. The appearance is not very normal. Regrowth of unwanted erectile tissue has sometimes presented problems.

Clitoroplasty, like phalloplasty, is a term that encompasses any surgical reconstruction of the clitoris, such as removal of the corpora. Clitoral recession and reduction can both be referred to as clitoroplasty.

Potential problems: Major complications can include scarring, contractures, loss of sensation, loss of capacity for orgasm, and unsatisfactory appearance.

Clitoral recession involves the repositioning of the erectile body and glans of the clitoris farther back under the symphysis pubis and/or skin of the preputium and mons. This was commonly done from the 1970s through the 1980s to reduce protrusion without sacrificing sensation. Outcomes were often unsatisfactory, and it fell into disfavor in the last 15 years. (Rangecroft, 2001)

Potential problems: Unfortunately the subsequent sensations were not always pleasant, and erection could be painful. Adults who had a clitoral recession in early childhood often report reduced capacity for enjoyment of sexual intercourse, though similar women who had not had surgery also report a high rate of sexual dysfunction. (Minto, 2003)

Clitoral reduction was developed in the 1980s to reduce size without reducing function. Lateral wedges of the erectile tissue of the clitoris are removed to reduce the size and protrusion. The neurovascular tissue is carefully spared to preserve function and sensation. Nerve stimulation and sensory responses are now often performed during the surgery to confirm function of the sensory nerves. (Chase, 1996; Rangecroft, 2001))

Potential problems: The degree to which the goal of preserving sexual sensations is attained is a subject of controversy. Many of the children who have had the newer versions of this procedure have not yet become adults.

Vaginoplasty, the construction or reconstruction of a vagina, can be fairly simple or quite complex, depending on the initial anatomy. If a normal internal uterus, cervix and upper vagina (the mullerian derivatives) exist, and the outer virilization is modest, surgery involves separating the fused labia and widening the vaginal introitus. With greater degrees of virilization, the major challenge of the procedure is to provide a passage connecting the outer vaginal opening to the cervix which will stay wide enough to allow coitus. XY girls or women with partial androgen insensitivity syndrome will have a blind vaginal pouch of varying degrees of depth. Sometimes this can be dilated to a usable depth. Sometimes surgery is performed to deepen it.

The most challenging surgery with the highest complication rate is construction of an entirely new vagina (a "neovagina"). The most common instance of this is when a child will be assigned and raised as a female despite complete virilization, as with Prader 5 CAH, or (in the past) when a genetic male infant with a severely defective penis was reassigned as a female. One method is to use a segment of colon, which provides a lubricated mucosal surface as a substitute for the vaginal mucosa. Another is to line the new vagina with a skin graft. (Creighton, 2001; Rink, 1998; Schnitzer, 2001)

Potential problems: Stenosis (narrowing) of the constructed vagina is the most common long-term complication and the chief reason that a revision may be required when a girl is older. When a neovagina is made from a segment of bowel, it tends to leak mucus; when made with a skin graft, lubrication is necessary. Less common complications include fistulas, uncomfortable scarring, and problems with urinary continence. (Alizai, 1999; Lobe, 1987; Minto, 2003)

Gonadectomy refers to removal of the gonads. If the gonads are dysgenetic testes or streak gonads and at least some of the cells have a Y chromosome, the gonads or streaks must be removed because they are nonfunctional but have a relatively high risk of developing gonadoblastoma. If the gonads are relatively "normal" testes, but the child is to be assigned and raised as female, (e.g., for intersex conditions with severe undervirilization, or major malformations involving an absent or unsalvageable penis) they must be removed before puberty to prevent virilization from rising testosterone. Testes in androgen insensitivity are a special case: if there is any degree of responsiveness to testosterone, they should be removed before puberty. On the other hand, if androgen insensitivity is complete, the testes may be left to produce estradiol (via testosterone) to induce breast development, but there is a slowly increasing risk of cancer in adult life. Streak gonads without a Y chromosome cell line need not be removed but will not function. Finally, the gonads in true hermaphroditism must be directly examined; abnormal gonads with Y line or potential testicular function should be removed but in rare instances a surgeon may try to preserve the ovarian part of an ovotestis. (Manuel, 1976)

Potential problems: Gonadectomy involves little risk beyond that of any abdominal surgery.

Cloacal exstrophy and **bladder exstrophy repair** is needed regardless of the sex of assignment or rearing. Simple bladder exstrophy in a genetic female does not usually involve the vagina. Cloacal exstrophy in a genetic female usually requires major surgical reconstruction of the entire perineum, including bladder, clitoris, symphysis pubis, and both the vaginal introitus and urethra. However, the uterus and ovaries are normally formed. Severe bladder exstrophy or cloacal exstrophy in genetic males often renders the phallus widely split, small, and unsalvageable. The scrotum is also widely split, though testes themselves are usually normal. From the 1960s until the last decade, many of these infants were assigned and raised as females, with fashioning of a vagina and gonadectomy as part of the perineal reconstruction. (Schober, 2002)

Potential problems: Surgery for the more severe degrees of cloacal exstrophy is extensive and usually multistage. A variety of potential problems and complications can occur, including need for long-term colostomy or vesicostomy. Creating a functional urethra is difficult and poor healing, with scarring, stricture, or fistula can require a vesicostomy to prevent urinary incontinence. Construction of a functional anal sphincter can be equally difficult when this has been disrupted as well. Functional problems can warrant a temporary or long-term colostomy. The added challenge for the most severely affected genetic females, and for genetic males who are being raised as females, is construction of a neovagina. Scarring is extensive and the lower torso disfigured even with the best outcomes. Finally, it has become apparent in recent years that some genetic males (without intersex conditions) who are reassigned and raised as females have not developed a female gender identity and have sought reassignment back to male. (Reiner, 2004)

Controversies and unsettled questions

Management practices for several types of intersex conditions and other abnormalities and injuries of the genitalia have evolved over the last 50 years. In the last decade several of the surgical practices have become the subject of public and professional controversy.

Is functional outcome better when surgery is performed in infancy, in adolescence, or adulthood, for vaginoplasty for markedly virilized females (e.g., from congenital adrenal hyperplasia, mixed gonadal dysgenesis, or partial androgen insensitivity)?

- Argued or putative advantages of infant surgery
    - Tissue is more elastic and heals better according to many surgeons.
    - Genital surgery performed before the age of memory is less emotionally traumatic.
    - Surgery in infancy avoids asking adolescent to make a decision that is stressful and difficult even for adults.
    - Assuming infant surgery is successful, there is no barrier to engaging in normal sexual activities, and less distortion of psychosexual identity.

- Argued or putative advantages of surgery in adolescence or later
    - If outcome is less than satisfactory, early surgery leaves a person wondering if she would have been better off without it.
    - Any surgery not absolutely necessary for physical health should be postponed until the person is old enough to give informed consent; parents should not be empowered to make medical decisions for their children.
    - Genital surgery should be handled differently than other birth defect surgery; this is the one type of surgery that parents should not be empowered to make decisions about because they will be under social pressure to make "bad" decisions.
    - By mid-adolescence or later, a woman may decide that her abnormal genitalia do not need to be changed.
    - Infant vaginoplasties should not be done because most women who have had them performed report some degree of difficulty with sexual function; even though we have no evidence that adult sexual function will be better if surgery is deferred, the outcomes couldn't be worse than they currently are after infant surgery.

Do any advantages of infant clitoral reduction surgery outweigh the potential disadvantages of reduced or distorted sexual sensation? Clitoral reduction is rarely done except in combination with vaginoplasty when substantial virilization is present.

- How much weight should be given to the cosmetic argument that there is value in making it more normal looking?

Should parents have the same ethical and legal right to consent on behalf of their child to genital surgery as to consent to other reconstructive surgery (e.g., cleft lip repair or birth mark removal) for largely psychosocial purposes?

- The high court in Colombia has ruled no , and some advocacy groups in the US and elsewhere agree (, comparing this type of surgery to genital mutilation(intactivism).

How can we minimize gender identity problems? Is it valid to assume in cases of ambiguous genitalia that the magnitude of the "innate" tendency to develop a specific gender identity is usually similar to the degree of genital virilization? Should we abandon completely the idea that an unambiguous XY child with an irreparably defective penis might be better off raised as a girl?

- Medical professionals have traditionally considered the worst outcomes after genital reconstruction in infancy to occur when the person develops a gender identity discordant with the sex assigned as an infant. Most of the cases in which a child or adult has voluntarily changed sex and rejected sex of assignment and rearing have occurred in partially or completely virilized genetic males who were reassigned and raised as females. This is the management practice that has been most thoroughly undermined in the last decade, as a result of a small number of

spontaneous self-reassignments back to male in a number of genetic males who had been raised as female because of birth defects of the penis which did not involve undervirilization (e.g., exstrophy or traumatic loss).

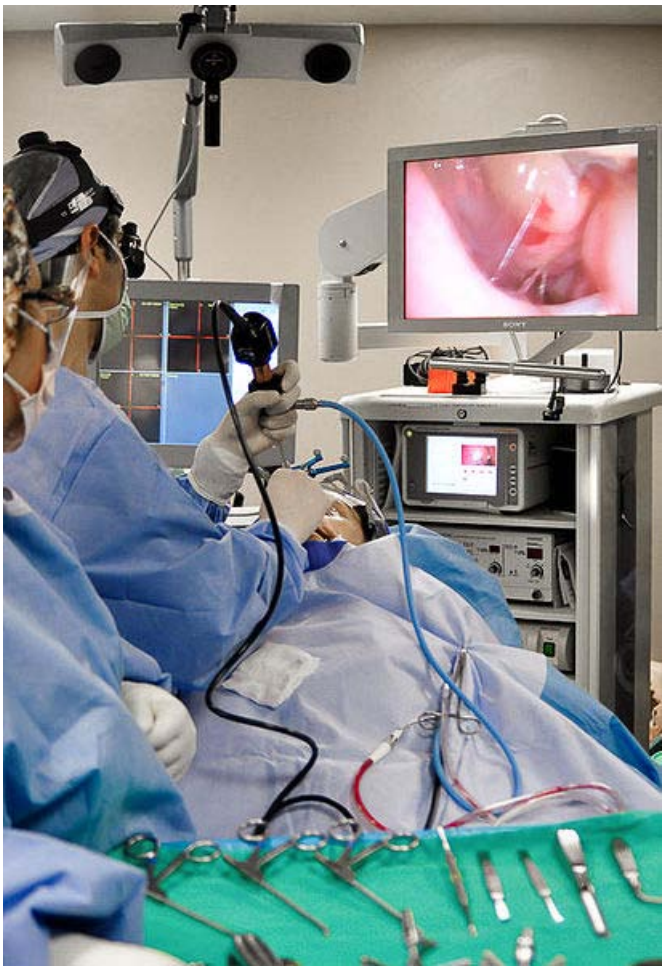
- Reducing the likelihood of a gender "mismatch" is also a claimed advantage of deferring reconstructive surgery until the patient is old enough to assess gender identity with confidence.
- However, support groups tend to identify intense feelings of shame and betrayal as the worst outcomes of a philosophy of management that focuses on normalizing the child's anatomy. Many individuals who have developed a discordant gender identity and rejected the sex assigned during infancy have done quite well after transition (Reiner 2004, Consortium 2006,). Gender identity may not be the most important variable to consider in caring for children with intersex conditions.

Within the last decade, some people have raised the question of whether surgery to correct abnormal genitalia should be done at all, especially for purposes of changing appearance. Opponents of all "corrective surgery" on abnormal genitalia suggest we should be attempting to change social opinion regarding the desirability of having genitalia that look more average, rather than performing surgery to try to make them more like other peoples'.

Historical background, supporting arguments, and changing practice standards are treated in more detail in History of intersex surgery, and in some of the following references (Creighton, 2001).

Chapter 6

Otolaryngology



Otolaryngologist performing an endoscopic sinus surgical procedure

Otolaryngology or **ENT** (**ear, nose, and throat**) is the branch of medicine and surgery that specializes in the diagnosis and treatment of ear, nose, throat, and head and neck disorders. The full name of the specialty is **otolaryngology–head and neck surgery.** Practitioners are called **otolaryngologists–head and neck surgeons**, or sometimes **otorhinolaryngologists** (ORL).

The term comes from the Classical Greek roots *ὠτ- - ot-* (root of οὖς) "ear", *λαρυγγ- - laryng-* (root of λάρυγξ) "larynx/throat", and the suffix *-logy* "study", and it literally means "the study of ear and throat".

The full term otorhinolaryngology (neoclassical Greek and modern Greek: ὠτο(ρ)ρινολαρυγγολογία), also includes *ῥίνο- - rhino-* (root of ῥίς) "nose".

Explanation

Otolaryngologists are medical doctors (MD, DO, MBBS, MBChB, etc.) who, in the United States, complete at least five years of surgical residency training. This is composed of one year in general surgical training and four years in otolaryngology–head and neck surgery; in the past it varied between two and three years of each.

Following residency training some otolaryngologists elect to complete advanced subspeciality fellowship training which can be 1–2 years in duration (pediatric otolaryngology, neuro-otology, laryngology, facial plastic and reconstructive surgery, rhinology, or head and neck oncology).

Subspecialties

Head and neck	Facial plastics	Otology	Neuro-otology*	Rhinology/sinus	Laryngology	Pediatrics*	Sleep*
Surgical oncology	Facial cosmetic surgery	Ear	Middle and inner ear	Sinusitis	Voice therapy	Velopalatine insufficiency	
Reconstruction	Maxillofacial	Hearing	Temporal bone	Allergy	Phono-surgery	Cleft lip and palate	
Endocrine surgery	Trauma		Skull base	Anterior skull base		Airway	
			Dizziness	Apnea and snoring		Vascular malformations	
						Cochlear implant/BAHA	

(* Currently recognized by American Board of Medical Subspecialties)

Topics in otolaryngology, head and neck surgery

Head and neck surgery

- Squamous cell carcinoma of the oral cavity, pharynx and larynx
- Oral cancer
- Thyroid cancer
- Endocrine surgery of the head and neck (thyroidectomy, parathyroidectomy)
- Microvascular free flap reconstruction
- Skull base surgery

Otology/neuro-otology

- Dizziness
    - BPPV – benign paroxysmal positional vertigo
    - labyrinthitis/vestibular neuronitis
    - Ménière's disease/endolymphatic hydrops
    - Perilymphatic fistula
    - acoustic neuroma

- Hearing loss
- Mastoiditis
- Otitis externa – outer ear or ear canal inflammation
- Otitis media – middle ear inflammation
- Otitis interna – inner ear inflammation
- Perforated eardrum (hole in the eardrum due to infection, trauma, explosion or loud noise)
- Ear surgery

Rhinology

Rhinology pertains to sinus diseases and the anterior skull base.

- Environmental allergies
- Sinusitis – acute, chronic
- Rhinitis
- Empty nose syndrome

Pediatrics

- Adenoidectomy
- Caustic ingestion
- Cricotracheal resection
- Decannulation
- laryngomalacia
- Laryngotracheal reconstruction

- Myringotomy and tubes
- Obstructive sleep apnea – pediatric
- Tonsillectomy

Laryngology

- Dysphonia/hoarseness
    - Laryngitis
    - Reinke's edema
    - Vocal cord nodules and polyps

- Spasmodic dysphonia
- Tracheostomy
- Cancer of the larynx
- Vocology – science and practice of voice habilitation

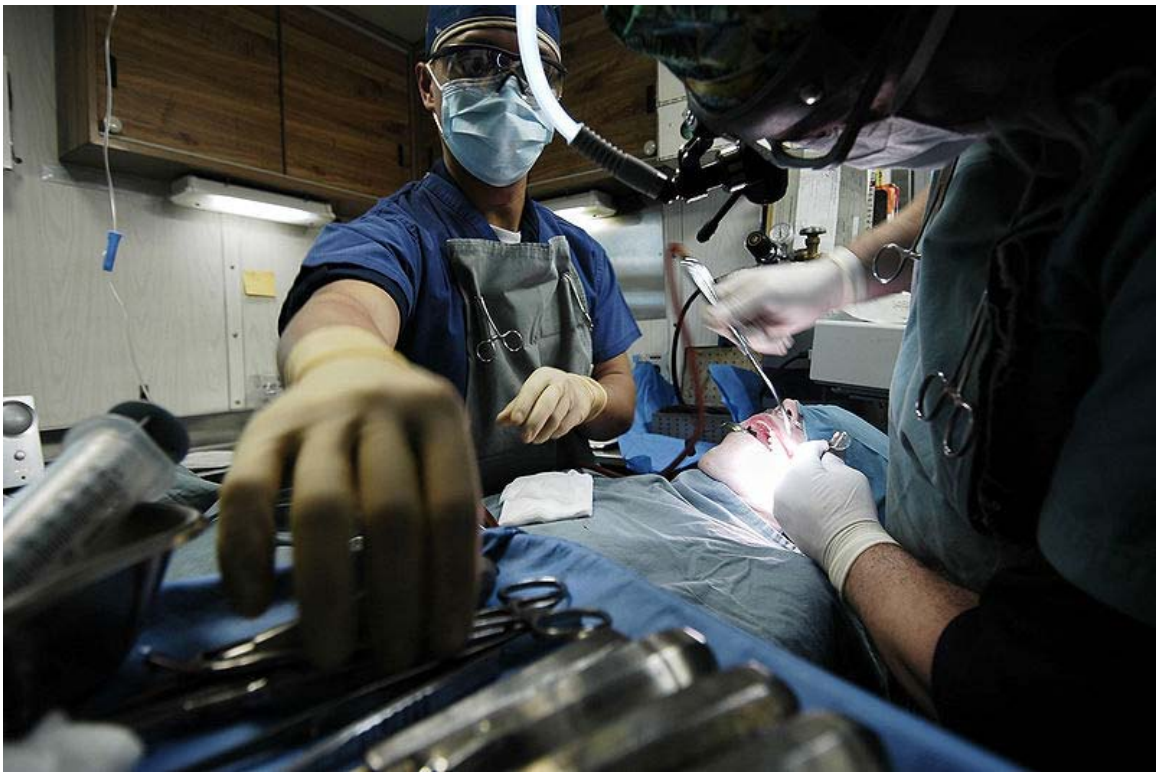
Facial plastic and reconstructive surgery

Facial plastic and reconstructive surgery is a one-year fellowship open to otolaryngologists and plastic surgeons who wish to specialize in the aesthetic and reconstructive surgery of the head, face, and neck.

- Rhinoplasty and septoplasty
- Facelift (rhytidectomy)
- Browlift
- Blepharoplasty
- Otoplasty
- Genioplasty
- Injectable cosmetic treatments
- Trauma to the face
    - Nasal bone fracture
    - Mandible fracture
    - Orbital fracture
    - Frontal sinus fracture
    - Complex lacerations and soft tissue damage

Chapter 7

Oral and Maxillofacial Surgery



Occupation

Oral and maxillofacial surgery is surgery to correct a wide spectrum of diseases, injuries and defects in the head, neck, face, jaws and the hard and soft tissues of the oral and maxillofacial region. It is a recognized international surgical specialty and it is one of the nine specialties of dentistry.

Regulations

In the U.S.A., UK, Canada, Australia, New Zealand and Brazil, oral and maxillofacial surgery is one of the 9 specialties recognized by the American Dental Association, Royal College of Surgeons of England, Royal College of Surgeons of Edinburgh, Royal College

of Dentists of Canada, Royal Australasian College of Dental Surgeons and Conselho Federal de Odontologia.

In other parts of the world oral and maxillofacial surgery as a specialty exists but under different forms as the work is sometimes performed by a single or dual qualified specialist depending on each country's regulations and training opportunities available.

Summary

An **oral and maxillofacial surgeon** is a regional specialist surgeon treating the entire craniomaxillofacial complex: anatomical area of the mouth, jaws, face, skull, as well as associated structures.

In the US, the name oral and maxillofacial surgery should be abbreviated most appropriately as OMS, rather than OMFS as some sources suggest. The abbreviation OMFS may be appropriate only in the European system where Maxillo-Facial is hyphenated. In the US, maxillofacial is the official entry in the American language dictionary defining the anatomical region, and is also the official term used by all related surgical organizations, including the AAOMS, ABOMS, and ACOMS.

Maxillofacial surgeons are usually initially qualified in dentistry and have undergone further surgical training. Some OMS residencies integrate a medical education as well and an appropriate degree in medicine (MBBS or MD or equivalent) is earned, although in the United States there is legally no difference in what a dual degree OMS can do compared to someone who earned a four year certificate. Oral & maxillofacial surgery is universally recognized as a one of the nine specialties of dentistry. However also in the UK and many other countries OMFS is a medical specialty as well culminating in the FRCS (Fellowship of the Royal College of Surgeons). Regardless, all oral & maxillofacial surgeons must obtain a degree in dentistry (BDS, BDent, DDS, or DMD or equivalent) before being allowed to begin residency training in oral and maxillofacial surgery.

They also may choose to undergo further training in a 1 or 2 year subspecialty fellowship training in the following areas:

- Head and neck cancer - microvascular reconstruction
- Cosmetic facial surgery
- Craniofacial surgery/Pediatric Maxillofacial surgery
- Cranio-maxillofacial trauma
- Head and neck reconstruction (plastic surgery of the head and neck region)
- Maxillofacial regeneration(reformation of the facial region by advanced stem cell technique)

The popularity of oral and maxillofacial surgery as a career for persons whose first degree was medicine, not dentistry, seems to be increasing in few EU countries However the public fund spend for 14 years of training is a big concern of the state. Integrated

programs are becoming more available to medical graduates allowing them to complete the dental degree requirement in about 3 years in order for them to advance to subsequently complete Oral and Maxillofacial surgical training.

Surgical procedures

Treatments may be performed on the craniomaxillofacial complex: mouth, jaws, neck, face, skull, and include:

- Dentoalveolar surgery (surgery to remove impacted teeth, difficult tooth extractions, extractions on medically compromised patients, bone grafting or preprosthetic surgery to provide better anatomy for the placement of implants, dentures, or other dental prostheses)
- Diagnosis and treatment of benign pathology (cysts, tumors etc.)
- Diagnosis and treatment (ablative and reconstructive surgery, microsurgery) of malignant pathology (oral & head and neck cancer).
- Diagnosis and treatment of cutaneous malignancy (skin cancer), lip reconstruction
- Diagnosis and treatment of congenital craniofacial malformations such as cleft lip and palate and cranial vault malformations such as craniosynostosis, (craniofacial surgery)
- Diagnosis and treatment of chronic facial pain disorders
- Diagnosis and treatment of temporomandibular joint (TMJ) disorders
- Diagnosis and treatment of dysgnathia (incorrect bite), and orthognathic (literally "straight bite") reconstructive surgery, orthognathic surgery, maxillomandibular advancement, surgical correction of facial asymmetry.
- Diagnosis and treatment of soft and hard tissue trauma of the oral and maxillofacial region (jaw fractures, cheek bone fractures, nasal fractures, LeFort fracture, skull fractures and eye socket fractures).
- Splint and surgical treatment of sleep apnea, maxillomandibular advancement, genioplasty (in conjunction with sleep labs or physicians)
- Surgery to insert osseointegrated (bone fused) dental implants and Maxillofacial implants for attaching craniofacial prostheses and bone anchored hearing aids.
- Cosmetic surgery limited to the head and neck: (rhytidectomy/facelift, browlift, blepharoplasty/Asian blepharoplasty, otoplasty, rhinoplasty, septoplasty, cheek augmentation, chin augmentation, genioplasty, oculoplastics, neck liposuction, lip enhancement, injectable cosmetic treatments, botox, chemical peel etc.)

In Australia, Canada, New Zealand, and the United States

Oral and Maxillofacial Surgery is one of the 9 dental specialties recognized by the American Dental Association, Royal College of Dentists of Canada, the Royal Australasian College of Dental Surgeonsand College of Physician and Surgeons Pakistan. Oral and Maxillofacial Surgery requires 4–6 years of further formal University training after dental school (DDS, BDent, DMD or BDS). Four-year residency programs grant a certificate of specialty training in Oral and Maxillofacial Surgery. Six-year residency programs grant the specialty certificate in addition to a medical degree (MD, DO, MBBS,

MBChB etc.). Specialists in this field are designated registrable U.S. “Board Eligible” and warrant exclusive titles. Approximately 50% of the training programs in the U.S., 100% of the programs in Australia and New Zealand, and 20% of Canadian training programs, are "dual-degree". The trainees obtain a degree in Medicine (MD, DO, MBBS, MBChB etc) as well as a specialty certificate in Oral and Maxillofacial Surgery.

The typical training program for an Oral and Maxillofacial Surgeon is:

- 2 - 4 Years Undergraduate Study (BS, BA, or equivalent degrees)
- 4 Years Dental Study (DMD, BDent, DDS or BDS)
- 4 - 6 Years Residency Training (additional time for acquiring medical degree)
- After completion of surgical training most undertake final specialty examinations: (U.S. "Board Certified (ABOMS)"), (Australia/NZ: "FRACDS(OMS)"), or (Canada: "FRCD(C)(OMS)")
- Many dually qualified oral and maxillofacial surgeons are now also obtaining Fellowships with the American College of Surgeons (FACS)
- Average total length after Secondary School: 12 - 14 Years

In addition, graduates of Oral and Maxillofacial Surgery training programs can pursue fellowships, typically 1 – 2 years in length, in the following areas:

- Head and neck cancer - microvascular reconstruction
- Cosmetic facial surgery (facelift, rhinoplasty, etc.)
- Craniofacial surgery/Pediatric Maxillofacial surgery (cleft lip and palate repair, surgery for craniosynostosis, etc.)
- Cranio-maxillofacial trauma (soft tissue and skeletal injuries to the face, head and neck)

Notable oral and maxillofacial surgeons

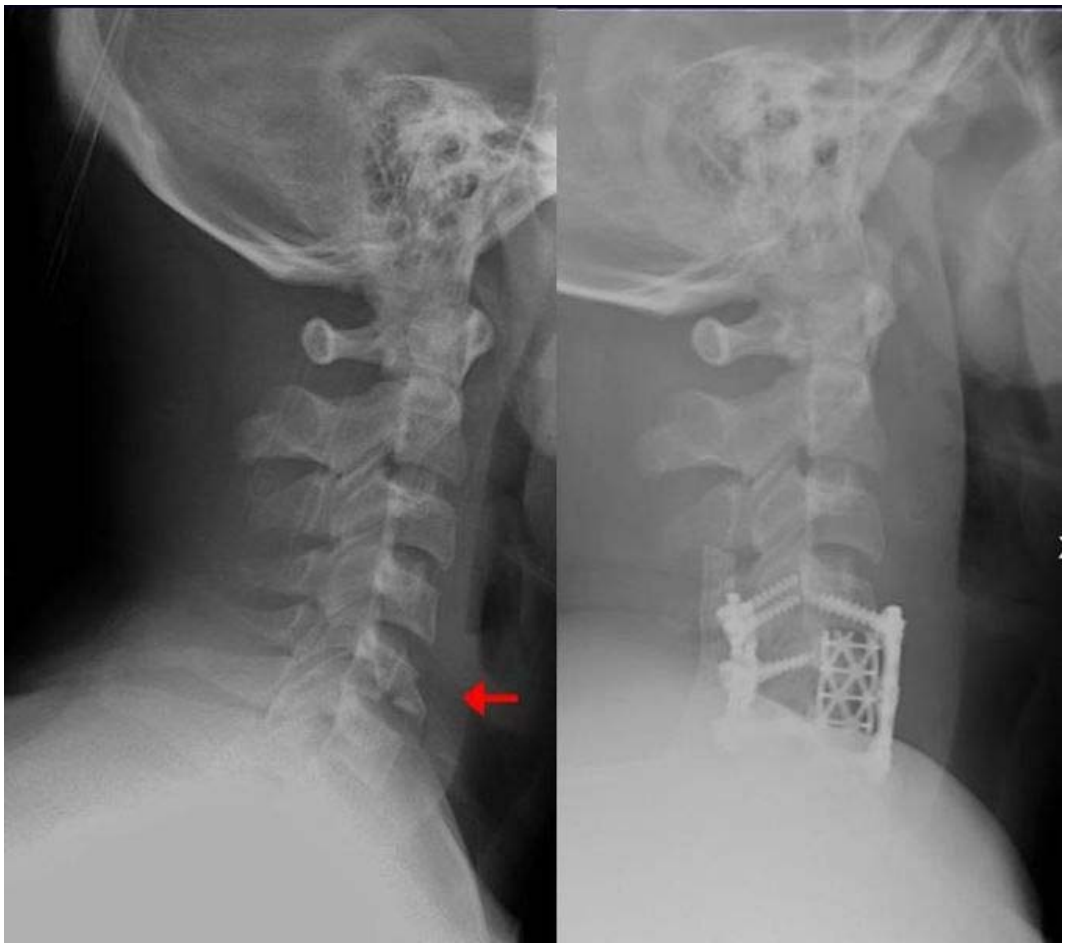
- Luc Chikhani reconstructed Trevor Rees-Jones's face, which was flattened by the impact of the car crash that killed Diana, Princess of Wales.
- Bernard Devauchelle a French oral and maxillofacial surgeon at Amiens University Hospital who in November 2005 successfully completed the first face transplant on Isabelle Dinoire.
- Tomaso Vercellotti developed a new technology to reduce damage caused by traditional burs and saws called Piezosurgery which uses ultra sonic vibrations to cut bone tissue leaving soft tissue unharmed.

Organizations

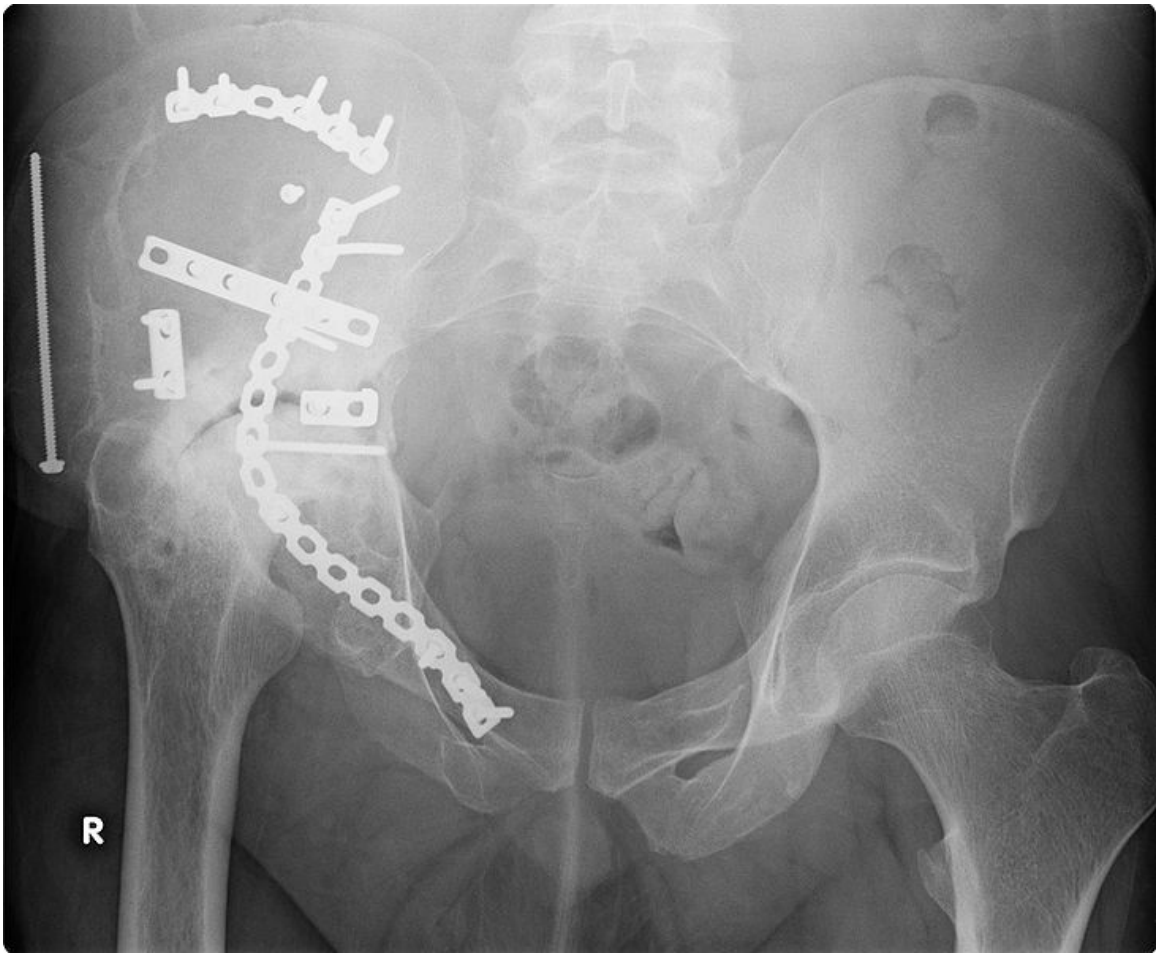
- American Association of Oral and Maxillofacial Surgeons
- American College of Surgeons
- The Royal College of Surgeons of England
- Faculty of Dental Surgery of The Royal College of Surgeons of England

Chapter 8

Orthopedic Surgery



This fracture of the lower cervical vertebrae, known as a "teardrop fracture", is one of the conditions treated by orthopedic surgeons and neurosurgeons.



This image, taken in September 2006, shows extensive repair work to the right acetabulum 6 years after it was carried out (2000). Further damage to the joint is visible due to the onset of arthritis.

Orthopedic surgery or **orthopedics** (also spelled **orthopaedics**) is the branch of surgery concerned with conditions involving the musculoskeletal system. Orthopedic surgeons use both surgical and nonsurgical means to treat musculoskeletal trauma, sports injuries, degenerative diseases, infections, tumors, and congenital disorders.

Nicholas Andry coined the word "orthopaedics", derived from Greek words for *orthos* ("correct", "straight") and *paideion* ("child"), when he published *Orthopaedia: or the Art of Correcting and Preventing Deformities in Children* in 1741. Correction of spinal and bony deformities became the cornerstone of orthopaedic practice. Today, over 6 months of training is dedicated to the treatment of the pediatric population.

In the United States *orthopedics* is standard, although the majority of university and residency programs, and even the American Academy of Orthopaedic Surgeons, still use Andry's spelling. Elsewhere, usage is not uniform; in Canada, both spellings are acceptable; *orthopaedics* usually prevails in the rest of the Commonwealth, especially in Britain.

Training

In the United States, orthopedic surgeons have typically completed four years of undergraduate education and four years of medical school. Subsequently, these medical school graduates undergo residency training in orthopedic surgery. The five-year residency consists of one year of general surgery training followed by four years of training in orthopedic surgery.

Selection for residency training in orthopedic surgery is extremely competitive. Approximately 700 physicians complete orthopedic residency training per year in the United States. About 10 percent of current orthopedic surgery residents are women; about 20 percent are members of minority groups. There are approximately 20,400 actively practicing orthopedic surgeons and residents in the United States. According to the latest Occupational Outlook Handbook (2009–2010) published by the United States Department of Labor, between 3–4% of all practicing physicians are orthopedic surgeons.

Many orthopedic surgeons elect to do further training, or fellowships, after completing their residency training. Fellowship training in an orthopedic subspeciality is typically one year in duration (sometimes two) and sometimes has a research component involved with the clinical and operative training. Examples of orthopedic subspecialty training in the United States are:

- Hand surgery
- Shoulder and elbow surgery
- Total joint reconstruction (arthroplasty)
- Pediatric orthopedics
- Foot and ankle surgery
- Spine surgery
- Musculoskeletal oncology
- Surgical sports medicine
- Orthopedic trauma

These specialty areas of medicine are not exclusive to orthopedic surgery. For example, hand surgery is practiced by some plastic surgeons and spine surgery is practiced by most neurosurgeons. Additionally, foot and ankle surgery is practiced by board-certified Doctors of Podiatric Medicine (D.P.M.) in the United States. Some family practice physicians practice sports medicine; however, their scope of practice is non-operative.

After completion of specialty residency/registrar training, an orthopedic surgeon is then eligible for board certification. Certification by the American Board of Orthopaedic Surgery means that the orthopedic surgeon has met the specified educational, evaluation, and examination requirements of the Board. The process requires successful completion of a standardized written exam followed by an oral exam focused on the surgeon's clinical and surgical performance over a 6-month period. In Canada, the certifying organization is the Royal College of Physicians and Surgeons of Canada; in Australia and New Zealand it is the Royal Australasian College of Surgeons.

In the United States, specialists in hand surgery and sports medicine may obtain a Certificate of Added Qualifications (CAQ) in addition to their board certification by successfully completing a separate standardized examination. There is no additional certification process for the other subspecialties.

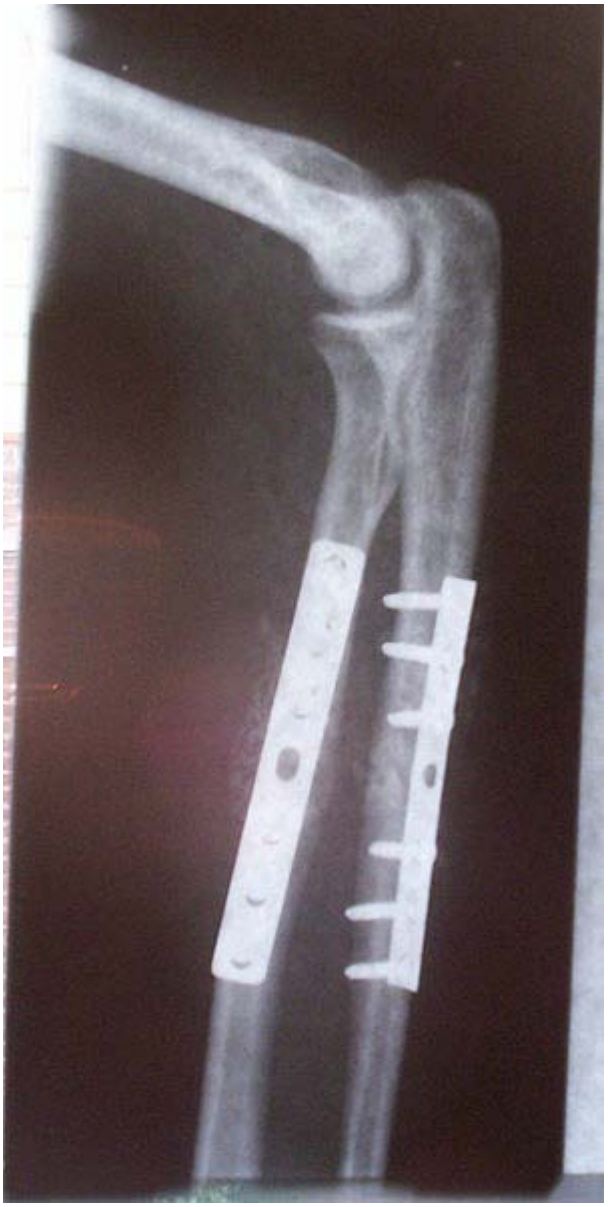
Practice

According to applications for board certification from 1999 to 2003, the top 25 most common procedures (in order) performed by orthopedic surgeons are as follows:

1. Knee arthroscopy and meniscectomy
2. Shoulder arthroscopy and decompression
3. Carpal tunnel release
4. Knee arthroscopy and chondroplasty
5. Removal of support implant
6. Knee arthroscopy and anterior cruciate ligament reconstruction and have nuts
7. Knee replacement
8. Repair of femoral neck fracture
9. Repair of trochanteric fracture
10. Debridement of skin/muscle/bone/fracture
11. Knee arthroscopy repair of both menisci
12. Hip replacement
13. Shoulder arthroscopy/distal clavicle excision
14. Repair of rotator cuff tendon
15. Repair fracture of radius (bone)/ulna
16. Laminectomy
17. Repair of ankle fracture (bimalleolar type)
18. Shoulder arthroscopy and debridement
19. Lumbar spinal fusion
20. Repair fracture of the distal part of radius
21. Low back intervertebral disc surgery
22. Incise finger tendon sheath
23. Repair of ankle fracture (fibula)
24. Repair of femoral shaft fracture
25. Repair of trochanteric fracture

A typical schedule for a practicing orthopedic surgeon involves 50–55 hours of work per week divided among clinic, surgery, various administrative duties and possibly teaching and/or research if in an academic setting. In 2009, the median salary for an orthopedic surgeon in the United States was $406,847.

History



Orthopedic implants to repair fractures to the radius and ulna. Note the visible break in the ulna. (right forearm)

Jean-Andre Venel established the first orthopedic institute in 1780, which was the first hospital dedicated to the treatment of children's skeletal deformities. He is considered by some to be the father of orthopedics or the first true orthopedist in consideration of the establishment of his hospital and for his published methods.

Antonius Mathysen, a Dutch military surgeon, invented the plaster of Paris cast in 1851. Many developments in orthopedic surgery resulted from experiences during wartime. On the battlefields of the Middle Ages the injured were treated with bandages soaked in

horses' blood which dried to form a stiff, but unsanitary, splint. Traction and splinting developed during World War I. The use of intramedullary rods to treat fractures of the femur and tibia was pioneered by Gerhard Küntscher of Germany. This made a noticeable difference to the speed of recovery of injured German soldiers during World War II and led to more widespread adoption of intramedullary fixation of fractures in the rest of the world. However, traction was the standard method of treating thigh bone fractures until the late 1970s when the Harborview Medical Center in Seattle group popularized intramedullary fixation without opening up the fracture. External fixation of fractures was refined by American surgeons during the Vietnam War but a major contribution was made by Gavril Abramovich Ilizarov in the USSR. He was sent, without much orthopedic training, to look after injured Russian soldiers in Siberia in the 1950s. With no equipment he was confronted with crippling conditions of unhealed, infected, and malaligned fractures. With the help of the local bicycle shop he devised ring external fixators tensioned like the spokes of a bicycle. With this equipment he achieved healing, realignment and lengthening to a degree unheard of elsewhere. His Ilizarov apparatus is still used today as one of the distraction osteogenesis methods.

Ruth Jackson became the first female Board-certified Orthopaedic Surgeon in the U.S in 1937. Orthopaedics continues to be a male-dominated field. In 2006, 12.4% of orthopaedics residents were women.

David L. MacIntosh pioneered the first successful surgery for the management of the torn anterior cruciate ligament (ACL) of the knee. This common and serious injury in skiers, field athletes, and dancers invariably brought an end to their athletics due to permanent joint instability. Working with injured football players, Dr MacIntosh devised a way to re-route viable ligament from adjacent structures to preserve the strong and complex mechanics of the knee joint and restore stability. The subsequent development of ACL reconstruction surgery has allowed numerous athletes to return to the demands of sports at all levels.

Modern orthopedic surgery and musculoskeletal research has sought to make surgery less invasive and to make implanted components better and more durable.

Arthroscopy

The use of arthroscopic techniques has been particularly important for injured patients. Arthroscopy was pioneered in the early 1950s by Dr. Masaki Watanabe of Japan to perform minimally invasive cartilage surgery and reconstructions of torn ligaments. Arthroscopy helped patients recover from the surgery in a matter of days, rather than the weeks to months required by conventional, 'open' surgery. Knee arthroscopy is one of the most common operations performed by orthopedic surgeons today and is often combined with meniscectomy or chondroplasty. The majority of orthopedic procedures are now performed arthroscopically.

Arthroplasty

The modern total hip replacement was pioneered by Sir John Charnley in England in the 1960s. He found that joint surfaces could be replaced by metal or high density polyethylene implants cemented to the bone with methyl methacrylate bone cement. Since Charnley, there have been continuous improvements in the design and technique of joint replacement (arthroplasty) with many contributors, including W. H. Harris, the son of R. I. Harris, whose team at Harvard pioneered uncemented arthroplasty techniques with the bone bonding directly to the implant.

Knee replacements using similar technology were started by McIntosh in rheumatoid arthritis patients and later by Gunston and Marmor for osteoarthritis in the 1970s developed by Dr John Insall in New York utilizing a fixed bearing system, and by Dr Frederick Buechel and Dr Michael Pappas utilizing a mobile bearing system.

Uni-compartmental knee replacement, in which only one weight-bearing surface of an arthritic knee is replaced, is an alternative to a total knee replacement in a select patient population.

Joint replacements are available for other joints on a limited basis, most notably shoulder, elbow, wrist, ankle, spine, and fingers.

In recent years, surface replacement of joints, in particular the hip joint, have become more popular amongst younger and more active patients. This type of operation delays the need for the more traditional and less bone-conserving total hip replacement, but carries significant risks of early failure from fracture and bone death.

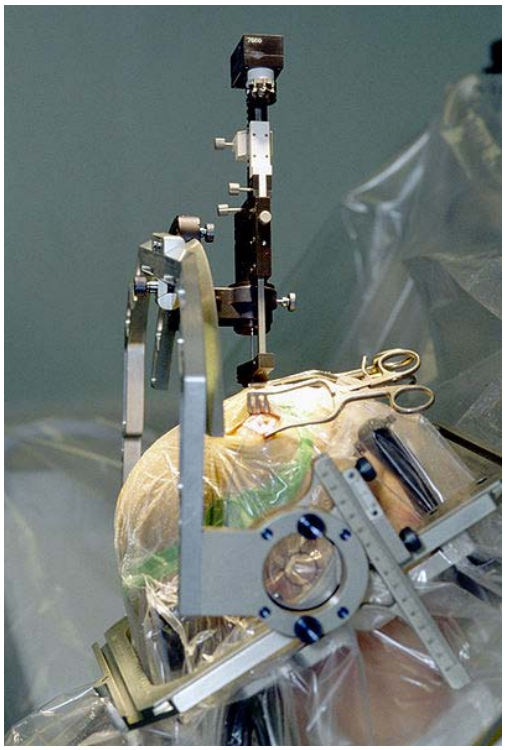
One of the main problems with joint replacements is wear of the bearing surfaces of components. This can lead to damage to surrounding bone and contribute to eventual failure of the implant. Use of alternative bearing surfaces has increased in recent years, particularly in younger patients, in an attempt to improve the wear characteristics of joint replacement components. These include ceramics and all-metal implants (as opposed to the original metal-on-plastic). The plastic (actually ultra high-molecular-weight polyethylene) can also be altered in ways that may improve wear characteristics.

Chapter 9

Neurosurgery and Podiatry

Neurosurgery

Neurosurgery



Occupation	
Activity sectors	Surgery
Description	
Education required	Doctor of Medicine
Fields of employment	Hospitals, Clinics

Neurosurgery (or **neurological surgery**) is the medical specialty concerned with the prevention, diagnosis, treatment and rehabilitation of disorders that affect the entire nervous system including the brain, spinal column, spinal cord, peripheral nerves, and extra-cranial cerebrovascular system.

Education and training

In the United States, a neurosurgeon must generally complete four years of college, four years of medical school, a year-long internship (PGY-1) that is usually affiliated with their residency program, and five to six years of neurosurgery residency (PGY-2-6). Most, but not all, residency programs have some component of basic science or clinical research. Neurosurgeons may pursue an additional training in a fellowship, after residency or in some cases, as a senior resident. These fellowships include pediatric neurosurgery, neurocritical care, functional and stereotactic surgery, surgical neuro-oncology, neurovascular surgery, Interventional neuroradiology, or skull base surgery. Neurosurgeons can also pursue fellowship training in neuropathology and neuro-ophthalmology.

In the UK students must earn A*- C Grades at GCSE (General Certificate of Secondary Education), then they must also achieve A*- C at A levels in Chemistry with at least one other Science or Maths. Also a UKCAT (UK Clinical Aptitude Test) or BMAT (BioMedical Admissions Test) can be used to gain access into some Medical Schools. Students have to study medicine for 5 years and achieve an MBBS qualification (Bachelor of Medicine and Bachelor of Surgery). Then the student must perform Foundation training lasting normally 2 years, this is a paid training job in a hospital or clinical situation setting covers a range of Medical specialties including Surgery. Core Surgical training is then taken which lasts for 2 years the difference in this is that the training would be themed towards a particular speciality.

Neurosurgical methods

Neuroradiology methods are used in modern neurosurgical diagnosis and treatment. computer assisted imaging computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), magnetoencephalography (MEG) and the development of stereotactic surgery. Some neurosurgical procedures involve the use of MRI and functional MRI intraoperatively.

Microsurgery is utilized in many aspects of neurological surgery. Microvascular anastomosis are required when EC-IC surgery is performed. The clipping of aneurysms is performed using a microscope. Minimally invasive spine surgery utilizes relies on these techniques. Procedures such as microdiscectomy, laminectomy, and artificial discs rely on microsurgery.

Minimally invasive endoscopic surgery is utilized by neurosurgeons. Techniques such as endoscopic endonasal surgery is used for pituitary tumors, craniopharyngiomas, chordomas, and the repair of cerebrospinal fluid leaks. Ventricular endoscopy is used for

colloid cysts and neurocysticercosis. Endoscopic techniques can be used to assist in the evaculation of hematomas and trigeminal neuralgia. Repair of craniofacial disorders and disturbance of cerebrospinal fluid circulation is done by neurosurgeons, and depending on the situation, plastic surgeons. Conditions such as chiari malformation, craniosynostosis, and syringomyelia are treated. This is called cranioplasty.

Neurosurgeons are involved in Stereotactic Radiosurgery along with Radiation Oncologists for tumor and AVM treatment. Radiosurgical methods such as Gamma knife and Cyberknife are used.

Neurosurgeons have begun to utilize endovascular image guided procedures for the treatment of aneurysms, AVMs, carotid stenosis, strokes, and spinal malformations, and vasospasms. Also, nonvascular procedures such as Vertoplasty and Kyphoplasty are used by neurosurgeons. Techniques such as angioplasty, stenting, clot retrieval, embolization, and diagnostic angiography are utilized.

Conditions

Other conditions treated by neurosurgeons include:

- Spinal disc herniation
- Cervical spinal stenosis and Lumbar spinal stenosis
- Hydrocephalus
- Head trauma (brain hemorrhages, skull fractures, etc.)
- Spinal cord trauma
- Traumatic injuries of peripheral nerves
- Infections
- Tumours of the spine, spinal cord and peripheral nerves
- Intracerebral hemorrhage, such as subarachnoid hemorrhage, intraparenchymal, and intraventricular hemorrhages
- Some forms of drug-resistant epilepsy
- Some forms of movement disorders (advanced Parkinson's disease, chorea) – this involves the use of specially developed minimally invasive stereotactic techniques (functional, stereotactic neurosurgery) such as ablative surgery and deep brain stimulation surgery
- Intractable pain of cancer or trauma patients and cranial/peripheral nerve pain
- Some forms of intractable psychiatric disorders
- Vascular malformations (i.e., arteriovenous malformations, venous angiomas, cavernous angiomas, capillary telangectasias) of the brain and spinal cord
- Peripheral neuropathies such as carpal tunnel syndrome and ulnar neuropathy
- Moyamoya disease

Podiatry

Podiatrist performing a bunionectomy and hammertoe correction surgery on a young female patient.

Podiatry is a branch of medicine devoted to the study, diagnosis, and treatment of disorders of the foot, ankle, and lower leg. Podiatrists are defined as physicians by the U.S. federal government and in most U.S. states.

The term *podiatry* came into use first in the early 20th century United States, where it now denotes a Doctor of Podiatric Medicine (DPM), a specialist who is qualified by their education and training to diagnose and treat conditions affecting the foot, ankle, and

related structures of the leg. Within the field of podiatry, practitioners can focus on many different specialty areas, including surgery, sports medicine, biomechanics, geriatrics, pediatrics, orthopedics, or primary care.

In January of 2011, the American Podiatric Medical Association (APMA) publicly launched the Today's Podiatrist campaign, which aims to educate the public, medical professionals, and students about the education and training of today's podiatrist.

Podiatry is practiced as a specialty in many countries including Australia, Brunei, Canada, Cyprus, Ireland, Malta, New Zealand, Singapore, South Africa, the United Kingdom, and the United States. In many English-speaking countries, the older title of "chiropodist" may still be used by some clinicians but is gradually falling out of use. In many non-English-speaking countries of Europe, the title used instead of podiatrist may be "podologist" " or "Podólogo". The level and scope of the practice of podiatry varies among countries. Podiatry is a very high paying job and was listed by *Forbes* as the 15th best paid profession in the United States.

History

The professional care of feet was in existence in ancient Egypt as evidenced by bas-relief carvings at the entrance to Ankmahor's tomb dating from about 2400 BC where work on hands and feet is depicted.

Corns and calluses were described by Hippocrates who recognised the need to physically reduce hard skin, followed by removal of the cause. He invented skin scrapers for this purpose and these were the original scalpels. Aulus Cornelius Celsus, a Roman scientist and philosopher, was probably responsible for giving corns their name. Later Paul of Aegina (AD 615–690) defined a corn as "a white circular body like the head of a nail, forming in all parts of the body, but more especially on the soles of the feet and the toes. It may be removed in the course of some time by paring away the prominent part of it constantly with a scalpel or rubbing it down with pumice. The same thing can be done with a callus."

Until the turn of the 20th century, chiropodists—now known as podiatrists—were separate from organized medicine. They were independently licensed physicians who treated the feet, ankles and related leg structures. Lewis Durlacher was one of the first people to recognize the need for a protected profession. He tried to establish the first association of practitioners in 1854, although it would take another century to come to pass.

There are records of the King of France employing a personal podiatrist, as did Napoleon. In the United States, President Abraham Lincoln suffered greatly with his feet and chose a chiropodist named Isachar Zacharie, who not only cared for the president’s feet, but also was sent by President Lincoln on confidential missions to confer with leaders of the Confederacy during the U.S. Civil War.

The first society of chiropodists, now known as podiatrists, was established in—and still operates in—New York in 1895 as NYSPMA, with the first school opening in 1911. One year later the British established a society at the London Foot Hospital and a school was added in 1919. In Australia professional associations appeared from 1924 onwards. The first American journal appeared in 1907, followed in 1912 by a UK journal. In 1939, the Australians introduced a training centre as well as a professional journal. The number of chiropodists increased markedly after the Great War then again after World War II.

Increased numbers of ex-soldiers needing to be gainfully employed gave chiropody a boost and led to the need for registration in all English speaking countries. The study of the foot (i.e. podology), brought greater knowledge to the practice of foot care or podiatry.

Specific country practices

Australia

In Australia, podiatry is classified as an allied health profession, and is practised by individuals licensed by their representative State Boards of Podiatry. There are seven registration boards and six teaching centres, with two levels of awards — unclassified bachelors degree and honours level. In Australia there exist 2 levels of professional accreditation and professional privilege: Podiatrist and Podiatric Surgeon. Australian podiatrists are able to practise abroad with their qualifications recognised in some Commonwealth countries.

Registration and regulation

Australian Podiatrists must register with the Podiatry Board of Australia. The Podiatry Board of Australia is responsible for regulation and recognition of Podiatrists and Podiatric Surgeons, and assessing foreign trained registrants.

The Podiatry Board of Australia recognizes 3 pathways to attain specialist registration as a Podiatric Surgeon:

1. Fellowship of the Australasian College of Podiatric Surgeons

2. Doctor of Clinical Podiatry, University of Western Australia

3. Eligibility for Fellowship of the Australasian College of Podiatric Surgeons

Education and training

Australian podiatrists complete an undergraduate degree ranging from 3 to 4 years of education. The first 2 years of this program are generally focused on various biomedical science subjects including anatomy, medical chemistry, biochemistry, physiology and

patient psychology, similar to the medical curriculum. The following two years will then be spent focusing on podiatry specific areas such as podiatric biomechanics and human gait, podiatric orthopaedics or the non-surgical management of foot abnormalities, pharmacology, general medicine, general pathology, local and general anaesthesia, and surgical techniques such as partial and total nail avulsions, wound debridement, and other cutaneous and electrosurgical procedures.

Australian podiatric surgeons are specialist podiatrists with further training in advanced medicine, advanced pharmacology, and training in foot surgery. Podiatrists wishing to pursue specialisation in podiatric surgery must meet the requirements for Fellowship with the Australasian College of Podiatric Surgeons. They first complete a degree of 4 years, which includes 2 years of didactic study and 2 years of clinical experience. Following this, a masters degree must be completed with focus on biomechanics, medicine, surgery, general surgery, advanced pharmacology, advanced medical imaging and clinical pathology. They then qualify for the status of Registrar with the Australasian College of Podiatric Surgeons. Following surgical training with a podiatric surgeon (3–5 years), rotations within other medical and surgeons' disciplines, overseas clinical rotations, and passing oral and written exams, Registrars may qualify for Fellowship status. Fellows are then given Commonwealth accreditation under the Health Insurance Act to be recognised as providers of *professional attention*, for the purposes of health insurance rebates.

Prescribing and referral rights

There is considerable variation between state laws regarding the prescribing rights of Australian podiatrists. While all registered podiatrists in each state or territory are able to utilize local anaesthesia for minor surgical techniques, some states allow suitably qualified podiatrists further privileges.

Recent legislative changes, which are expected to come into effect soon, will allow registered podiatrists and podiatric surgeons in Victoria and New South Wales to prescribe relevant schedule 4 poisons. In other states, such as Western Australia and South Australia, podiatrists with Masters Degree's in Podiatry, and extensive training in pharmacology are authorised to prescribe S4 poisons. In Queensland, Fellows of the Australasian College of Podiatric Surgeons are authorised to prescribe a range of Schedule 4 and one Schedule 8 drug for the treatment of podiatric conditions.

All podiatrists may refer patients for Medicare rebatable plain x-rays of the foot, leg, knee and femur, as well as ultrasound examination of soft tissue conditions of the foot. Podiatrists may refer patients for other radiology investigations such as CT, MRI or bone scans, however Medicare rebates do not currently exist for these examinations. Similarly, podiatrists may refer patients when needed to specialist medical practitioners, or for pathology testing, however similar exclusions in the Medicare Benefits Schedule prevent rebates being available to patients for these referrals.

Canada

In Canada the definition and scope of practice of podiatry can mean very different things. For instance, in some provinces like British Columbia and Alberta, the standards are the same as in the United States where the Doctor of Podiatric Medicine (DPM)is the accepted qualification. Quebec, too, has recently changed to the DPM level of training although other academic designations may also register. Also in Quebec, in 2004, Université du Québec à Trois-Rivières started the first program of Podiatric Medicine in Canada based on the American definition of podiatry. In the prairie and atlantic provinces, the standard was originally based on the British model now called podiatry (chiropody). That model of podiatry is now the accepted model for most of the world including the United Kingdom, Australia and South Africa. The province of Ontario, now only registers Chiropodists since July 1993 where the Ontario Government imposed a cap on new podiatrists. Even if an American, British or other countries registered podiatrist were to emigrate to Ontario they would have to registar and practice as a chiropodist. The podiatrists who were practicing in Ontario previous to this cap were grandfathered and kept the title of podiatrist as a subclass of chiropody. The scope of these grandfathered (mostly American trained) podiatrists includes boney procedures of the forefoot and the ordering of x-rays in addition to the scope of the chiropodist.

New Zealand

Chiropody became a registered profession in New Zealand in 1969 with the requirement that all applicants take a recognized three-year course of training. Soon after the professional title was changed from Chiropody to Podiatry and The New Zealand School of Podiatry was established in 1970 at Petone under the direction of John Gallocher. Later the school moved to the Central Institute of Technology, Upper Hutt, Wellington. In 1976 the profession gained the legal right to use a local anaesthetic and began to introduce minor surgical ingrown toenail procedures as part of the scope of practice.

New Zealand podiatrists were granted the right of direct referral to radiologists for X-rays in 1984. Acknowledgement of podiatric expertise marked improved services to patients and eventually in 1989 suitably trained podiatrists were able to become licensed to take X-rays within their own practice. Diagnostic radiographic training is incorporated into the degree syllabus and on successful completion of the course, graduates register with the New Zealand National Radiation Laboratory.

In 1986, the profession undertook a needs analysis in conjunction with the Central Institute of Technology to identify competencies for podiatry in 2000. A Bachelor of Health Science was introduced in 1993. Auckland University of Technology is now the only provider of podiatry training in New Zealand.

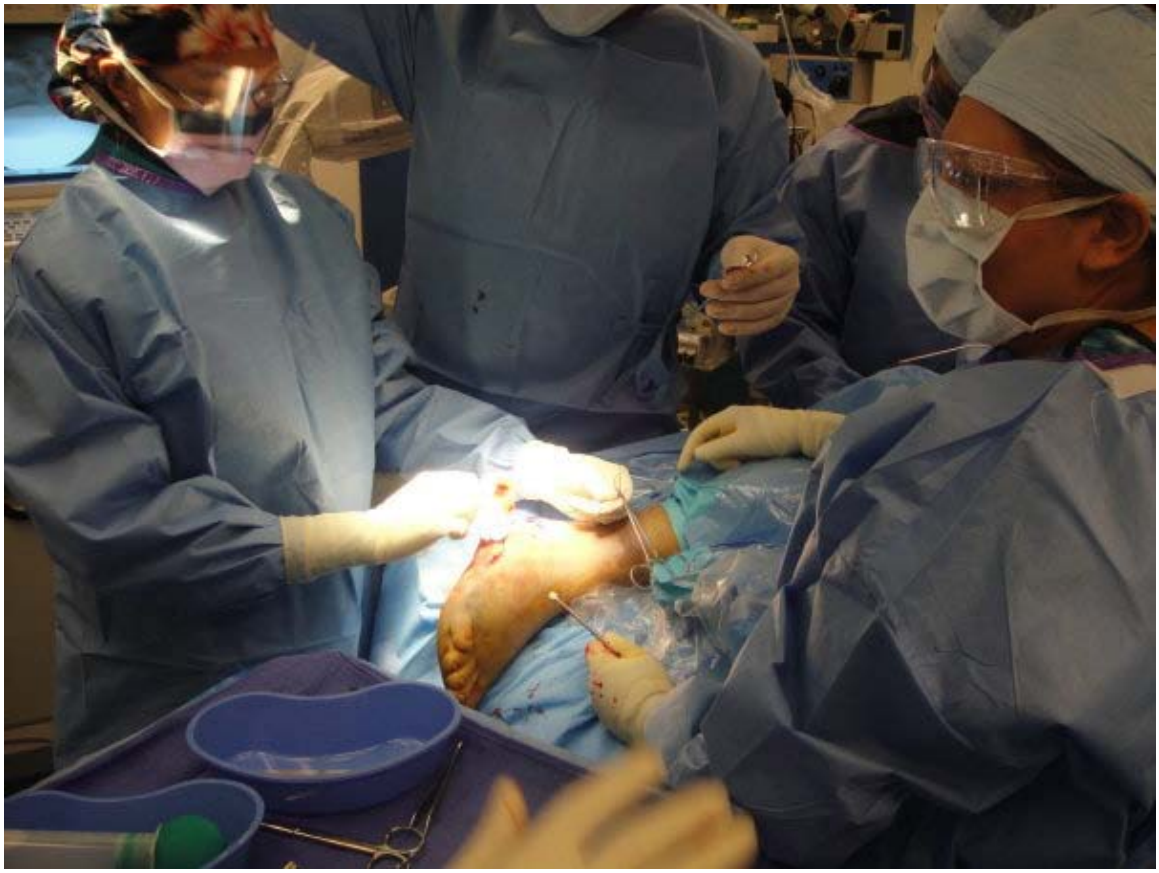
United Kingdom

A podiatrist is qualified by their education and training to diagnose and treat conditions affecting the foot, ankle, and related structures of the leg. Podiatrists are uniquely

qualified among medical and health professionals to treat the foot and ankle based on their education, training and experience. The scope of practice of UK podiatrists on registration after their degree in podiatric medicine includes the use and supply of some prescription only medicines, injection therapy and non-invasive surgery e.g. performing partial or total nail resection and removal, with chemical destruction of the tissues. Podiatrists complete some 1,200 supervised clinical hours in the course of their training which enables then to recognise systemic disease as it manifests in the foot and will refer on to the appropriate health care professional. Those in the NHS interface between the patients and multidisciplinary teams. The Scope of Practice of a Podiatrist is varied.

In a similar way to podiatrists in Australasia, UK podiatrists may continue their studies and qualify as podiatric surgeons. This training programme has developed over the last 30 years including development of standards in co-operation with the Scottish Royal Surgical Colleges. The training requires a number of years study at postgraduate level including a Masters degree in the Principles of Podiatric Surgery, then a year as a pre-surgical trainee working within a podiatric surgical team, at least 2 years as a surgical trainee working to complete parts C and D of the surgical training and complete pre-Fellowship surgical training. Following this, and having successfully passed a practical surgical assessment, a Podiatric surgeon will work at a specialist registrar (SpR) level for a minimum of three years under a Consultant Podiatric Surgeon. This SpR period must be satisfactorily completed before being eligible to apply for a Consultant National Health Service (NHS) post. These posts are subject to an appointments panel including an assessor from the Faculty of Surgery of the College of Podiatrists (an existing consultant podiatric surgeon). Only if successfully appointed to such an NHS post may he/she then be able to use the title Consultant Podiatric Surgeon.

Podiatric surgery in the UK is not a recent development. The First UK training in podiatric surgery developed over 30 years ago in North London. The original podiatric surgery faculty invited over by UK podiatric surgeons who had trained with them in the USA were leading US podiatric surgeons including; E Dalton McGlamry, Tildern Sockaloff, Guido LaPorta and later Lowell Scott Weil. The First specific podiatric surgery in the NHS was provided via Shropshire Health Authority in 1983 and shortly after in the adjacent English county of Herefordshire. The first specific podiatric surgery service was approved by Herefordshire Health Authority in 1986. Subsequently these NHS services developed with Consultant Podiatric Surgeons being appointed to lead these growing services. The First dedicated NHS Podiatric Daysurgery Unit was officially opened in Hereford in 1993. There are now a number of NHS dedicated NHS Podiatric Daysurgery Units and many NHS Trusts providing podiatric surgery.



A podiatric resident performs surgery on a patient who sustained trauma to the foot

Podiatric surgeons specialise in invasive foot surgery. The scope of practice is defined as "surgery of the foot and associated structures". The majority of work reflects the frequency of foot pathology presenting in the UK, most commonly digital and forefoot surgery, as well as mid foot and rearfoot surgery including triple arthrodeses, ankle stabilisations and Achilles tendon lengthenings/repairs. At present these surgeries are not carried out by all Podiatric Surgeons.

In the UK, individuals may not use the title "chiropodist" or “podiatrist” unless they are registrants of the Health Professions Council (HPC). They are protected titles and their use by non-registrants is unlawful. This protection extends to titles including the adjectival forms e.g. "podiatric surgeon" or "chiropody practitioner". Such registration is normally only granted to those holding a specialized Bachelors degree or Diploma in podiatry from one of the 13 recognized schools of podiatry in the UK.

The nomenclature surrounding the job titles of podiatric surgeons has been the source of some criticism from some constituencies within the medical community (in particular orthopaedics). The stated concern underlying the criticism is that podiatric surgeons are not medically qualified or regulated by the Royal Surgical Colleges and may be misleading lay-people into believing that their title 'podiatric surgeon' implies that they are medically qualified and regulated by the Royal Surgical Colleges. This issue has been

debated several times over the last 30 years despite the fact that all podiatric surgeons provide clear information to their patients regarding their training and qualifications as part of the process of informed consent. Despite this much co-operation exists and in many areas podiatric surgeons and orthopaedic surgeons work closely together for the greatest benefit of patients, in multidisciplinary teams while respecting each others' professional independence. Appropriately qualified podiatrists are licensed to access and supply a limited range of POMs including antibiotics, analgesics, and steroids for injection.

Professional bodies recognised by the Health Professions Council are : The Society of Chiropodists and Podiatrists, The Institute of Chiropodists and Podiatrists, The British Chiropody and Podiatry Association and The Alliance of Private Sector Chiropody and Podiatry Practitioners. **Foot Health Practitioners**: Since the recent statutory regulation/registration of the Chiropody/podiatry sector by the Health Professions Council there has been an increase in the number of former practitioners (of private sector routine footcare) not being allowed to use their former title – (Chiropodist/Podiatristas a higher degree (or the alternative diploma) in podiatric medicine etc became the required standard for statutory registration. Former practitioners of Chiropody in the UK who did not meet the requirements to be admitted to the HPC register now use the title of Foot Health Practitioner which came in being in 2005. These practitioners provide basic footcare and may refer clients who require more advanced treatments to a Chiropodist/Podiatrist. Clients who have a condition not directly related to the health of the foot, but which is recognised by the Foot Health Practitioner may be referred to a medical doctor for examination (this can be the case especially with elderly clients). It should be noted that it is not only former private sector chiropodists/podiatrists who use the title of Foot Health Practitioner – There are now courses available from well established private training colleges throughout the UK The longest established being The Smae Institute – Founded in 1919) allowing individuals with little or no health care experience to train to become an FHP. Appropriately trained Foot Health Practitioners can become associate members of the following Podiatry/Chiropody bodies: The Institute of Chiropodists and Podiatrists & The Alliance of Private Sector Chiropody and Podiatry Practitioners as well as other professional organizations that are not recognized by the HPC. There is currently no statutory registration/ regulation for practitioners in the private foot health sector – much like the lack of regulation of private sector Chiropody/Podiatry prior to 2003–2005. The title "Foot Health Practitioner" is a title not regulated by statute and can be used by anyone regardless of training levels. The HPC has no plans at present to regulate FHPs despite representations being made by those professional organisation who have FHPs as members.

United States

In the United States, medical and surgical care of the foot and ankle is mainly provided by two groups of physicians: *podiatrists* (Doctor of Podiatric Medicine or DPM) and *orthopedists* (MDs or DOs).

The first year of podiatric medical school is similar to training that either medical doctors or osteopathic doctors receive, but with an emphasized scope on foot, ankle, and lower extremity. Being classified as a second entry degree, in order to be considered for admission an applicant must first complete a minimum of 90 semester hours at the university level and/or complete a bachelor's degree. In addition, potential students are required to take the Medical College Admission Test (MCAT). The DPM degree itself takes a minimum of four years to complete.

A podiatry student examines the adduction angle of the hallux

The four-year podiatric medical school is followed by a residency, which is hands-on post-doctoral training. There are two standard residencies named Podiatric Medicine and Surgery 24 or 36 (PM&S 24 or PM&S 36). These represent the two- or three-year residency training. Podiatric residents rotate through all main areas of medicine such as emergency, pediatric, internal medicine, and general surgery and of course podiatry — both clinic and surgical. During these rotations, attending podiatrists train the resident physicians in medicine and surgery.

Podiatric Surgical Training

Upon completion of their residency, podiatrists can become board certified by either the American Board of Podiatric Orthopedics and Primary Podiatric Medicine or the American Board of Podiatric Surgery.

Podiatrists certified by the ABPS have successfully completed an intense board certification process comparable to that undertaken by individual MD and DO specialties. Certification by the ABPS involves written, oral, and computer-based patient simulation questions, in addition to submission of surgical case logs. Prerequisites for board qualification in Foot and Reconstructive Rearfoot/Ankle Surgery require successful completion of a three-year podiatric surgical program and passing a written examination.

Another recognized board is the American Board of Multiple Specialties in Medicine and American Board of Multiple Specialties in Surgery. Criteria for certification is similar to the previously mentioned boards. Computer based patient simulation written examination must be successfully completed followed by submission of case logs. Prerequisites with an approved podiatric surgical and medical residencies are also required.

Practice characteristics

While the majority of podiatric physicians are in solo practice, there has been a movement toward larger group practices as well as the use of podiatrists in multi-specialty groups including orthopedic groups, treating diabetes, or in multi-specialty orthopedic surgical groups. Some podiatrists work within clinic practices such as the Indian Health System (IHS), the Rural Health Centers (RHC) and Community Health Center (FQHC) systems established by the US government to provide services to under-insured and non-insured patients as well as within the United States Department of Veterans Affairs providing care to veterans of military service.

Some podiatrists have primarily surgical practices. Some specialists complete additional fellowship training in reconstruction of the foot and ankle. Many podiatric surgeons specialize in minimally invasive percutaneous surgery. Most podiatrists utilize medical, orthopedic, biomechanical and surgical practices. Surgical podiatric principles rest on a base of orthopedic and kinesthetic knowledge.

Invasive surgery can be avoided in some limited foot problems, including certain bunion related problems.

Colleges and education

There are nine colleges of podiatric medicine in the United States. These are governed by the American Association of Colleges of Podiatric Medicine (AACPM). The AACPM describes its mission as to enhance academic podiatric medicine. All podiatric medical schools in the United States are accredited by the Council on Podiatric Medical Education.

- Western University School of Health Sciences
- Arizona Podiatric Medicine Program (AZPod) at Midwestern University
- Barry University School of Podiatric Medicine
- California School of Podiatric Medicine
- Des Moines University College of Podiatric Medicine and Surgery
- New York College of Podiatric Medicine
- Ohio College of Podiatric Medicine
- Scholl College of Podiatric Medicine
- Temple University School of Podiatric Medicine

Speciality branches

Podiatrists treat a wide variety of foot and lower extremity conditions, through nonsurgical and surgical approaches. There are those podiatric physicians who also subspecialize in such fields of practice as:

- Reconstructive Rearfoot and Ankle Surgery
- Sports Medicine

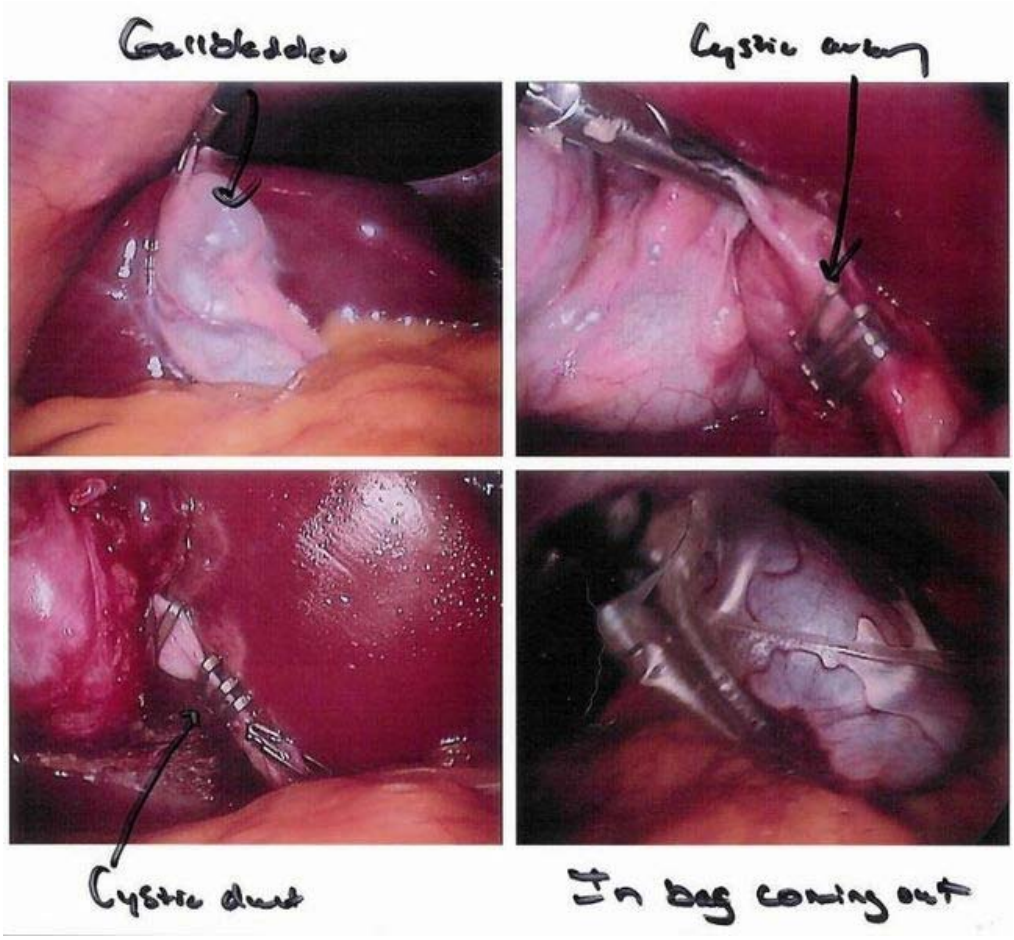
- Diabetic limb salvage and wound care
- Podopaediatrics (the study of children's foot and ankle conditions)
- Forensic Podiatry (the study of footprints, footwear, shoeprints and feet associated with crime scene investigations)

Professional societies and organizations

- Alberta Podiatry Association (APA)
- Alpha Gamma Kappa Fraternity
- American Podiatric Medical Association (APMA)
- American Society of Podiatric Surgeons (ASPS)
- American Society of Forensic Podiatry
- American College of Foot and Ankle Surgeons (ACFAS)
- American Board of Podiatric Surgery (ABPS)
- American College of Foot & Ankle Orthopedics & Medicine (ACFAOM)
- American Board of Podiatric Orthopedics and Primary Podiatric Medicine (ABPOPPM)
- American Board of Multiple Specialties in Podiatric Medcine
- American Board of Multiple Specialties in Podiatric Surgery
- American Academy of Podiatric Sports Medicine (AAPSM)
- American Society of Podiatric Dermatology (ASPD)
- Canadian Podiatric Medical Association (CPMA)
- American Academy of Podiatric Practise Management (AAPPM)
- Federation Internationale des Podologues (FIP)
- International Foot and Ankle Biomechanics Community (i-FAB)
- Student National Podiatric Medical Association (SNPMA)
- American Podiatric Medical Students' Association (APMSA)
- Australasian College of Podiatric Surgeons (ACPS)
- Australasian Podiatry Council (APodC)
- Podiatry Board of Australia (PBA)

Chapter 10

Laparoscopic Surgery



Cholecystectomy as seen through a laparoscope

Laparoscopic surgery, also called *minimally invasive surgery* (MIS)*, bandaid surgery*, *keyhole surgery* is a modern surgical technique in which operations in the abdomen are performed through small incisions (usually 0.5–1.5 cm) as compared to the larger incisions needed in laparotomy.

Keyhole surgery uses images displayed on TV monitors for magnification of the surgical elements.

Laparoscopic surgery includes operations within the abdominal or pelvic cavities, whereas keyhole surgery performed on the thoracic or chest cavity is called thoracoscopic surgery. Laparoscopic and thoracoscopic surgery belong to the broader field of endoscopy.

There are a number of advantages to the patient with laparoscopic surgery versus an open procedure. These include reduced pain due to smaller incisions and hemorrhaging, and shorter recovery time.

The key element in laparoscopic surgery is the use of a laparoscope. There are two types: (1) a telescopic rod lens system, that is usually connected to a video camera (single chip or three chip), or (2) a digital laparoscope where the charge-coupled device is placed at the end of the laparoscope, eliminating the rod lens system. Also attached is a fiber optic cable system connected to a 'cold' light source (halogen or xenon), to illuminate the operative field, inserted through a 5 mm or 10 mm cannula or trocar to view the operative field. The abdomen is usually insufflated, or essentially blown up like a balloon, with carbon dioxide gas. This elevates the abdominal wall above the internal organs like a dome to create a working and viewing space. CO_2 is used because it is common to the human body and can be absorbed by tissue and removed by the respiratory system. It is also non-flammable, which is important because electrosurgical devices are commonly used in laparoscopic procedures.

History

It is difficult to credit one individual with the pioneering of the laparoscopic approach. In 1902, Georg Kelling, of Dresden, Saxony, performed the first laparoscopic procedure in dogs and in 1910, Hans Christian Jacobaeus of Sweden reported the first laparoscopic operation in humans. In the ensuing several decades, numerous individuals refined and popularized the approach further for laparoscopy. The start of computer chip television camera was a seminal event in the field of laparoscopy. This technological innovation provided the means to project a magnified view of the operative field onto a monitor and, at the same time, freed both the operating surgeon's hands, thereby facilitating performance of complex laparoscopic procedures. Prior to its conception, laparoscopy was a surgical approach with very limited application, used mainly for purposes of diagnosis and performance of simple procedures in gynecologic applications.

The first publication on Diagnostic Laparoscopy by Raoul Palmer appeared in the early 1950s, followed by the publication of Frangenheim and Semm. Hans Lindermann and Kurt Semm practised CO2 hysteroscopy during the mid-1970s.

In 1972, Clarke invented, published, patented, presented, and recorded on film laparoscopic surgery, with instruments marketed by the Ven Instrument Company of Buffalo, New York, USA.

In 1975, Tarasconi, from the Department of Ob-Gyn of the University of Passo Fundo Medical School (Passo Fundo, RS, Brazil), started his experience with organ ressection by Laparoscopy (Salpingectomy), first reported in the Third AAGL Meeting, Hyatt Regency Atlanta, November 1976 and later published in The Journal of Reproductive Medicine in 1981. This Laparoscopic Surgical Procedure was the first Laparoscopic organ resection reported in the Medical Literature.

In 1981, Semm, from the Universitats Frauenklinik, Kiel, Germany, performed the first Laparoscopic Appendectomy. Following his lecture on Laparoscopic Appendectomy, the President of the German Surgical Society wrote to the Board of Directors of the German Gynecological society suggesting suspension of Semm from medical practice. Subsequently, Semm submitted a paper on Laparoscopic Appendectomy to the American Journal of Obstetrics and Gynecology, at first rejected as unacceptable for publication on the ground that the technique reported on was ' unethical,' but finally published in the Journal Endoscopy. The Abstract of his paper on "Endoscopic Appendectomy" can be found at here. Semm established several standard procedures that were regularly performed, such as ovarian cyst enucleation, myomectomy, treatment of ectopic pregnancy and finally laparoscopic-assisted vaginal hysterectomy (nowadays termed as Cervical intra-fascial Semm hysterectomy). He also developed a medical instrument company Wisap in Munich, Germany, which still produces various endoscopic instruments of high quality. In 1985, he constructed the pelvi-trainer = laparo-trainer, a practical surgical model whereby colleagues could practice laparoscopic techniques. Semm published over 1000 papers in various journals. He also produced over 30 endoscopic films and more than 20,000 colored slides to teach and inform interested colleagues about his technique. His first atlas, More Details on Pelviscopy and Hysteroscopy was published in 1976, a slide atlas on pelviscopy, hysteroscopy, and fetoscopy in 1979, and his books on gynecological endoscopic surgery in German, English, and many other languages in 1984, 1987, and 2002.

Prior to 1990, the only specialty performing laparoscopy on a widespread basis was gynecology, mostly for relatively short, simple procedures such as a diagnostic laparoscopy or tubal ligation. The introduction in 1990 of a laparoscopic clip applier with twenty automatically advancing clips (rather than a single load clip applier that would have to be taken out, reloaded and reintroduced for each clip application) made general surgeons more comfortable with making the leap to laparoscopic cholecystectomies (gall bladder removal). On the other hand, some surgeons continue to use the single clip appliers as they save as much as $200 per case for the patient, detract nothing from the quality of the clip ligation, and add only seconds to case lengths.

Procedures

Surgeons perform laparoscopic stomach surgery

Laparoscopic cholecystectomy is the most common laparoscopic procedure performed. In this procedure, 5-10mm diameter instruments (graspers, scissors, clip applier) can be introduced by the surgeon into the abdomen through trocars (hollow tubes with a seal to keep the CO_2 from leaking). Dr. Eddie Joe Reddick of Nashville, TN was the pioneer of laparoscopic cholecystectomies in the U.S., and was instrumental in teaching other surgeons the procedure and establishing the technique as the standard of care for gall bladder removal. Over one million cholecystectomies are performed in the U.S. annually, with over 96% of those being performed laparoscopically.

There are two different formats for laparoscopic surgery. Multiple incisions are required for technology such as the "Da Vinci" system, which uses a console located away from the patient, with the surgeon controlling a camera, vacuum pump, saline cleansing solution, cutting tools, etc. each located within its own incision site, but oriented toward the surgical objective. The surgeon uses two PlayStation type controls to manipulate the devices.

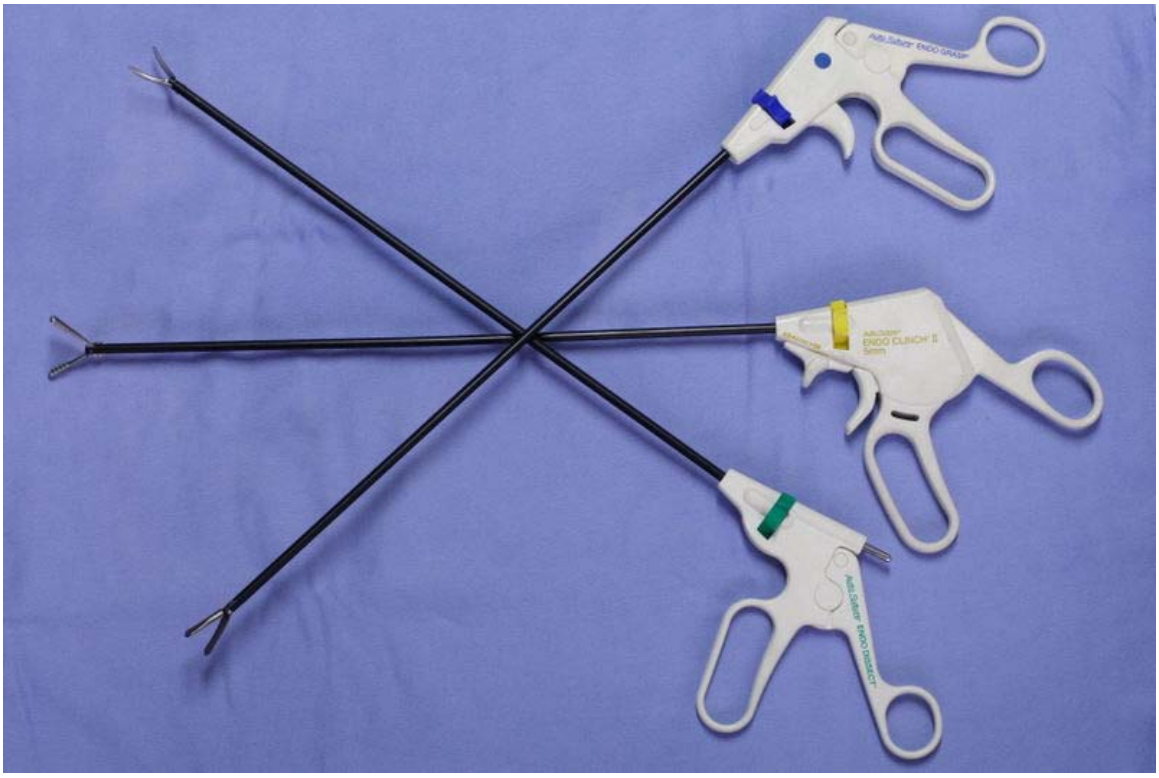
In contrast, requiring only a single small incision, the "Bonati system" (invented by Dr. Alfred Bonati), uses a single 5-function control, so that a saline solution and the vacuum pump operate together when the laser cutter is activated. A camera and light provide

feedback to the surgeon, who sees the enlarged surgical elements on a TV monitor. The Bonati system was designed for spinal surgery and has been promoted only for that purpose.

Rather than a minimum 20 cm incision as in traditional (open) cholecystectomy, four incisions of 0.5–1.0 cm will be sufficient to perform a laparoscopic removal of a gallbladder. Since the gall bladder is similar to a small balloon that stores and releases bile, it can usually be removed from the abdomen by suctioning out the bile and then removing the deflated gallbladder through the 1 cm incision at the patient's navel. The length of postoperative stay in the hospital is minimal, and same-day discharges are possible in cases of early morning procedures.

In certain advanced laparoscopic procedures where the size of the specimen being removed would be too large to pull out through a trocar site, as would be done with a gallbladder, an incision larger than 10mm must be made. The most common of these procedures are removal of all or part of the colon (colectomy), or removal of the kidney (nephrectomy). Some surgeons perform these procedures completely laparoscopically, making the larger incision toward the end of the procedure for specimen removal, or, in the case of a colectomy, to also prepare the remaining healthy bowel to be reconnected (create an anastomosis). Many other surgeons feel that since they will have to make a larger incision for specimen removal anyway, they might as well use this incision to have their hand in the operative field during the procedure to aid as a retractor, dissector, and to be able to feel differing tissue densities (palpate), as they would in open surgery. This technique is called hand-assist laparoscopy. Since they will still be working with scopes and other laparoscopic instruments, CO2 will have to be maintained in the patient's abdomen, so a device known as a hand access port (a sleeve with a seal that allows passage of the hand) must be used. Surgeons that choose this hand-assist technique feel it reduces operative time significantly versus the straight laparoscopic approach. It also gives them more options in dealing with unexpected adverse events (i.e. uncontrolled bleeding) that may otherwise require creating a much larger incision and converting to a fully open surgical procedure.

Conceptually, the laparoscopic approach is intended to minimise post-operative pain and speed up recovery times, while maintaining an enhanced visual field for surgeons. Due to improved patient outcomes, in the last two decades, laparoscopic surgery has been adopted by various surgical sub-specialties including gastrointestinal surgery (including bariatric procedures for morbid obesity), gynecologic surgery and urology. Based on numerous prospective randomized controlled trials, the approach has proven to be beneficial in reducing post-operative morbidities such as wound infections and incisional hernias (especially in morbidly obese patients), and is now deemed safe when applied to surgery for cancers such as cancer of colon.



Laparoscopic instruments

The restricted vision, the difficulty in handling of the instruments (new hand-eye coordination skills are needed), the lack of tactile perception and the limited working area are factors which add to the technical complexity of this surgical approach. For these reasons, minimally invasive surgery has emerged as a highly competitive new sub-specialty within various fields of surgery. Surgical residents who wish to focus on this area of surgery gain additional laparoscopic surgery training during one or two years of fellowship after completing their basic surgical residency. In OBGYN residency programs, the average laparoscopy-to-laparotomy quotient (LPQ) is 0.55.

The first transatlantic surgery (Lindbergh Operation) ever performed was a laparoscopic gallbladder removal.

Laparoscopic techniques have also been developed in the field of veterinary medicine. Due to the relative high cost of the equiment required, however, it has not become commonplace in most traditional practices today but rather limited to specialty-type practices. Many of the same surgeries performed in humans can be applied to animal cases - everything from an egg-bound tortoise to a German Shepherd can benefit from MIS. A paper published in JAVMA (Journal of the American Veterinary Medical Association) in 2005 showed that dogs spayed laparoscopically experienced significantly less pain (65%)than those that were spayed with traditional 'open' methods. Arthroscopy, thoracoscopy, cystoscopy are all performed in veterinary medicine today. The University of Georgia School of Veterinary Medicine and Colorado State University's School of Veterinary Medicine are two of the main centers where veterinary laparoscopy got started

and have excellent training programs for veterinarians interested in getting started in MIS.

Advantages

There are a number of advantages to the patient with laparoscopic surgery versus an open procedure. These include:

- Reduced hemorrhaging, which reduces the chance of needing a blood transfusion.
- Smaller incision, which reduces pain and shortens recovery time, as well as resulting in less post-operative scarring.
- Less pain, leading to less pain medication needed.
- Although procedure times are usually slightly longer, hospital stay is less, and often with a same day discharge which leads to a faster return to everyday living.
- Reduced exposure of internal organs to possible external contaminants thereby reduced risk of acquiring infections.

Although laparoscopy in adult age group is widely accepted, its advantages in pediatric age group is questioned. Benefits of laparoscopy appears to recede with younger age. Efficacy of laparoscopy is inferior to open surgery in certain conditions such as pyloromyotomy for Infantile hypertrophic pyloric stenosis. Although laparoscopic appendiectomy has lesser wound problems than open surgery, the former is associated with more intra-abdominal abscesses.

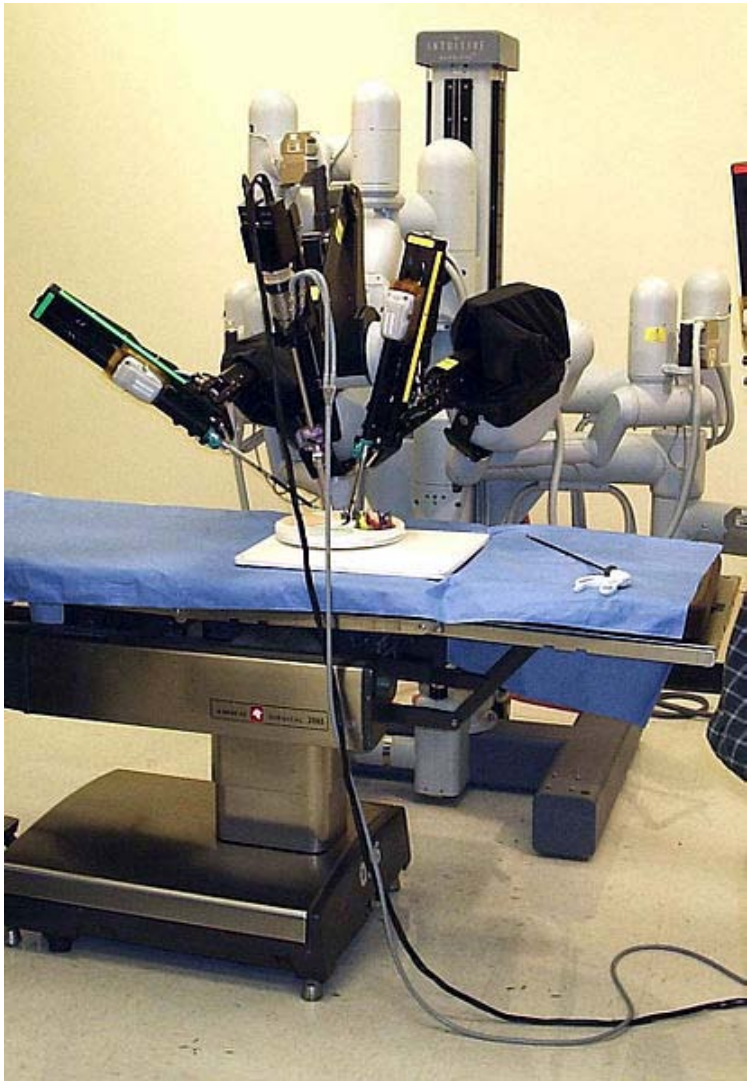
Risks

Some of the risks are briefly described below:

- The most significant risks are from trocar injuries to either blood vessels or small or large bowel. The risk of such injuries is increased in patients who have below average body mass index or have a history of prior abdominal surgery. The initial trocar is typically inserted blindly. While these injuries are rare, significant complications can occur. Vascular injuries can result in hemorrhage that may be life threatening. Injuries to the bowel can cause a delayed peritonitis. It is very important that these injuries be recognized as early as possible.
- Some patients have sustained electrical burns unseen by surgeons who are working with electrodes that leak current into surrounding tissue. The resulting injuries can result in perforated organs and can also lead to peritonitis. This risk is eliminated by utilizing active electrode monitoring.
- There may be an increased risk of hypothermia and peritoneal trauma due to increased exposure to cold, dry gases during insufflation. The use of heated and humidified CO_2 may reduce this risk.
- Many patients with existing pulmonary disorders may not tolerate pneumoperitoneum (gas in the abdominal cavity), resulting in a need for conversion to open surgery after the initial attempt at laparoscopic approach.

- Not all of the CO_2 introduced into the abdominal cavity is removed through the incisions during surgery. Gas tends to rise, and when a pocket of CO_2 rises in the abdomen, it pushes against the diaphragm (the muscle that separates the abdominal from the thoracic cavities and facilitates breathing), and can exert pressure on the phrenic nerve. This produces a sensation of pain that may extend to the patient's shoulders. For an appendectomy, the right shoulder can be particularly painful. In some cases this can also cause considerable pain when breathing. In all cases, however, the pain is transient, as the body tissues will absorb the CO_2 and eliminate it through respiration.
- Coagulation disorders and dense adhesions (scar tissue) from previous abdominal surgery may pose added risk for laparoscopic surgery and are considered relative contra-indications for this approach.

Robotics and technology



A laparoscopic robotic surgery machine

The process of minimally invasive surgery has been augmented by specialized tools for decades. For example, TransEnterix of Durham, North Carolina received U.S. Food and Drug Administration approval in October 2009 for its SPIDER Surgical System using flexible instruments and one incision in the navel area instead of several, allowing quicker healing for patients. Dr. Richard Stac of Duke University developed the process.

In recent years, electronic tools have been developed to aid surgeons. Some of the features include:

- Visual magnification — use of a large viewing screen improves visibility
- Stabilization — Electromechanical damping of vibrations, due to machinery or shaky human hands
- Simulators — use of specialized virtual reality training tools to improve physicians' proficiency in surgery
- Reduced number of incisions

Robotic surgery has been touted as a solution to underdeveloped nations, whereby a single central hospital can operate several remote machines at distant locations. The potential for robotic surgery has had strong military interest as well, with the intention of providing mobile medical care while keeping trained doctors safe from battle.

Non-robotic hand guided assistance systems

There are also user-friendly non robotic assistance systems that are single hand guided devices with a high potential to save time and money. These assistance devices are not bound by the restrictions of common medical robotic systems. The systems enhance the manual possibilities of the surgeon and his team, regarding the need of replacing static holding force during the intervention.

Some of the features are:

- The stabilisation of the camera picture because the whole static workload is conveyed by the assistance system.

- Some systems enable a fast repositioning and very short time for fixation of less than 0.02 seconds at the desired position. Some systems are lightweight constructions (18 kg) and can withstand a force of 20 N in any position and direction.

- The benefit – a physically relaxed intervention team can work concentrated on the main goals during the intervention.

- The potentials of these systems enhance the possibilities of the mobile medical care with those lightweight assistance systems. These assistance systems meet the demands of true solo surgery assistance systems and are robust, versatile, and easy to use.

Chapter 11

Microsurgery

Microsurgery is a general term for surgery requiring an operating microscope. The most obvious developments have been procedures developed to allow anastomosis of successively smaller blood vessels and nerves (typically 1 mm in diameter) which have allowed transfer of tissue from one part of the body to another and re-attachment of severed parts. Although microsurgery is used mostly in plastic surgery, microsurgical techniques are utilized by all specialties today, especially those involved in reconstructive surgery such as: general surgery, ophthalmology, orthopedic surgery, gynecological surgery, otolaryngology, neurosurgery, oral and maxillofacial surgery, and pediatric surgery.

History

The advances in the techniques and technology that popularized microsurgery began in the early 1960s. The first microvascular surgery, using a microscope to aid in the repair of blood vessels, was described by vascular surgeon, Jules Jacobson, of the University of Vermont in 1960. Using an operating microscope, he performed coupling of vessels as small as 1.4 mm and coined the term "microsurgery." Hand surgeons at the University of Louisville (KY), Drs. Harold Kleinert and Mort Kasdan, performed the first revascularization of a partial digital amputation in 1963.

Nakayama, a Japanese cardiothoracic surgeon, reported the first true series of microsurgical free-tissue transfers using vascularized intestinal segments to the neck for esophageal reconstruction after cancer resections using 3-4mm vessels.

Contemporary reconstructive microsurgery was introduced by an American plastic surgeon, Dr. Harry J. Buncke. In 1964, Buncke reported a rabbit ear replantation, famously using a garage as a lab/operating theatre and home-made instruments. This was the first report of successfully using blood vessels 1 millimeter in size. In 1966, Buncke used microsurgery to transplant a primate's great toe to its hand.

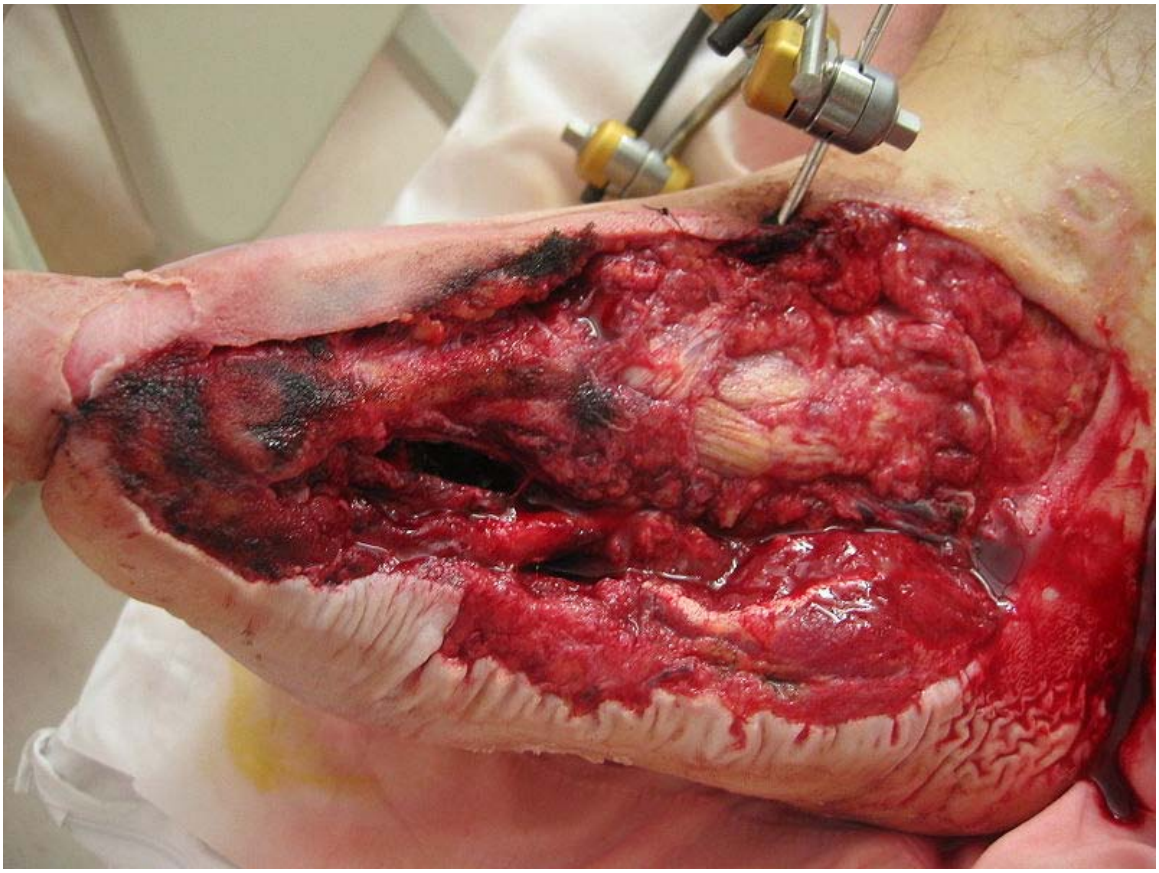
During the late sixties and early 1970s, plastic surgeons ushered in many new microsurgical innovations that were previously unimaginable. The first human microsurgical transplantation of the great toe (big toe) to thumb was performed in April 1968 by Mr. John Cobbett, in England. In Australia work by Dr. Ian Taylor saw new

techniques developed to reconstruct head and neck cancer defects with living bone from the hip or the fibula.

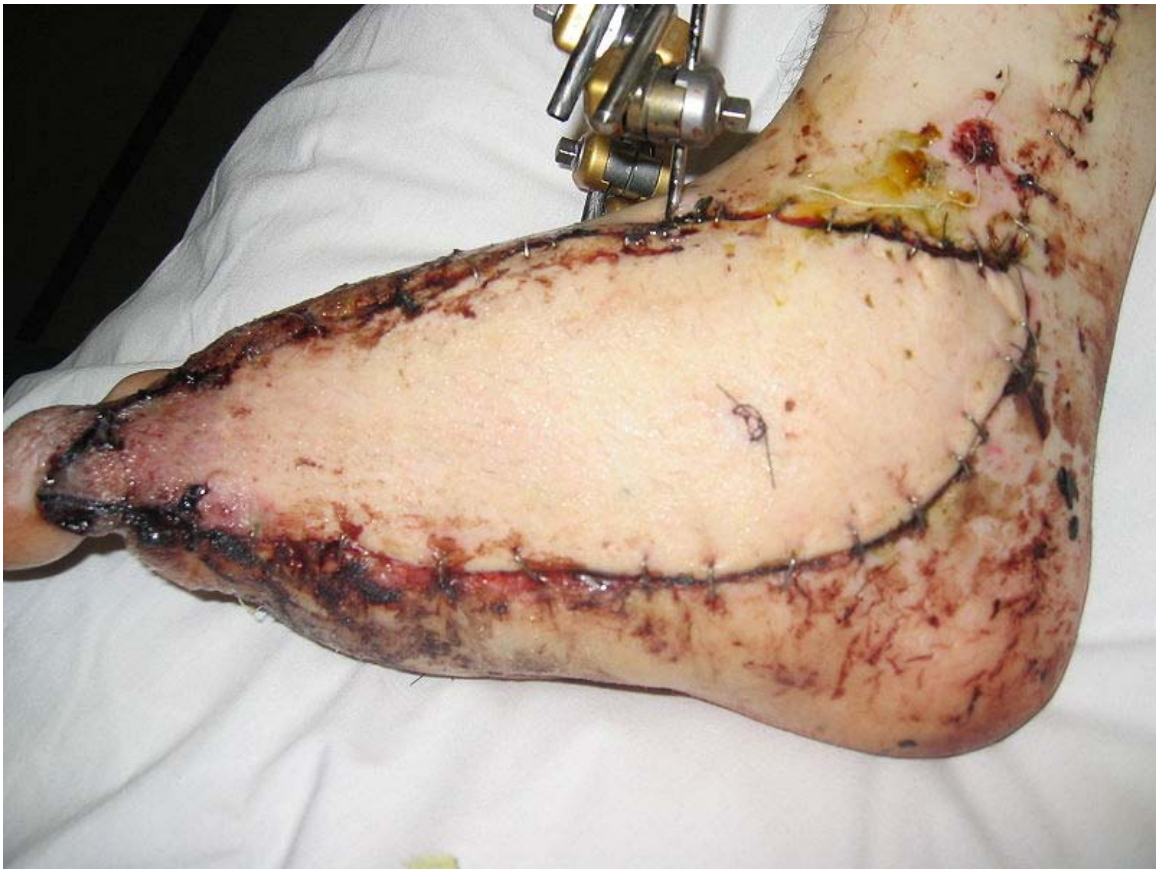
Although primarily developed and used by plastic surgeons, a number of surgical specialties now use microsurgical techniques. Otolaryngologists (ear, nose, and throat doctors) perform microsurgery on structures of the inner ear or the vocal cords. Maxillofacial surgeons and Otolaryngologists use microsurgical techniques when reconstructing head and neck cancer patients. Cataract surgery, corneal transplants, and treatment of conditions like glaucoma are performed by ophthalmologists. Urologists and gynecologists can frequently now reverse vasectomies and tubal ligations to restore fertility.

Free tissue transfer

Free tissue transfer is a surgical reconstructive procedure using microsurgery. A region of "donor" tissue is selected that can be isolated on a feeding artery and vein; this tissue is usually a composite of several tissue types (e.g., skin, muscle, fat, bone). Common donor regions include the rectus abdominis muscle, latissimus dorsi muscle, fibula, and radial forearm bone and skin lateral arm skin. The composite tissue is transferred (moved as a free flap of tissue) to the region on the patient requiring reconstruction (e.g., mandible after oral cancer resection, breast after cancer resection, traumatic tissue loss, congenital tissue absence). The vessels that supply the free flap are anastomosed with microsurgery to matching vessels (artery and vein) in the reconstructive site. The procedure was first done in the early 1970s and has become a popular "one-stage" (single operation) procedure for many surgical reconstructive applications.



Traumatic foot/ankle soft tissue wound from motor vehicle accident



Anterio-lateral thigh flap free-tissue transfer reconstruction

Replantation

Replantation is the reattachment of a completely detached body part. Fingers and thumbs are the most common but the ear, scalp, nose, face, arm and penis have all been replanted. Generally replantation involves restoring blood flow through arteries and veins, restoring the bony skeleton and connecting tendons and nerves as required.

Initially, when the techniques were developed to make replantation possible, success was defined in terms of a survival of the amputated part alone. However, as more experience was gained in this field, surgeons specializing in replantation began to understand that survival of the amputated piece was not enough to ensure success of the replant. In this way, functional demands of the amputated specimen became paramount in guiding which amputated pieces should and should not be replanted. Additional concerns about the patients ability to tolerate the long rehabilitation process that is necessary after replantation both on physical and psychological levels also became important. So, when fingers are amputated, for instance, a replantation surgeon must seriously consider the contribution of the finger to the overall function of the hand. In this way, every attempt will be made to salvage an amputated thumb, since a great deal of hand function is dependent on the thumb, while an index finger or small finger may not be replanted,

depending on the individual needs of the patient and the ability of the patient to tolerate a long surgery and a long course of rehabilitation.

However, if an amputated specimen is not able to be replanted to its original location entirely, this does not mean that the specimen is unreplantable. In fact, replantation surgeons have learned that only a piece or a portion may be necessary to obtain a functional result, or especially in the case of multply amputated fingers, a finger or fingers may be transposed to a more useful location to obtain a more functional result. This concept is called "spare parts" surgery.

Transplantation

Microsurgical techniques have played a crucial role in the development of transplantation immunological research because it allowed the use of rodents models, which are more appropriate for transplantation research (there are more reagents, monoclonal antibodies, knockout animals, and other immunological tools for mice and rats than other species). Before it was introduced, transplant immunology was studied in rodents using the skin transplantation model, which is limited by the fact it is not vascularized. Thus, microsurgery represents the link between surgery and transplant immunological research. The first microsurgical experiments (porto-caval anastomosis in the rat) were performed by Dr. Sun Lee (pioneer of microsurgery) at the University of Pittsburgh in 1958. After a short time, many models of organ tranplants in rat and mice have been established. Today, virtually every rat or mouse organ can be transplanted with relative high success rate. Microsurgery was also important to develop new techniques of transplantation, that would be later performed in humans. In addition, it allows reconstruction of small arteries in clinical organ transplantation (e.g. accessory arteries in cadaver liver transplantation, polar arteries in renal transplantation and in living liver donor transplantation).

Chapter 12

Elective Surgery and Exploratory Surgery

Elective surgery

Elective surgery is surgery that is scheduled in advance because it does not involve a medical emergency. **Semi-elective surgery** is a surgery that must be done to preserve the patient's life, but does not need to be performed immediately.

By contrast, an **urgent surgery** is one that can wait until the patient is medically stable, but should generally be done today or tomorrow, and an **emergency surgery** is one that must be performed without delay; the patient has no choice other than immediate surgery, if he does not want to risk permanent disability or death.

Most surgeries are elective.

Types

Elective surgeries include all optional surgeries performed for non-medical reasons, i.e., cosmetic surgery. They also include most surgeries necessary for medical reasons.

Cosmetic surgery, such as a facelift or the placement of breast implants, is typically performed to subjectively improve a patient's physical appearance. Cosmetic and aesthetic surgeries are elective surgeries are pre-scheduled at a time that is mutually convenient for the patient, the surgeon, and the medical facility.

Many medically necessary surgeries are also elective surgeries. For example, cataract surgery, mastectomy for breast cancer, and the donation of a kidney by a living donor are performed as elective surgeries.

Increasing urgency

When a condition is worsening, but has not yet reached the point of a true emergency, surgeons speak of semi-elective surgery: the peccant part must be dealt with, but a delay is not expected to affect the outcome.

In a patient with multiple medical conditions, problems classified as needing semi-elective surgeries may be postponed until emergent conditions have been addressed and the patient is medically stable. For example, whenever possible, pregnant women typically postpone all elective and semi-elective procedures until after giving birth. In some situations, an urgently needed surgery will be postponed briefly to permit even more urgent conditions to be addressed. In other situations, emergency surgery may be performed at the same time as life-saving resuscitation efforts.

Semi-elective procedures are typically scheduled within a time frame deemed appropriate for the patient's condition and disease. Removal of a malignancy, for example, is usually scheduled as semi-elective surgery, to be performed within a set number of days or weeks. Urgent surgery is typically performed with 48 hours of diagnosis. Emergency surgery is performed as soon as a surgeon is available.

Many surgeries can be performed as either elective or emergency surgeries, depending on the patient's needs. A sudden worsening of gallbladder disease may require immediate removal of the gallbladder by emergency surgery, but this surgery is more commonly scheduled in advance.

Exploratory surgery

Exploratory surgery is a diagnostic method used by doctors when trying to find a diagnosis for an ailment. It can be performed in both humans and animals, but it is far more common in animals. It is used most commonly to diagnose or locate cancer in humans, but it can be used for other ailments as well.

The use of new technologies such as MRIs have made exploratory surgeries less frequent.

Exploratory surgery and cancer

Sometimes, cancer is located in a place where standard tests cannot detect it. In this case, doctors must go into surgery and look for the cancerous mass manually. This procedure, which is what is commonly associated with exploratory surgery, is not used for treatment at all. Instead, it is used chiefly to identify the location of the tumor and the extent of its damage. If a tumor is found, a biopsy is performed and tests are run to see what type of cancer was found.

Exploratory surgery in animals

Because animals cannot voice their symptoms as easily as humans, exploratory surgery is more common in animals. Exploratory surgery is done when looking for a foreign body that may be lodged in the animal's body, when looking for cancer, or when looking for

various other gastrointestinal problems. It is a fairly routine procedure that is done only after tests and bloodwork reveal nothing abnormal.

Chapter 13

Refractive Surgery

Refractive eye surgery is any eye surgery used to improve the refractive state of the eye and decrease or eliminate dependency on glasses or contact lenses. This can include various methods of surgical remodeling of the cornea or cataract surgery. The most common methods today use excimer lasers to reshape curvature of the cornea. Successful refractive eye surgery can reduce or cure common vision disorders such as myopia, hyperopia and astigmatism.

According to surveys of members of the American Society of Cataract and Refractive Surgery, approximately 948,266 refractive surgery procedures were performed in the United States during 2004 and 928,737 in 2005.

History

The first experimental studies about refractive surgery were published in 1896 by Lendeer Jans Lans, an ophthalmology teacher in Holland, where he developed a theoretical work proposing penetrating corneal cuts to correct astigmatism. In 1930 the Japanese ophthalmologist Tsutomu Sato made the first practical attempt to perform such surgery in military pilots. He practiced radial cuts in the cornea to correct effects by up to 6 diopters, but this procedure was soon rejected by the medical community because of the high rate of corneal degeneration.

In 1963, in the Barraquer ophthalmologic clinic (Bogotá, Colombia) Ignacio Barraquer developed the first proficient refractive surgery technique called keratomileusis, meaning corneal reshaping (from Greek *κέρας* (kéras: horn) and *σμίλευσις* (smileusis: carving)). Keratomileusis allowed correction of not only myopia but also hyperopia. These early surgeries removed a corneal layer, froze it so it could be manually sculpted in the required shape, and finally reimplanted the layer (Keratomileusis with freezing). While this form of surgery was later improved by Dr. Swinger in 1986 (keratomileusis without freezing), it was still a relatively imprecise technique.

Meanwhile, experiments in 1970 using a xenon dimer and in 1975 using noble gas halides resulted in the invention of a type of laser called an excimer laser. While excimer lasers were initially used for industrial purposes, in 1980, R. Srinivasan, a scientist of IBM who was using an excimer laser to make microscopic circuits in microchips for informatics equipment, discovered that the excimer could also be used to cut organic

tissues with high accuracy without significant thermal damage. The discovery of an effective biological cutting laser, along with the development of computers to control it, allowed new refractive techniques which were previously unavailable. In 1983, scientist Stephen Trokel of Columbia University in collaboration with Srinivasan performed the first Photorefractive Keratectomy (PRK) or keratomileusis in situ (without separation of corneal layer) in Germany. The first patent for LASIK was granted by the US Patent Office to Gholam A. Peyman, MD on June 20, 1989, US Patent #4,840,175, "METHOD FOR MODIFYING CORNEAL CURVATURE", describing the surgical procedure in which a flap is cut in the cornea and pulled back to expose the corneal bed. This exposed surface is then ablated to the desired shape with an excimer laser, following which the flap is replaced. In 1991 Creta University and the Vardinoyannion Eye coined the name "LASIK".

Techniques

Flap procedures

Excimer laser ablation is done under a partial-thickness lamellar corneal flap.

- Automated lamellar keratoplasty (ALK): The surgeon uses an instrument called a microkeratome to cut a thin flap of the corneal tissue. The flap is lifted like a hinged door, targeted tissue is removed from the corneal stroma, again with the microkeratome, and then the flap is replaced.
- Laser Assisted In-Situ Keratomileusis (LASIK): The surgeon uses a microkeratome or femtosecond laser to cut a flap of the corneal tissue (usually with a thickness of 100-180 micrometres). The flap is lifted like a hinged door, but in contrast to ALK, the targeted tissue is removed from the corneal stroma with an excimer laser. The flap is subsequently replaced. Another method of creating this flap is by using a procedure called IntraLase, in which a femtosecond laser is used to create the flap. Proponents of this method assert its superiority over "traditional" LASIK, but there have been no conclusive independent studies to prove that this is a true statement.

Surface procedures

The excimer laser is used to ablate the most anterior portion of the corneal stroma. These procedures do not require a partial thickness cut into the stroma. Surface ablation methods differ only in the way the epithelial layer is handled.

- Photorefractive keratectomy (PRK) is an outpatient procedure generally performed with local anesthetic eye drops (as with LASIK/LASEK) . It is a type of refractive surgery which reshapes the cornea by removing microscopic amounts of tissue from the corneal stroma, using a computer-controlled beam of light (excimer laser). The difference from LASIK is that the top layer of the epithelium is removed (and a bandage contact lens is used), so no flap is created. Recovery time is longer with PRK than with LASIK, though the final outcome

(after 3 months) is about the same (very good). More recently, customized ablation has been performed with LASIK, LASEK, and PRK.

- Laser Assisted Sub-Epithelium Keratomileusis (LASEK) is a procedure that also changes the shape of the cornea using an excimer laser to ablate the tissue from the corneal stroma, under the corneal epithelium, which is kept mostly intact to act as a natural bandage. The surgeon uses an alcohol solution to loosen then lift a thin layer of the epithelium with a trephine blade (usually with a thickness of 50 micrometres). During the weeks following LASEK, the epithelium heals, leaving no permanent flap in the cornea. This healing process can involve discomfort comparable to that with PRK.
- EPI-LASIK is a new technique similar to LASEK that uses an epi-keratome (rather than a trephine blade and alcohol), to remove the top layer of the epithelium (usually with thickness of 50 micrometres), which is subsequently replaced. For some people it can provide better results than regular LASEK in that it avoids the possibility of negative effects from the alcohol, and recovery may involve less discomfort.
- C-Ten (Customized TransEpithelial Non-contact ablation) is a refinement of Lasek, EPI-Lasik, and PRK. It is the newest and the fastest Laser treatment. “C” for Customized refers to the individualization of the treatment for each patient, conforming to each individual’s requirements determined by the shape of the cornea and the topography of its surface, the extent of the correction, pupillary size and reaction, and the patient’s lifestyle requirements. “TEN” (Trans Epithelial, Non-Contact) means that the ablation of the epithelial layer, the regenerative surface of the eye, is accomplished with the laser alone, with no direct contact with the eye. C-Ten is the only treatment technique done without actual contact with the eye. Prior to the start of the procedure each eye is examined and measurements are made using two instruments specially designed for the laser treatments. The “Precisio” measures the corneal topography, both its shape and thickness. The "Pupillometer” measures the size of the pupil under various light relationships. These measurements ensure that the area undergoing treatment is neither too small (with the danger of ensuing halos or blinding) nor too large (which could cause ablation of excessive tissue). After the Laser treatment the epithelium regenerates within a few days, all the while being protected by a contact lens. The technique, in comparison to other superficial laser treatments, causes the least post-operative discomfort. Over 80% of patients report almost no pain. In contrast to other laser treatments, C-Ten has a very low incidence of dry eye. Another advantage of C-Ten is the absence of flap associated complications that can occur after Lasik or Femto-Lasik and changes in corneal stability are minimal. This is in contrast to Lasik, after which there is an unmistakable decrease in. C-Ten is especially suited to the treatment of myopia and irregular astigmatism. Up 12 diopters of myopia and over 6 diopters of corneal distortions can be corrected. Surface treatments are less suited for correction of hyperopia.

M. G. La Tegola, G. Alessio, C. Sborgia: Topographic customized photorefractive keratectomy for regular and irregular astigmatism after penetrating keratoplasty using the

LIGI CIPTA/LaserSight platform. In: J. Refrst. Surg. 7, September 2007, S. 681–693. ↑ E. Pedrotti, A. Sbabo, G. Marchini: Customized transepithelial photorefractive keratectomy for iatrogenic ametropia after penetrating or deep lamellar keratoplasty. In: J. Refract. Surg. 32 Nr. 8, August 2006 S. 1288–1291.

Corneal incision procedures

- Radial keratotomy (RK) uses spoke-shaped incisions (usually made with a diamond knife) to alter the shape of the cornea and reduce myopia or astigmatism; this technique has now been largely replaced by the other methods (that use excimer laser).

- Arcuate keratotomy (AK) is similar to radial keratotomy, but the incisions on the cornea are done at the periphery of the cornea. Arcuate keratotomy is used to correct astigmatism. Although most incisional procedures are replaced nowadays by Lasik, AK is still used in some special cases (correction of residual astigmatism after a keratoplasty procedure or during cataract surgery).

- Limbal relaxing incisions (LRI) are incisions near the outer edge of the iris, used to correct minor astigmatism (typically less than 2 diopters). This is often performed in conjunction with an Intraocular Lens implantation.

Other procedures

- Thermal keratoplasty is used to correct hyperopia by putting a ring of 8 or 16 small burns surrounding the pupil, and steepen the cornea with a ring of collagen constriction. It can also be used to treat selected types of astigmatism.
- Laser thermal keratoplasty (LTK) is a non-touch thermal keratoplasty performed with a Holmium laser, while conductive keratoplasty (CK) is thermal keratoplasty performed with a high-frequency electric probe. Thermal keratoplasty can also be used to improve presbyopia or reading vision after age 40.
- Intrastromal corneal ring segments (Intacs) are approved by FDA for treatment of low degrees of myopia.
- Lens implantation inside the eye can also be used to change refractive errors.
- Generally refractive surgery can be broadly divided into : corneal surgery, scleral surgery, lens related surgery(including phakic IOL implantation, clear lens extraction, photophacoreduction and photophacomodulation for correction of pesbyopia)
- For presbyopia correction, a corneal inlay consisting of a porous black ring surrounding a small clear aperture was originally developed by D. Miller and a group at Acufocus. The inlay is placed under a lasik flap or in a stromal pocket.

Christie,B, et al: Optical performance of a corneal inlay for presbyopia. Invest Ophth Vis Sci. Abstract 695, 2005

Silvestrini, TA, et al: Analysis of glucose diffusion across Acufocus inlay. Invest Ophth Vis Sci, abstract 2195, 2005

Expectations

Research conducted by the Magill Research Center for Vision Correction, Medical University of South Carolina, showed that the overall patient satisfaction rate after primary LASIK surgery was 95.4%. They further differentiated between myopic LASIK (95.3%) and hyperopic LASIK (96.3%). They concluded that that vast majority (95.4%) of patients were satisfied with their outcome after LASIK surgery.

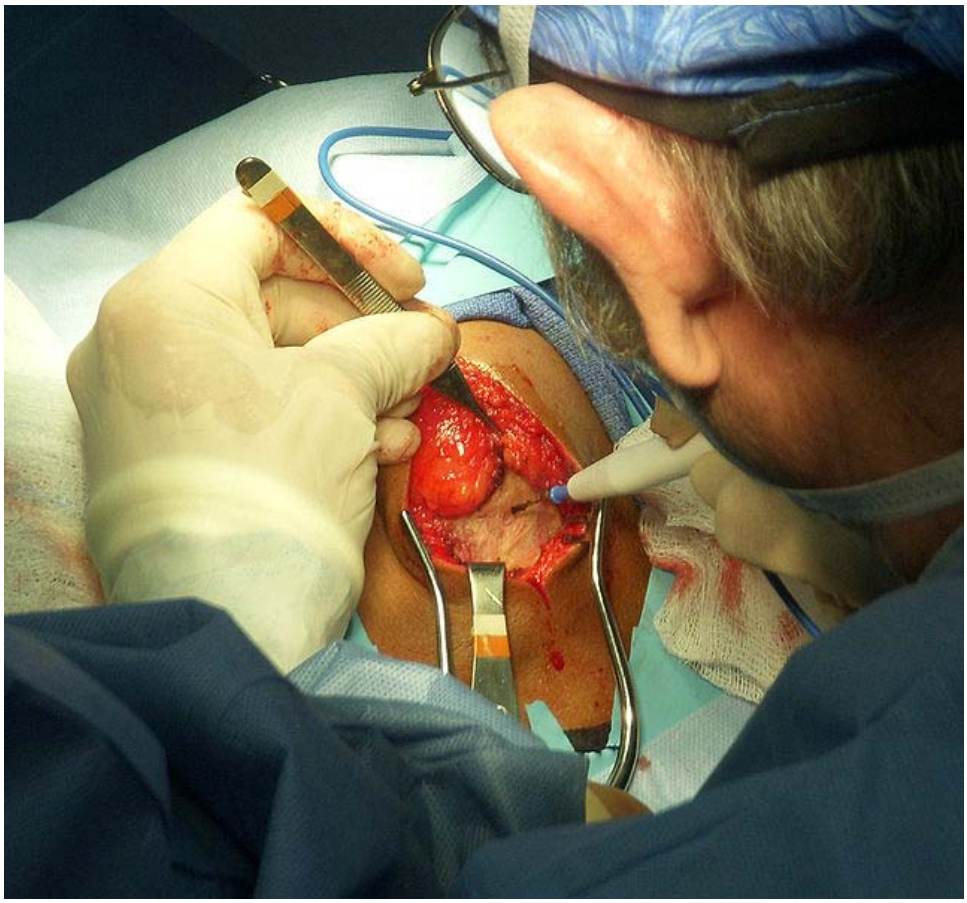
Risks

While refractive surgery is becoming more affordable and safe, it may not be recommended for everybody. Patients that have medical conditions such as glaucoma or diabetes, uncontrolled vascular disease, autoimmune disease, pregnant women or people with certain eye diseases involving the cornea or retina, are not good candidates for refractive surgery. Keratoconus, a progressive thinning of the cornea, is a common corneal disorder. Keratoconus occurring after refractive surgery is called Corneal Ectasia. It is believed that additional thinning of the cornea via refractive surgery may contribute to advancement of the disease, that may lead to the need for a corneal transplant. Therefore, keratoconus is a contraindication to refractive surgery. Corneal topography, pachymetry and, more recently, Pentacam exams are used to screen for abnormal corneas. Furthermore, some people's eye shape may not permit effective refractive surgery without removing excessive amounts of corneal tissue. Those considering laser eye surgery should have a full eye examination.

Although the risk of complications is decreasing compared to the early days of refractive surgery, there is still a small chance for serious problems. These include vision problems such as ghosting, halos, starbursts, double-vision, and dry-eye syndrome. With procedures that create a permanent flap in the cornea (such as LASIK), there is also the possibility of accidental traumatic flap displacement years after the surgery, with potentially disastrous results if not given prompt medical attention.

Chapter 14

Electrosurgery



A surgeon using (monopolar) electrosurgical coagulation in the excision of a lipoma

Electrosurgery is the application of a high-frequency electric current to biological tissue as a means to cut, coagulate, desiccate, or fulgurate tissue. (These terms are used in specific ways for this methodology). Its benefits include the ability to make precise cuts with limited blood loss. Electrosurgical devices are frequently used during surgical operations helping to prevent blood loss in hospital operating rooms or in outpatient procedures.

In electrosurgical procedures, the tissue is heated by an electric current. Although electrical devices may be used for the cauterization of tissue in some applications, electrosurgery is usually used to refer to a quite different method than electrocautery. The latter uses heat conduction from a probe heated to a glowing temperature by a direct current (much in the manner of a soldering iron). This may be accomplished by direct current from dry-cells in a penlight-type device. Electrosurgery, by contrast, uses alternating current to directly heat the tissue itself. When this results in destruction of small blood vessels and halting of bleeding, it is technically a process of *electrocoagulation,* although "electrocautery" is sometimes loosely and nontechnically used to describe it.

Often electrosurgery is mistakenly referred to as diathermy. Unlike Ohmic heating by electric current passing through the conductive tissue in conventional electrosurgery, diathermy means dielectric heating, produced by rotation of molecular dipoles in high frequency alternating electric field. This effect is most widely used in microwave ovens which operate at gigahertz frequencies.

Electrosurgery is commonly used in dermatological, gynecological, cardiac, plastic, ocular, spine, ENT, maxillofacial, orthopedic, urological, neuro- and general surgical procedures as well as certain dental procedures.

Electrosurgery is performed using an electrosurgical generator (also referred to as power supply or waveform generator) and a handpiece including one or several electrodes, sometimes referred to as an RF Knife. The apparatus when used for cutting or coagulation in surgery is still often referred to informally by surgeons as a "Bovie," after the inventor.

History

Development of the first commercial electrosurgical device is credited to Dr. William T. Bovie, who worked on it from 1914 to 1927 while employed at Harvard University The first use of an electrosurgical generator in operating room occurred on October 1, 1926. The surgery was performed by Dr. Harvey Cushing. The low powered Hyfrecator for office use was introduced in 1940.

Tissue heating by electric current

When voltage is applied across the material it produces electric field which exerts force on charged particles. A flow of free charge carriers – electrons and ions - is called electric current. In metals and semiconductors the charge carriers are primarily electrons, whereas in liquids the charge is carried predominantly by ions. Electrical conduction in biological tissues is primarily due to the conductivity of the interstitial fluids, and thus is predominantly ionic. Transition between the electronic and ionic conduction is governed by electrochemical processes at the electrode–electrolyte interface. Value of electric current, I, is determined by the applied voltage, V, and material's resistance, R, according to Ohm's law:

$$I = \frac{V}{R}$$

Electric current of a constant polarity is referred to as direct current (DC). A current of alternating polarity is referred to as alternating current (AC). Its frequency is measured in cycles per second or hertz (Hz).

Current flowing through a resistor causes the generation of Joule heating. In other words, the resistance of the tissue converts the electric energy of the voltage source into heat (thermal energy) which causes the tissue temperature to rise. The deposited electric power (energy per time) can be calculated using:

$$P = I \cdot V = I^2 \cdot R = \frac{V^2}{R}$$

where *P* represents the electric power, typically measured in watts.

In absence of heat conduction, the rate of temperature rise, *dT*/*dt*, in a heated object is proportional to the deposited power *P*, and inversely proportional to its heat capacity, which is in turn proportional to the mass *m* of the object and its specific heat capacity *c*:

$$\frac{dT}{dt} = \frac{P}{c \cdot m}.$$

Larger amount of heat is required to increase the temperature of a heavier object. Thus when heat is generated in a small region of an object, the temperature of that localized region will rise much faster than if the same amount of heat is evenly dispersed over the entire object.

Current density, *j* is a measure of the concentration of electric current. A higher current density results in a higher concentration of Joule heating. Power density generated by electric current in the material, *p* is proportional to the square of the current density, and to the material's resistivity, *g*:

$$p = j^2 \cdot g$$

In absence of heat conduction, the rate of local temperature rise is proportional to the power density, *p*, produced in that region of tissue, and inversely proportional to its specific heat capacity and density ρ .

$$\frac{dT}{dt} = \frac{p}{c \cdot \rho}.$$

Electrical stimulation of neural and muscle cells

Neural and muscle cells are electrically-excitable, i.e. they can be stimulated by electric current. In human patients such stimulation may cause acute pain, muscle spasms, and even cardiac arrest. Sensitivity of the nerve and muscle cells to electric field is due to the voltage-gated ion channels present in their cell membranes. Stimulation threshold does not vary much at low frequencies (so called rheobase-constant level). However, the threshold starts increasing with decreasing duration of a pulse (or a cycle) when it drops below a characteristic minimum (so called chronaxie). Typically, chronaxie of neural cells is in the range of 0.1–10 ms, so the sensitivity to electrical stimulation (inverse of the stimulation threshold) decreases with increasing frequency in the kHz range and above. (Note that frequency of the alternating electric current is an inverse of the duration of a single cycle). To minimize the effects of muscle and neural stimulation, electrosurgical equipment typically operates in the radio frequency (RF) range of 100 kHz to 5 MHz.

Operation at higher frequencies also helps minimizing the amount of hydrogen and oxygen generated by electrolysis of water. This is especially important consideration for applications in liquid medium in closed compartments, where generation of gas bubbles may interfere with the procedure. For example, bubbles produced during an operation inside an eye may obscure a field of view.

Common electrode configurations for ground-return-pad devices

There are several commonly used *electrode configurations* or circuit topologies:

In *bipolar* configuration the voltage is applied to the patient using a pair of similarly-sized electrodes. For example, special forceps, with one tine connected to one pole of the AC generator and the other tine connected to the other pole of the generator. When a piece of tissue is held by the forceps, a high frequency electric current flows from one to the other forceps tine, heating the intervening tissue.

In *monopolar* configuration the patient is attached to the *return electrode*, a relatively large metal plate or a flexible metalized plastic pad which is connected to the return electrode of the AC source. The surgeon uses a pointed electrode to make contact with the tissue. The electric current flows from the active electrode, through the body to the return electrode, and then back to the electrosurgical generator. Since electric current spreads from the pointed electrode as it enters the body the current density is rapidly (quadratically) decreasing with distance from the electrode. Since the rate of heating is proportional to the square of current density, the heating occurs in a very localized region, only near the probe tip. On an extremity such as a finger, there is limited cross-sectional area for the return current to spread across, which might result in higher current density and some heating throughout the volume of the extremity.

There is also a common intermediate configuration, when both electrodes are located on the same probe, but the return electrode is much larger than the active one. Since current density is higher in front of the smaller electrode, the heating and associated tissue effects take place only (or primarily) in front of the active electrode, and exact position of the return electrode on tissue is not critical. Sometimes such configuration is called *sesquipolar*, even though the origin of this term in Latin (*sesqui*) means a ratio of 1.5.

Dedicated non-ground-return machines

Relatively low-powered high frequency electrosurgery can be performed on conscious outpatients with no return electrode at all . Operating with no return electrode is possible, because at the very high frequencies and low currents, the self-capacitance of the patient's body (which is between the patient's body and the machine's return potential) is large enough to allow the resulting displacement current to act as a return path.

One example of such a machine is called a hyfrecator. This term began in 1940 as a Birtcher Corporation brandname Hyfrecator® for "**Hi**gh **Fre**quency Eradi**cator**", but now serves generically to describe a general class of single-electrode, non-grounded low-powered electrosurgical machines intended mainly for office use. An accidental additional return path through an earth-ground provides a danger of a burn at a site far away from the probe electrode, and for this reason single-electrode devices are used only on conscious patients who would be aware of such complications, and only on carefully insulated tables.

In such a setting, hyfrecators are not used to cut tissue, but to destroy relatively small lesions, and also to stop bleeding in surgical incisions made by blade instruments under local anesthesia.

Electrosurgical modalities

In **cutting mode** electrode touches the tissue, and sufficiently high power density is applied to vaporize its water content. Since water vapor is not conductive under normal cirumstances, electric current cannot flow through the vapor layer. Energy delivery beyond the vaporization threshold can continue if sufficiently high voltage is applied (> +/-200 V) to ionize vapor and convert it into a conductive plasma. Vapor and fragments of the overheated tissue are ejected, forming a crater . Electrode surfaces intended to be used for cutting often feature a finer wire or wire loop, as opposed to a more flat blade with a rounded surface.

Coagulation is performed using waveforms with lower average power, generating heat insufficient for explosive vaporization, but producing a thermal coagulum instead.

Electrosurgical desiccation occurs when the electrode touches the tissue open to air, and the amount of generated heat is lower than that required for cutting. The tissue surface and some of the tissue more deep to the probe dries out and forms a coagulum (a dry

patch of dead tissue). This technique may be used for treating nodules under the skin where minimal damage to the skin surface is desired.

In fulguration mode, the electrode is held away from the tissue, so that when the air gap between the electrode and the tissue is ionized, an electric arc discharge develops. In this approach the burning to the tissue is more superficial, because the current is spread over the tissue area larger than the tip of electrode. Under these conditions, superficial skin charring or carbonization is seen over a wider area than when operating in contact with the probe, and this technique is therefore used for very superficial or protrusive lesions such as skin tags. Ionization of an air gap requires voltage in the kV range.

Besides the thermal effects in tissue, electric field can produce pores in the cellular membranes - a phenomenon called electroporation. This effect may affect cells beyond the range of thermal damage.

Wet field electrosurgery

There are wet and dry field electrosurgical devices. Wet field devices operate in a saline solution, or in an open wound. Heating is as a result of an alternating current that passes between two electrodes. Heating is usually greatest where the current density is highest. Therefore it is usually the smallest or sharpest electrode that generates the most heat.

Cut/Coag Most wet field electrosurgical systems operate in two modes: "Cut" causes a small area of tissue to be vaporized, and "Coag" causes the tissue to "dry" (in the sense of bleeding being stopped). "Dried" tissues are killed (and will later slough or be replaced by fibrotic tissue) but they are temporarily physically intact after electrosurgical application. The depth of tissue death is typically a few millimeters near the contact of the electrode.

Cut If the voltage level is high enough, the heat generated can generates a vapour pocket. The vapour pocket typically reaches temperatures of approximately 400 degrees Celsius, which vaporizes and explodes a small section of soft tissue, resulting in an incission.

Coag When the system is operating in "coag mode" the voltage output is usually lower than in cut mode and less power is delivered. This therefore generates less heat and a vapour pocket is not generated. Tissue remains grossly intact, but cells are destroyed at the point of contact, and smaller vessels are destroyed and sealed, stopping capillary and small-arterial bleeding.

Electrosurgical waveforms

Different waveforms can be used for different electrosurgical procedures. For cutting, a continuous single frequency sine wave is often employed. Rapid tissue heating leads to explosive vaporization of interstitial fluid. If the voltage is sufficiently high (> 400 V peak-to-peak) the vapor sheath is ionized, forming conductive plasma. Electric current continues to flow from the metal electrode through the ionized gas into the tissue. Rapid

overheating of tissue results in its vaporization, fragmentation and ejection of fragments, allowing for tissue cutting. In applications of a continuous wave the heat diffusion typically leads to formation of a significant thermal damage zone at the edges of the lesion. Open circuit voltage in electrosurgical waveforms is typically in the range of 300–10,000 V peak-to-peak.

Higher precision can be achieved with pulsed waveforms . Using bursts of several tens of microseconds in duration the tissue can be cut, while the size of the heat diffusion zone does not exceed the cellular scale. Heat accumulation during repetitive application of bursts can also be avoided if sufficient delay is provided between the bursts, allowing the tissue to cool down . The proportion of ON time to OFF time can be varied to allow control of the heating rate. A related parameter, duty cycle, is defined as the ratio of the ON time to the period (the time of a single ON-OFF cycle). In the terminology of electrical engineering, this process of altering an amplitude of a periodic waveform is called modulation.

For coagulation, the average power is typically reduced below the threshold of cutting. Typically, sine wave is turned on and off in a rapid succession. The overall effect is a slower heating process, which causes tissue to coagulate. In simple coagulation/cutting mode machines, the lower duty cycle typical of coagulation mode is usually heard by the ear as a *lower frequency* and a rougher tone than the higher frequency tone typical of cutting mode with the same equipment.

Many modern electrosurgical generators provide sophisticated waveforms with power adjusted in real time, based on changes of the tissue impedance.

Prevention of unintended burns in patients

For high power surgical uses during anesthesia the *monopolar modality* relies on a good electrical contact between a large area of the body (typically at least the entire back of the patient) and the return electrode. If contact with the return pad is insufficient, severe burns (3rd degree) can occur in areas of poor contact with the return pad, or with metal objects in contact with Earth-ground serving as an unintended (capacitative) return path.

To prevent unintended burns, the skin is cleaned and a conductive gel is used to enhance contact. Proper electrical grounding practices must be followed in the electrical wiring of the building. It is also recommended to use a newer electrosurgical unit that includes alarms for ground circuit interruption. Grounding pads should always have full contact with the skin and be placed on the same side of the body and close to the body part where the procedure is occurring.

If there is any metal in the body of the patient, the grounding pad is placed on the opposite side of the body from the metal and be placed between the metal and the operation site. This prevents current from passing selectively through metal on the way to ground. For example, for a patient who has had a right sided hip replacement who is scheduled for surgery, the grounding pad is placed on the left side of the body on the

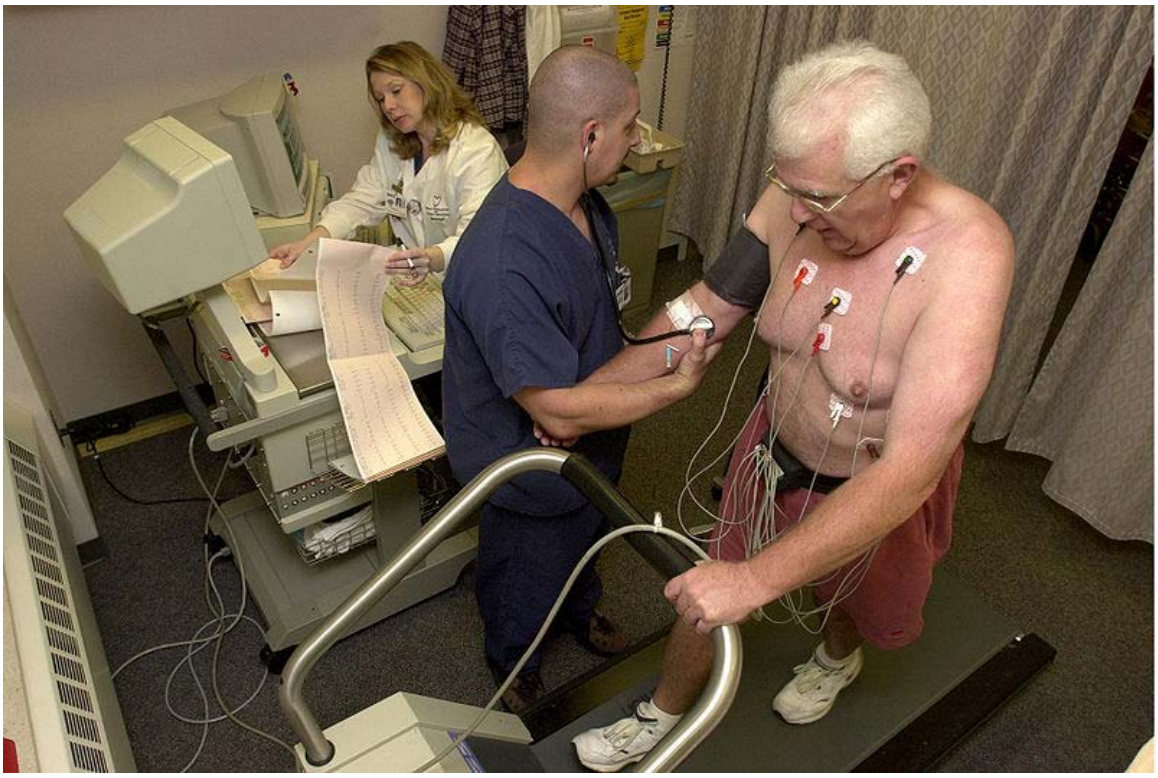
lateral side of the lower abdomen, which places the grounding pad between the location of the metal and the surgical site and on the opposite side from the metal. If there is metal on both sides of the body, the grounding pad is placed between the metal and the procedure site when possible. Common grounding pad locations include lateral portions of the outer thighs, abdomen, back, or shoulder blades.

The use of the bipolar option does not require the placement of a grounding pad because the electric current does not flow through the bulk of the body.

Electrosurgery should only be performed by a physician who has received specific training in this field and who is familiar with the techniques used to prevent burns.

Chapter 15

Cardiac Stress Test



A male patient walks on a stress test treadmill to have his heart's function checked

Cardiac stress test (or **Cardiac diagnostic test**) is a test used in medicine and cardiology to measure the heart's ability to respond to external stress in a controlled clinical environment.

The stress response is induced by exercise or drug stimulation. Cardiac stress tests compare the coronary circulation while the patient is at rest with the same patient's circulation observed during maximum physical exertion, showing any abnormal blood flow to the myocardium. The results can be interpreted as a reflection on the general physical condition of the test patient. This test can be used to diagnose ischemic heart disease, and for patient prognosis after a myocardial infarction.

Cardiac Stress Test

The cardiac stress test is done with heart stimulation, either by exercise on a treadmill or with intravenous pharmacological stimulation, with the patient connected to an electrocardiogram (or ECG).

The level of mechanical stress is progressively increased by adjusting the difficulty (steepness of the slope) and speed. The test administrator or attending physician examines the symptoms and blood pressure response. With use of ECG, the test is most commonly called a cardiac stress test, but is known by other names, such as exercise testing, stress testing treadmills, exercise tolerance test, stress test or stress test ECG.

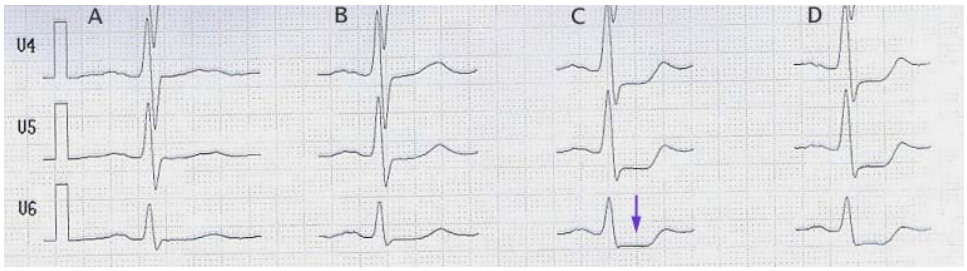
Nuclear Stress Test

Typically, a radiotracer (Tc-99 sestamibi or Tl-201) may be injected during the test. After a suitable waiting period to ensure proper distribution of the radiotracer, photos are taken with a gamma camera to capture images of the blood flow. Photos taken before and after exercise are examined to assess the state of the coronary arteries of the patient.

Showing the relative amounts of radioisotope within the heart muscle, the nuclear stress tests more accurately identify regional areas of reduced blood flow.

Stress and potential cardiac damage from exercise during the test is a problem in patients with ECG abnormalities at rest or in patients with severe motor disability. Pharmacological stimulation from vasodilators such as dipyridamole or adenosine, or positive chronotropic agents such as dobutamine can be used. Testing personnel can include a cardiac radiologist, a nuclear medicine physician, a cardiologist, and/or a nurse.

Function



Stress-ECG of a patient with coronary heart disease: ST-segment depression (arrow) at 100 Watt. A in rest, B at 75 Watt, C at 100 Watt, D at 125 Watt.

The American Heart Association recommends ECG treadmill testing as the first choice for patients with medium risk of coronary heart disease according to risk factors of smoking, family history of coronary artery stenosis, hypertension, diabetes and high cholesterol.

- Perfusion stress test (or sestamibi) is appropriate for select patients, especially those with an abnormal resting electrocardiogram.
- Intracoronary ultrasound or angiogram can provide more information at the risk of complications associated with cardiac catheterization.

Diagnostic Value

The common approach for stress testing by American College of Cardiology and American Heart Association indicates the following:

- Treadmill test: sensitivity 67%, specificity 70%
- Nuclear test: sensitivity 81%, specificity 85-95%

The value of stress tests has always been recognized as limited in assessing heart disease such as atherosclerosis, a condition which mainly produces wall thickening and enlargement of the arteries. This is because the stress test compares the patient's coronary flow status before and after exercise and is suitable to detecting specific areas of ischemia and lumen narrowing, not a generalized arterial thickening.

According to the 'American Heart Association data, about 65% of men and 47% of women have their first symptom of cardiovascular disease manifesting in a heart attack or sudden death. Stress tests, carried out shortly before these events, are not relevant to the prediction of infarction in the majority of individuals tested. Over the past two decades, better methods have been developed to identify atherosclerotic disease before it becomes symptomatic.

These detection methods have included either *anatomical* or *physiological*.

Examples of anatomical methods include

- CT coronary calcium score
- IMT carotid medial intima thickness
- IVUS

Examples of physiological methods include

- Lipoprotein analysis
- HbA1c
- Hs-CRP
- Homocysteine

The anatomic methods directly measure some aspects of the actual process of atherosclerosis itself and therefore offer the possibility of early diagnosis, but are often more expensive and may be invasive (in the case of IVUS, for example). The physiological methods are often less expensive and more secure, but are not able to quantify the current status of the disease or directly track progression.

Absolute Contraindications

Absolute contraindications to cardiac stress test include:

- Acute myocardial infarction within 48 hours
- Unstable angina not yet stabilized with medical therapy
- Uncontrolled cardiac arrhythmia, which may have significant hemodynamic responses (e.g. ventricular tachycardia)
- Severe symptomatic aortic stenosis, aortic dissection, pulmonary embolism, and pericarditis
- Multivessel coronary artery diseases that have a high risk of producing an acute myocardial infarction

Adverse Effects

Side effects from cardiac stress testing may include

- Palpitations, chest pain, shortness of breath, headache, nausea or fatigue.
- Adenosine and dipyridamole can cause mild hypotension.
- As the tracers used for this test are carcinogenic, frequent use of these tests carries a small risk of cancer.

Pharmacological Agents

The choice of pharmacologic stress agents used in the test depends on factors such as potential drug interactions with other treatments and concomitant diseases. Commonly used agents include:

- Dobutamine
- Adenosine
- Dipyridamole

Dobutamine is used to treat asthma (or severe COPD).

Adenosine or dipyridamole is generally used when a patient has poorly controlled hypertension, glaucoma, or has a left bundle branch block.

The effects of beta-agonists such as dobutamine can be reversed by administering beta-blockers such as propranolol.

Test Limits

The stress test does not detect:

- Atheroma
- Vulnerable plaques

The test has relatively high rates of false positives and false negatives compared with other clinical tests.

Preparations

Before a stress test, the patient should

- Receive the drugs necessary for a heart response, as indicated by the attending physician
- Bring any currently prescribed cardiac medication or inhalers to the test
- Have his or her blood sugar level measured
- Wear comfortable clothing and running shoes
- Do stretches and warm-ups to prevent cramps
- Remain well-hydrated

Before a stress test, the patient should not

- Eat or drink for several hours
- Consume caffeine in any form (cola, coffee etc) for 24 hrs prior to the test.
- Smoke tobacco in the hours leading up to the test.

Results

Once the stress test is completed, the patient generally is advised to not suddenly stop activity, but to slowly decrease the intensity of the exercise over the course of several minutes.

- Increased spatial resolution allows a more sensitive detection of ischemia.

- Stress testing, even if made in time, is not able to guarantee the prevention of symptoms, fainting, or death. Stress testing, although more effective than a resting ECG at detecting heart function, is only able to detect certain cardiac properties.

- The detection of high-grade coronary artery stenosis by a cardiac stress test was the key to recognizing people who have heart attacks since 1980. From 1960 to 1990, despite the success of stress testing to identify many who were at high risk of heart attack, the inability of this test correctly identify many others is discussed in medical circles but unexplained.

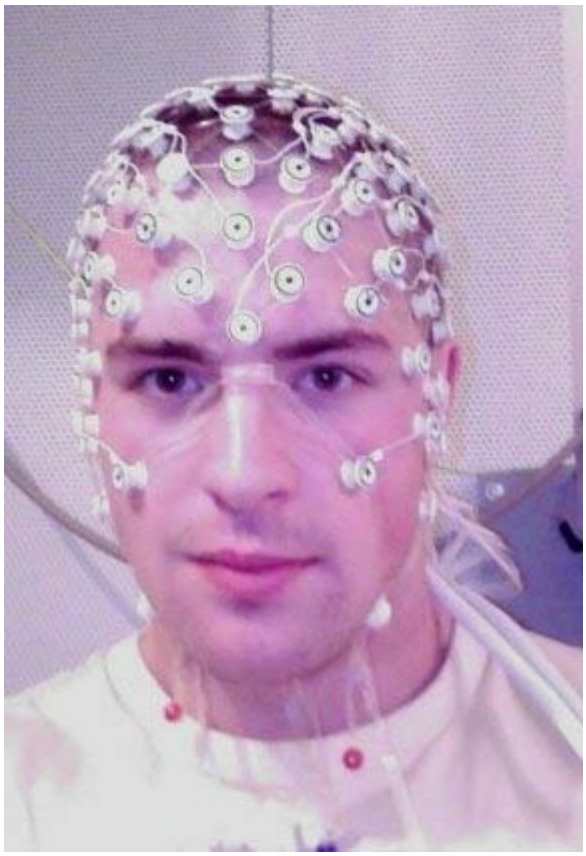
- High degrees of coronary artery stenosis, which are detected by stress testing methods are often, though not always, responsible for recurrent symptoms of angina.

- Unstable atheroma produces "vulnerable plaques" hidden within the walls of coronary arteries which go undetected by this test.

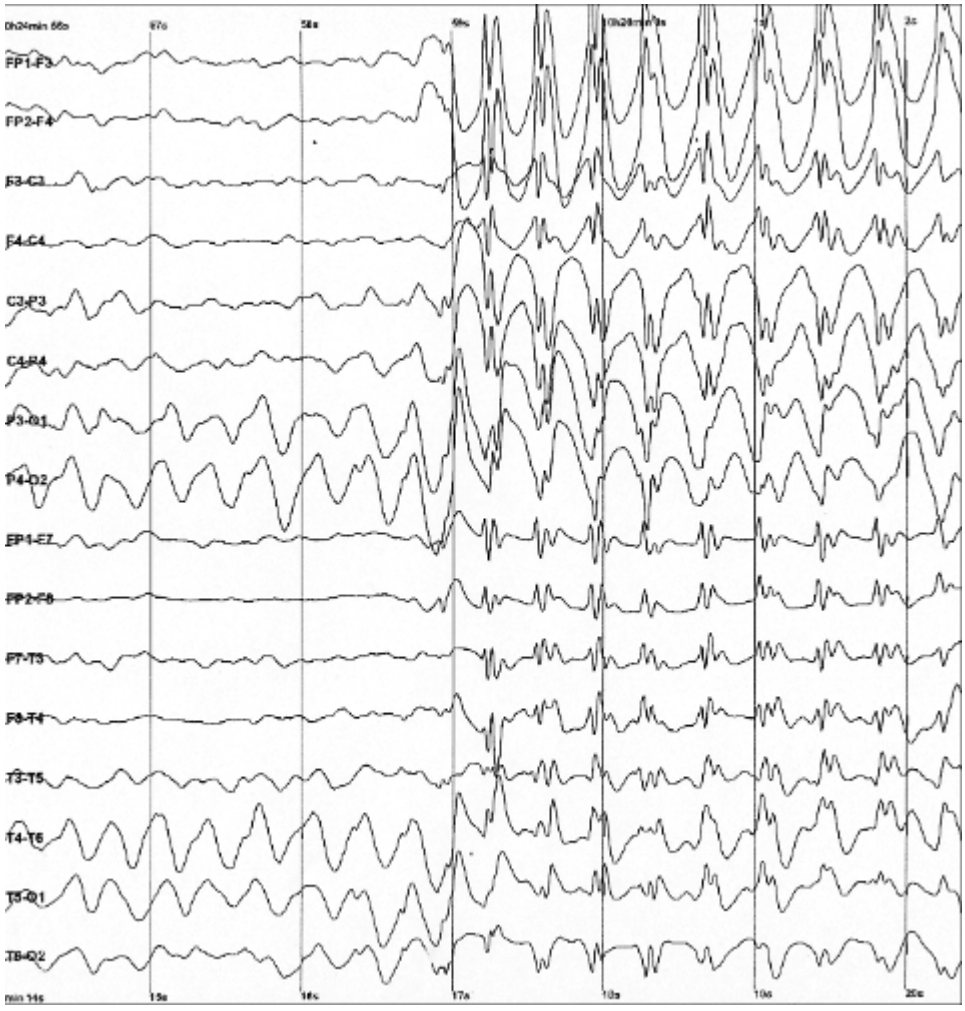
- Limitation in blood flow to the left ventricle can lead to recurrent angina pectoris.

Chapter 16

Electroencephalography



An EEG recording net (Electrical Geodesics, Inc.) being used on a participant in a brain wave study



Epileptic spike and wave discharges monitored with EEG

Electroencephalography (**EEG**) is the recording of electrical activity along the scalp produced by the firing of neurons within the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp. In neurology, the main diagnostic application of EEG is in the case of epilepsy, as epileptic activity can create clear abnormalities on a standard EEG study. A secondary clinical use of EEG is in the diagnosis of coma, encephalopathies, and brain death. EEG used to be a first-line method for the diagnosis of tumors, stroke and other focal brain disorders, but this use has decreased with the advent of anatomical imaging techniques such as MRI and CT.

Derivatives of the EEG technique include evoked potentials (EP), which involves averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, somatosensory, or auditory). Event-related potentials (ERPs) refer to averaged EEG responses that are time-locked to more complex processing of stimuli; this technique is used in cognitive science, cognitive psychology, and psychophysiological research.

Source of EEG activity

The brain's electrical charge is maintained by billions of neurons. Neurons are electrically charged (or "polarized") by membrane transport proteins that pump ions across their membranes. When a neuron receives a signal from its neighbor via an action potential, it responds by releasing ions into the space outside the cell. Ions of like charge repel each other, and when many ions are pushed out of many neurons at the same time, they can push their neighbors, who push their neighbors, and so on, in a wave. This process is known as volume conduction. When the wave of ions reaches the electrodes on the scalp, they can push or pull electrons on the metal on the electrodes. Since metal conducts the push and pull of electrons easily, the difference in push, or voltage, between any two electrodes can be measured by a voltmeter. Recording these voltages over time gives us the EEG.

The electric potentials generated by single neurons are far too small to be picked by EEG or MEG. EEG activity therefore always reflects the summation of the synchronous activity of thousands or millions of neurons that have similar spatial orientation. If the cells do not have similar spatial orientation, their ions do not line up and create waves to be detected. Pyramidal neurons of the cortex are thought to produce most EEG signal because they are well-aligned and fire together. Because voltage fields fall off with the square of the distance, activity from deep sources is more difficult to detect than currents near the skull.

Scalp EEG activity shows oscillations at a variety of frequencies. Several of these oscillations have characteristic frequency ranges, spatial distributions and are associated with different states of brain functioning (e.g., waking and the various sleep stages). These oscillations represent synchronized activity over a network of neurons. The neuronal networks underlying some of these oscillations are understood (e.g., the thalamocortical resonance underlying sleep spindles), while many others are not (e.g., the system that generates the posterior basic rhythm). Research that measures both EEG and neuron spiking finds the relationship between the two is complex with the power of surface EEG only in two bands that of gamma and delta relating to neuron spike activity.

Clinical use

A routine clinical EEG recording typically lasts 20–30 minutes (plus preparation time) and usually involves recording from scalp electrodes. Routine EEG is typically used in the following clinical circumstances:

- to distinguish epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope (fainting), sub-cortical movement disorders and migraine variants.
- to differentiate "organic" encephalopathy or delirium from primary psychiatric syndromes such as catatonia
- to serve as an adjunct test of brain death
- to prognosticate, in certain instances, in patients with coma

- to determine whether to wean anti-epileptic medications

At times, a routine EEG is not sufficient, particularly when it is necessary to record a patient while he/she is having a seizure. In this case, the patient may be admitted to the hospital for days or even weeks, while EEG is constantly being recorded (along with time-synchronized video and audio recording). A recording of an actual seizure (i.e., an ictal recording, rather than an inter-ictal recording of a possibly epileptic patient at some period between seizures) can give significantly better information about whether or not a spell is an epileptic seizure and the focus in the brain from which the seizure activity emanates.

Epilepsy monitoring is typically done:

- to distinguish epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope (fainting), sub-cortical movement disorders and migraine variants.
- to characterize seizures for the purposes of treatment
- to localize the region of brain from which a seizure originates for work-up of possible seizure surgery

Additionally, EEG may be used to monitor certain procedures:

- to monitor the depth of anesthesia
- as an indirect indicator of cerebral perfusion in carotid endarterectomy
- to monitor amobarbital effect during the Wada test

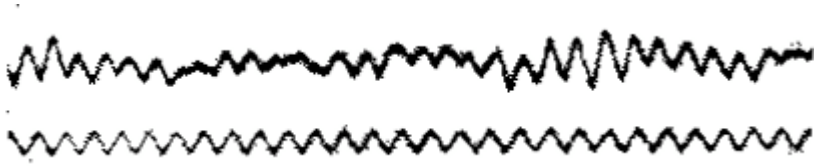
EEG can also be used in intensive care units for brain function monitoring:

- to monitor for non-convulsive seizures/non-convulsive status epilepticus
- to monitor the effect of sedative/anesthesia in patients in medically induced coma (for treatment of refractory seizures or increased intracranial pressure)
- to monitor for secondary brain damage in conditions such as subarachnoid hemorrhage (currently a research method)

If a patient with epilepsy is being considered for resective surgery, it is often necessary to localize the focus (source) of the epileptic brain activity with a resolution greater than what is provided by scalp EEG. This is because the cerebrospinal fluid, skull and scalp *smear* the electrical potentials recorded by scalp EEG. In these cases, neurosurgeons typically implant strips and grids of electrodes (or penetrating depth electrodes) under the dura mater, through either a craniotomy or a burr hole. The recording of these signals is referred to as electrocorticography (ECoG), subdural EEG (sdEEG) or intracranial EEG (icEEG)--all terms for the same thing. The signal recorded from ECoG is on a different scale of activity than the brain activity recorded from scalp EEG. Low voltage, high frequency components that cannot be seen easily (or at all) in scalp EEG can be seen clearly in ECoG. Further, smaller electrodes (which cover a smaller parcel of brain

surface) allow even lower voltage, faster components of brain activity to be seen. Some clinical sites record from penetrating microelectrodes.

Research use



The first human EEG recording obtained by Hans Berger in 1924. The upper tracing is EEG, and the lower is a 10 Hz timing signal.

EEG, and its derivative, ERPs, are used extensively in neuroscience, cognitive science, cognitive psychology, and psychophysiological research. Many techniques used in research contexts are not standardized sufficiently to be used in the clinical context.

A different method to study brain function is functional magnetic resonance imaging (fMRI). Some benefits of EEG compared to fMRI include:

- Hardware costs are significantly lower for EEG sensors versus an fMRI machine
- EEG sensors can be deployed into a wider variety of environments than can a bulky, immobile fMRI machine
- EEG enables higher temporal resolution, on the order of milliseconds, rather than seconds
- EEG is relatively tolerant of subject movement versus an fMRI (where the subject must remain completely still)
- EEG is silent, which allows for better study of the responses to auditory stimuli
- EEG does not aggravate claustrophobia

Limitations of EEG as compared with fMRI include:

- Significantly lower spatial resolution
- ERP studies require relatively simple paradigms, compared with block-design fMRI studies

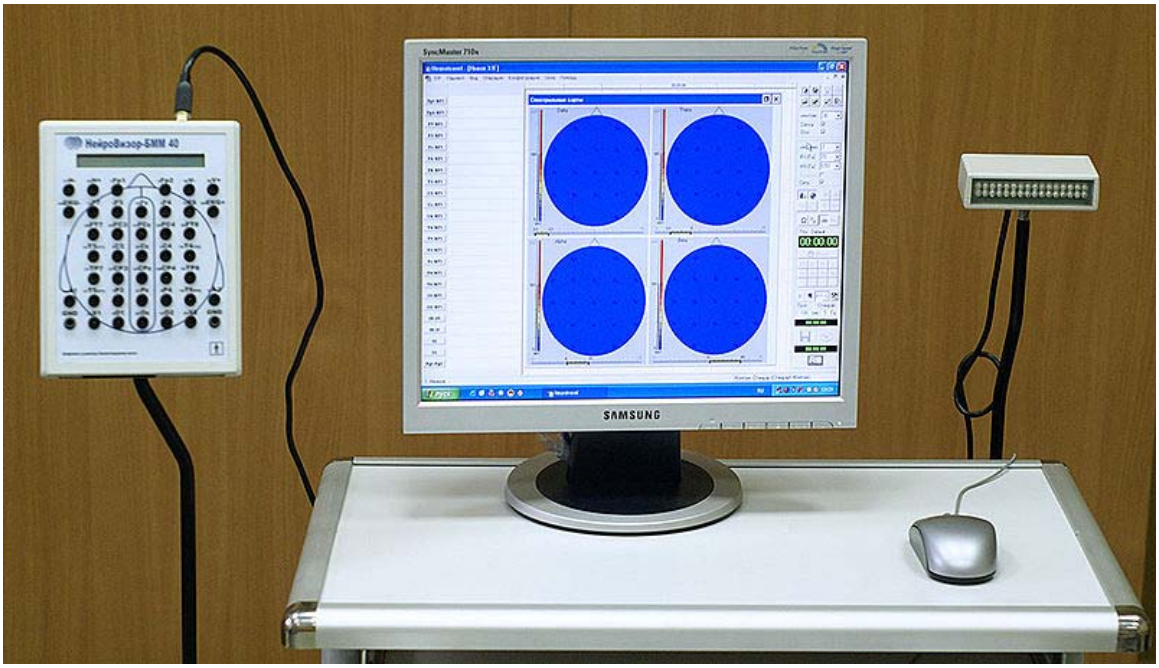
EEG recordings have been successfully obtained simultaneously with fMRI scans, though successful simultaneous recording requires that several technical issues be overcome, such as the presence of ballistocardiographic artifact, MRI pulse artifact and the induction of electrical currents in EEG wires that move within the strong magnetic fields of the MRI.

EEG also has some characteristics that compare favorably with behavioral testing:

- EEG can detect covert processing (i.e., processing that does not require a response)

- EEG can be used in subjects who are incapable of making a motor response
- Some ERP components can be detected even when the subject is not attending to the stimuli
- As compared with other reaction time paradigms, ERPs can elucidate stages of processing (rather than just the final end result)

Method



Computer Electroencephalograph *Neurovisor-BMM 40*

In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp with a conductive gel or paste, usually after preparing the scalp area by light abrasion to reduce impedance due to dead skin cells. Many systems typically use electrodes, each of which is attached to an individual wire. Some systems use caps or nets into which electrodes are embedded; this is particularly common when high-density arrays of electrodes are needed.

Electrode locations and names are specified by the International 10–20 system for most clinical and research applications (except when high-density arrays are used). This system ensures that the naming of electrodes is consistent across laboratories. In most clinical applications, 19 recording electrodes (plus ground and system reference) are used. A smaller number of electrodes are typically used when recording EEG from neonates. Additional electrodes can be added to the standard set-up when a clinical or research application demands increased spatial resolution for a particular area of the brain. High-density arrays (typically via cap or net) can contain up to 256 electrodes more-or-less evenly spaced around the scalp.

Each electrode is connected to one input of a differential amplifier (one amplifier per pair of electrodes); a common system reference electrode is connected to the other input of each differential amplifier. These amplifiers amplify the voltage between the active electrode and the reference (typically 1,000–100,000 times, or 60–100 dB of voltage gain). In analog EEG, the signal is then filtered (next paragraph), and the EEG signal is output as the deflection of pens as paper passes underneath. Most EEG systems these days, however, are digital, and the amplified signal is digitized via an analog-to-digital converter, after being passed through an anti-aliasing filter. Analog-to-digital sampling typically occurs at 256–512 Hz in clinical scalp EEG; sampling rates of up to 20 kHz are used in some research applications.

During the recording, a series of activation procedures may be used. These procedures may induce normal or abnormal EEG activity that might not otherwise be seen. These procedures include hyperventilation, photic stimulation (with a strobe light), eye closure, mental activity, sleep and sleep deprivation. During (inpatient) epilepsy monitoring, a patient's typical seizure medications may be withdrawn.

The digital EEG signal is stored electronically and can be filtered for display. Typical settings for the high-pass filter and a low-pass filter are 0.5-1 Hz and 35–70 Hz, respectively. The high-pass filter typically filters out slow artifact, such as electrogalvanic signals and movement artifact, whereas the low-pass filter filters out high-frequency artifacts, such as electromyographic signals. An additional notch filter is typically used to remove artifact caused by electrical power lines (60 Hz in the United States and 50 Hz in many other countries). As part of an evaluation for epilepsy surgery, it may be necessary to insert electrodes near the surface of the brain, under the surface of the dura mater. This is accomplished via burr hole or craniotomy. This is referred to variously as "electrocorticography (ECoG)", "intracranial EEG (I-EEG)" or "subdural EEG (SD-EEG)". Depth electrodes may also be placed into brain structures, such as the amygdala or hippocampus, structures, which are common epileptic foci and may not be "seen" clearly by scalp EEG. The electrocorticographic signal is processed in the same manner as digital scalp EEG (above), with a couple of caveats. ECoG is typically recorded at higher sampling rates than scalp EEG because of the requirements of Nyquist theorem—the subdural signal is composed of a higher predominance of higher frequency components. Also, many of the artifacts that affect scalp EEG do not impact ECoG, and therefore display filtering is often not needed.

A typical adult human EEG signal is about 10μV to 100 μV in amplitude when measured from the scalp and is about 10–20 mV when measured from subdural electrodes.

Since an EEG voltage signal represents a difference between the voltages at two electrodes, the display of the EEG for the reading encephalographer may be set up in one of several ways. The representation of the EEG channels is referred to as a *montage.*

Bipolar montage

Each channel (i.e., waveform) represents the difference between two adjacent electrodes. The entire montage consists of a series of these channels. For example,

the channel "Fp1-F3" represents the difference in voltage between the Fp1 electrode and the F3 electrode. The next channel in the montage, "F3-C3," represents the voltage difference between F3 and C3, and so on through the entire array of electrodes.

Referential montage
: Each channel represents the difference between a certain electrode and a designated reference electrode. There is no standard position for this reference; it is, however, at a different position than the "recording" electrodes. Midline positions are often used because they do not amplify the signal in one hemisphere vs. the other. Another popular reference is "linked ears," which is a physical or mathematical average of electrodes attached to both earlobes or mastoids.

Average reference montage
: The outputs of all of the amplifiers are summed and averaged, and this averaged signal is used as the common reference for each channel.

Laplacian montage
: Each channel represents the difference between an electrode and a weighted average of the surrounding electrodes.

When analog (paper) EEGs are used, the technologist switches between montages during the recording in order to highlight or better characterize certain features of the EEG. With digital EEG, all signals are typically digitized and stored in a particular (usually referential) montage; since any montage can be constructed mathematically from any other, the EEG can be viewed by the electroencephalographer in any display montage that is desired.

The EEG is read by a neurologist, optimally one who has specific training in the interpretation of EEGs. This is done by visual inspection of the waveforms, called graphoelements. The use of computer signal processing of the EEG—so-called quantitative EEG—is somewhat controversial when used for clinical purposes (although there are many research uses).

Limitations

EEG has several limitations. Most important is its poor spatial resolution. EEG is most sensitive to a particular set of post-synaptic potentials: those generated in superficial layers of the cortex, on the crests of gyri directly abutting the skull and radial to the skull. Dendrites, which are deeper in the cortex, inside sulci, in midline or deep structures (such as the cingulate gyrus or hippocampus), or producing currents that are tangential to the skull, have far less contribution to the EEG signal.

The meninges, cerebrospinal fluid and skull "smear" the EEG signal, obscuring its intracranial source.

It is mathematically impossible to reconstruct a unique intracranial current source for a given EEG signal, as some currents produce potentials that cancel each other out. This is referred to as the inverse problem. However, much work has been done to produce

remarkably good estimates of, at least, a localized electric dipole that represents the recorded currents.

EEG vs fMRI and PET

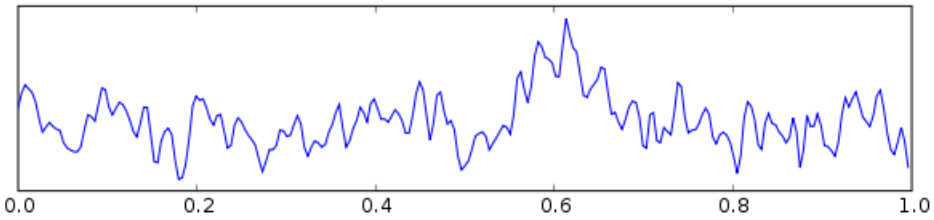
EEG has several strong points as a tool for exploring brain activity. EEG's can detect changes within a millisecond timeframe, excellent considering an action potential takes approximately 0.5-130 milliseconds to propagate across a single neuron, depending on the type of neuron. Other methods of looking at brain activity, such as PET and fMRI have time resolution between seconds and minutes. EEG measures the brain's electrical activity directly, while other methods record changes in blood flow (e.g., SPECT, fMRI) or metabolic activity (e.g., PET), which are indirect markers of brain electrical activity. EEG can be used simultaneously with fMRI so that high-temporal-resolution data can be recorded at the same time as high-spatial-resolution data, however, since the data derived from each occurs over a different time course, the data sets do not necessarily represent exactly the same brain activity. There are technical difficulties associated with combining these two modalities, including the need to remove the *MRI gradient artifact* present during MRI acquisition and the ballistocardiographic artifact (resulting from the pulsatile motion of blood and tissue) from the EEG. Furthermore, currents can be induced in moving EEG electrode wires due to the magnetic field of the MRI.

EEG vs MEG

EEG reflects correlated synaptic activity caused by post-synaptic potentials of cortical neurons. The ionic currents involved in the generation of fast action potentials may not contribute greatly to the averaged field potentials representing the EEG . More specifically, the scalp electrical potentials that produce EEG are generally thought to be caused by the extracellular ionic currents caused by dendritic electrical activity, whereas the fields producing magnetoencephalographic signals are associated with intracellular ionic currents .

EEG can be recorded at the same time as MEG so that data from these complementary high-time-resolution techniques can be combined.

Normal activity



One second of EEG signal

The EEG is typically described in terms of (1) rhythmic activity and (2) transients. The rhythmic activity is divided into bands by frequency. To some degree, these frequency

bands are a matter of nomenclature (i.e., any rhythmic activity between 8–12 Hz can be described as "alpha"), but these designations arose because rhythmic activity within a certain frequency range was noted to have a certain distribution over the scalp or a certain biological significance. Frequency bands are usually extracted using spectral methods (for instance Welch) as implemented for instance in freely available EEG software such as EEGLAB.

Most of the cerebral signal observed in the scalp EEG falls in the range of 1–20 Hz (activity below or above this range is likely to be artifactual, under standard clinical recording techniques).

Comparison table

Comparison of EEG bands

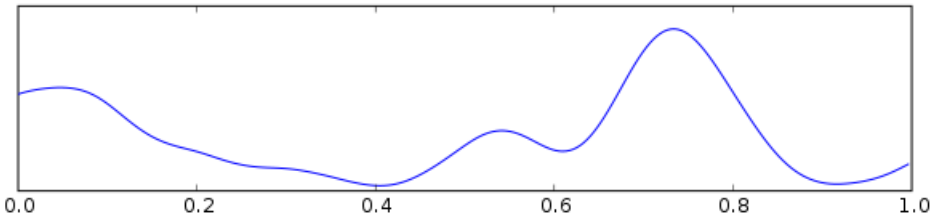
Type	Frequency (Hz)	Location	Normally	Pathologically
Delta	up to 4	frontally in adults, posteriorly in children; high amplitude waves	• adults slow wave sleep • in babies • Has been found during some continuous attention tasks (Kirmizi-Alsan et al. 2006)	• subcortical lesions • diffuse lesions • metabolic encephalopathy hydrocephalus • deep midline lesions
Theta	4 – 7	Found in locations not related to task at hand	• young children • drowsiness or arousal in older children and adults • idling • Associated with inhibition of elicited responses (has been found to spike in situations where a person is actively trying to repress a response or action) (Kirmizi-Alsan et al. 2006).	• focal subcortical lesions • metabolic encephalopathy • deep midline disorders • some instances of hydrocephalus
Alpha	8 – 12	posterior regions of head, both sides, higher in amplitude on	• relaxed/reflecting • closing the eyes • Also associated with inhibition control, seemingly with the	• coma

		dominant side. Central sites (c3-c4) at rest.	purpose of timing inhibitory activity in different locations across the brain (Klimesch, Sauseng, & Hanslmayr 2007; Coan & Allen 2008).	
Beta	12 – 30	both sides, symmetrical distribution, most evident frontally; low amplitude waves	• alert/working • active, busy or anxious thinking, active concentration	• benzodiazepines
Gamma	30 – 100+	Somatosensory cortex	• Displays during cross-modal sensory processing (perception that combines two different senses, such as sound and sight) (Kisley & Cornwell 2006; Kanayama, Sato, & Ohira 2007; Nieuwenhuis, Yeung, & Cohen 2004) • Also is shown during short term memory matching of recognized objects, sounds, or tactile sensations (Herrmann, Frund, & Lenz 2009)	• A decrease in gamma band activity may be associated with cognitive decline, especially when related the theta band; however, this has not been proven for use as a clinical diagnostic measurement yet (Moretti et al. 2009).
Mu	8 – 13	Sensorimotor cortex	• Shows rest state motor neurons (Gastaut, 1952).	• Mu suppression could be indicative for motor mirror neurons working, and deficits in Mu suppression, and thus in mirror neurons, might play

a role in autism. (Oberman et al., 2005)

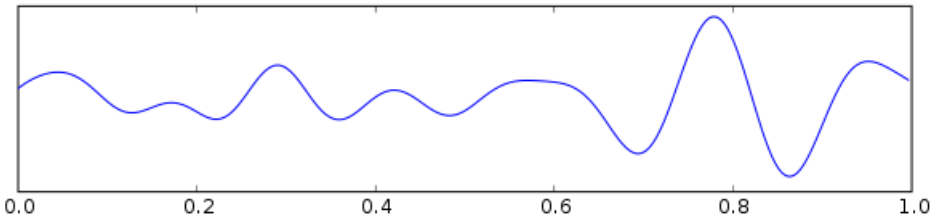
It should be noted that while these are the universally recognized ranges, they are not concrete definitions of the range of brain-waves. While researchers tend to follow these guidelines, many scholars use their own specific boundaries depending on the range they choose to focus on. Additionally, some researchers define the bands using decimal values rather than rounding to whole numbers (for example, one researcher may define the lower Beta band cut-off as 12.1, while another may use the value 13), while still others sometimes divide the bands into sub-bands. Generally, this is only done for the sake of analysis.

Wave patterns



delta waves

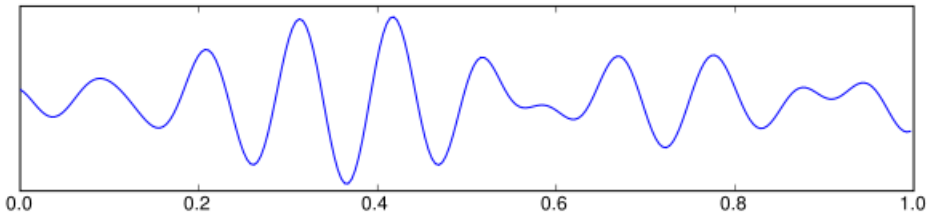
- Delta is the frequency range up to 4 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow wave sleep. It is also seen normally in babies. It may occur focally with subcortical lesions and in general distribution with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions. It is usually most prominent frontally in adults (e.g. FIRDA - Frontal Intermittent Rhythmic Delta) and posteriorly in children (e.g. OIRDA - Occipital Intermittent Rhythmic Delta).



theta waves

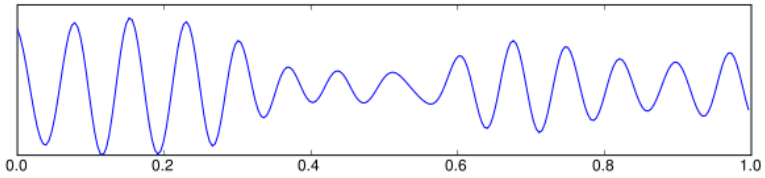
- Theta is the frequency range from 4 Hz to 7 Hz. Theta is seen normally in young children. It may be seen in drowsiness or arousal in older children and adults; it can also be seen in meditation. Excess theta for age represents abnormal activity. It can be seen as a focal disturbance in focal subcortical lesions; it can be seen in

generalized distribution in diffuse disorder or metabolic encephalopathy or deep midline disorders or some instances of hydrocephalus. On the contrary this range has been associated with reports of relaxed, meditative, and creative states.



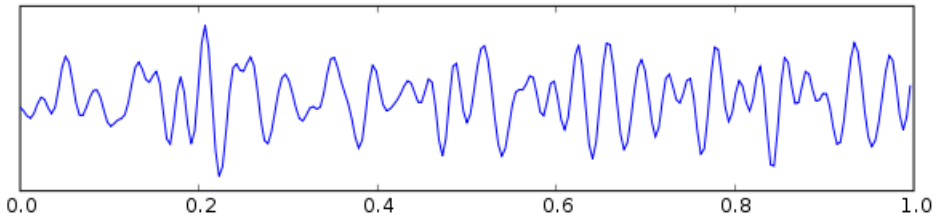
alpha waves

- Alpha is the frequency range from 8 Hz to 12 Hz. Hans Berger named the first rhythmic EEG activity he saw as the "alpha wave". This was the "posterior basic rhythm" (also called the "posterior dominant rhythm" or the "posterior alpha rhythm"), seen in the posterior regions of the head on both sides, higher in amplitude on the dominant side. It emerges with closing of the eyes and with relaxation, and attenuates with eye opening or mental exertion. The posterior basic rhythm is actually slower than 8 Hz in young children (therefore technically in the theta range).



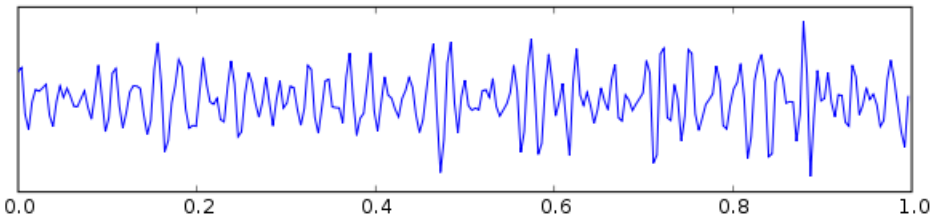
sensorimotor rhythm aka mu rhythm

In addition to the posterior basic rhythm, there are other normal alpha rhythms such as the mu rhythm (alpha activity in the contralateral sensory and motor cortical areas that emerges when the hands and arms are idle; and the "third rhythm" (alpha activity in the temporal or frontal lobes). Alpha can be abnormal; for example, an EEG that has diffuse alpha occurring in coma and is not responsive to external stimuli is referred to as "alpha coma".



beta waves

- Beta is the frequency range from 12 Hz to about 30 Hz. It is seen usually on both sides in symmetrical distribution and is most evident frontally. Beta activity is closely linked to motor behavior and is generally attenuated during active movements. Low amplitude beta with multiple and varying frequencies is often associated with active, busy or anxious thinking and active concentration. Rhythmic beta with a dominant set of frequencies is associated with various pathologies and drug effects, especially benzodiazepines. It may be absent or reduced in areas of cortical damage. It is the dominant rhythm in patients who are alert or anxious or who have their eyes open.



gamma waves

- Gamma is the frequency range approximately 30–100 Hz. Gamma rhythms are thought to represent binding of different populations of neurons together into a network for the purpose of carrying out a certain cognitive or motor function.

- Mu ranges 8–13 Hz., and partly overlaps with other frequencies. It reflects the synchronous firing of motor neurons in rest state. Mu suppression is thought to reflect motor mirror neuron systems, because when an action is observed, the pattern extinguishes, possibly because of the normal neuronal system and the mirror neuron system "go out of sync", and interfere with each other.

"Ultra-slow" or "near-DC" activity is recorded using DC amplifiers in some research contexts. It is not typically recorded in a clinical context because the signal at these frequencies is susceptible to a number of artifacts.

Some features of the EEG are transient rather than rhythmic. Spikes and sharp waves may represent seizure activity or interictal activity in individuals with epilepsy or a predisposition toward epilepsy. Other transient features are normal: vertex waves and sleep spindles are seen in normal sleep.

Note that there are types of activity that are statistically uncommon, but not associated with dysfunction or disease. These are often referred to as "normal variants." The mu rhythm is an example of a normal variant.

The normal Electroencephalography (EEG) varies by age. The neonatal EEG is quite different from the adult EEG. The EEG in childhood generally has slower frequency oscillations than the adult EEG.

The normal EEG also varies depending on state. The EEG is used along with other measurements (EOG, EMG) to define sleep stages in polysomnography. Stage I sleep (equivalent to drowsiness in some systems) appears on the EEG as drop-out of the posterior basic rhythm. There can be an increase in theta frequencies. Santamaria and Chiappa cataloged a number of the variety of patterns associated with drowsiness. Stage II sleep is characterized by sleep spindles—transient runs of rhythmic activity in the 12–14 Hz range (sometimes referred to as the "sigma" band) that have a frontal-central maximum. Most of the activity in Stage II is in the 3–6 Hz range. Stage III and IV sleep are defined by the presence of delta frequencies and are often referred to collectively as "slow-wave sleep." Stages I-IV comprise non-REM (or "NREM") sleep. The EEG in REM (rapid eye movement) sleep appears somewhat similar to the awake EEG.

EEG under general anesthesia depends on the type of anesthetic employed. With halogenated anesthetics, such as halothane or intravenous agents, such as propofol, a rapid (alpha or low beta), nonreactive EEG pattern is seen over most of the scalp, especially anteriorly; in some older terminology this was known as a WAR (widespread anterior rapid) pattern, contrasted with a WAIS (widespread slow) pattern associated with high doses of opiates. Anesthetic effects on EEG signals are beginning to be understood at the level of drug actions on different kinds of synapses and the circuits that allow synchronized neuronal activity.

Artifacts

Biological artifacts

Electrical signals detected along the scalp by an EEG, but that originate from non-cerebral origin are called artifacts. EEG data is almost always contaminated by such artifacts. The amplitude of artifacts can be quite large relative to the size of amplitude of the cortical signals of interest. This is one of the reasons why it takes considerable experience to correctly interpret EEGs clinically. Some of the most common types of biological artifacts include:

- Eye-induced artifacts (includes eye blinks, eye movements and extra-ocular muscle activity)
- EKG (cardiac) artifacts
- EMG (muscle activation)-induced artifacts
- Glossokinetic artifacts

The most prominent eye-induced artifacts are caused by the potential difference between the cornea and retina, which is quite large compared to cerebral potentials. When the eyes and eyelids are completely still, this corneo-retinal dipole does not affect EEG. However, blinks occur several times per minute, the eyes movements occur several times per second. Eyelid movements, occurring mostly during blinking or vertical eye movements, elicit a large potential seen mostly in the difference between the Electrooculography (EOG) channels above and below the eyes. An established explanation of this potential regards the eyelids as sliding electrodes that short-circuit the positively charged cornea to

the extra-ocular skin. Rotation of the eyeballs, and consequently of the corneo-retinal dipole, increases the potential in electrodes towards which the eyes are rotated, and decrease the potentials in the opposing electrodes. Eye movements called saccades also generate transient electromyographic potentials, known as saccadic spike potentials (SPs). The spectrum of these SPs overlaps the gamma-band, and seriously confounds analysis of induced gamma-band responses, requiring tailored artifact correction approaches. Purposeful or reflexive eye blinking also generates electromyographic potentials, but more importantly there is reflexive movement of the eyeball during blinking that gives a characteristic artifactual appearance of the EEG.

Eyelid fluttering artifacts of a characteristic type were previously called Kappa rhythm (or Kappa waves). It is usually seen in the prefrontal leads, that is, just over the eyes. Sometimes they are seen with mental activity. They are usually in the Theta (4–7 Hz) or Alpha (8–13 Hz) range. They were named because they were believed to originate from the brain. Later study revealed they were generated by rapid fluttering of the eyelids, sometimes so minute that it was difficult to see. They are in fact noise in the EEG reading, and should not technically be called a rhythm or wave. Therefore, current usage in electroencephalography refers to the phenomenon as an eyelid fluttering artifact, rather than a Kappa rhythm (or wave).

Some of these artifacts can be useful in various applications. The EOG signals, for instance, can be used to detect and track eye-movements, which are very important in polysomnography, and is also in conventional EEG for assessing possible changes in alertness, drowsiness or sleep.

EKG artifacts are quite common and can be mistaken for spike activity. Because of this, modern EEG acquisition commonly includes a one-channel EKG from the extremities. This also allows the EEG to identify cardiac arrhythmias that are an important differential diagnosis to syncope or other episodic/attack disorders.

Glossokinetic artifacts are caused by the potential difference between the base and the tip of the tongue. Minor tongue movements can contaminate the EEG, especially in parkinsonian and tremor disorders.

Environmental artifacts

In addition to artifacts generated by the body, many artifacts originate from outside the body. Movement by the patient, or even just settling of the electrodes, may cause *electrode pops*, spikes originating from a momentary change in the impedance of a given electrode. Poor grounding of the EEG electrodes can cause significant 50 or 60 Hz artifact, depending on the local power system's frequency. A third source of possible interference can be the presence of an IV drip; such devices can cause rhythmic, fast, low-voltage bursts, which may be confused for spikes.

Artifact correction

Recently, independent component analysis techniques have been used to correct or remove EEG contaminates. These techniques attempt to "unmix" the EEG signals into some number of underlying components. There are many source separation algorithms, often assuming various behaviors or natures of EEG. Regardless, the principle behind any particular method usually allow "remixing" only those components that would result in "clean" EEG by nullifying (zeroing) the weight of unwanted components. Fully automated artifact rejection methods, which use ICA, have also been developed.

Abnormal activity

Abnormal activity can broadly be separated into epileptiform and non-epileptiform activity. It can also be separated into focal or diffuse.

Focal epileptiform discharges represent fast, synchronous potentials in a large number of neurons in a somewhat discrete area of the brain. These can occur as interictal activity, between seizures, and represent an area of cortical irritability that may be predisposed to producing epileptic seizures. Interictal discharges are not wholly reliable for determining whether a patient has epilepsy nor where his/her seizure might originate.

Generalized epileptiform discharges often have an anterior maximum, but these are seen synchronously throughout the entire brain. They are strongly suggestive of a generalized epilepsy.

Focal non-epileptiform abnormal activity may occur over areas of the brain where there is focal damage of the cortex or white matter. It often consists of an increase in slow frequency rhythms and/or a loss of normal higher frequency rhythms. It may also appear as focal or unilateral decrease in amplitude of the EEG signal.

Diffuse non-epileptiform abnormal activity may manifest as diffuse abnormally slow rhythms or bilateral slowing of normal rhythms, such as the PBR.

Intracortical Encephalogram electrodes and sub-dural electrodes can be used in tandem to discriminate and discretize artifact from epileptiform and other severe neurological events.

More advanced measures of abnormal EEG signals have also recently received attention as possible biomarkers for different disorders such as Alzheimer's disease.

History

A timeline of the history of EEG is given by Swartz. Richard Caton (1842–1926), a physician practicing in Liverpool, presented his findings about electrical phenomena of the exposed cerebral hemispheres of rabbits and monkeys in the British Medical Journal in 1875. In 1890, Polish physiologist Adolf Beck published an investigation of

spontaneous electrical activity of the brain of rabbits and dogs that included rhythmic oscillations altered by light.

In 1912, Russian physiologist, Vladimir Vladimirovich Pravdich-Neminsky published the first animal EEG and the evoked potential of the mammalian (dog). In 1914, Napoleon Cybulski and Jelenska-Macieszyna photographed EEG-recordings of experimentally induced seizures.

German physiologist and psychiatrist Hans Berger (1873–1941) recorded the first human EEG in 1924. Expanding on work previously conducted on animals by Richard Caton and others, Berger also invented the electroencephalogram (giving the device its name), an invention described "as one of the most surprising, remarkable, and momentous developments in the history of clinical neurology". His discoveries were first confirmed by British scientists Edgar Douglas Adrian and B. H. C. Matthews in 1934 and developed by them.

In 1934, Fisher and Lowenback first demonstrated epileptiform spikes. In 1935 Gibbs, Davis and Lennox described interictal spike waves and the 3 cycles/s pattern of clinical absence seizures, which began the field of clinical electroencephalography. Subsequently, in 1936 Gibbs and Jasper reported the interictal spike as the focal signature of epilepsy. The same year, the first EEG laboratory opened at Massachusetts General Hospital.

Franklin Offner (1911–1999), professor of biophysics at Northwestern University developed a prototype of the EEG that incorporated a piezoelectric inkwriter called a Crystograph (the whole device was typically known as the Offner Dynograph).

In 1947, The American EEG Society was founded and the first International EEG congress was held. In 1953 Aserinsky and Kleitman describe REM sleep.

In the 1950s, William Grey Walter developed an adjunct to EEG called EEG topography, which allowed for the mapping of electrical activity across the surface of the brain. This enjoyed a brief period of popularity in the 1980s and seemed especially promising for psychiatry. It was never accepted by neurologists and remains primarily a research tool.

Various uses

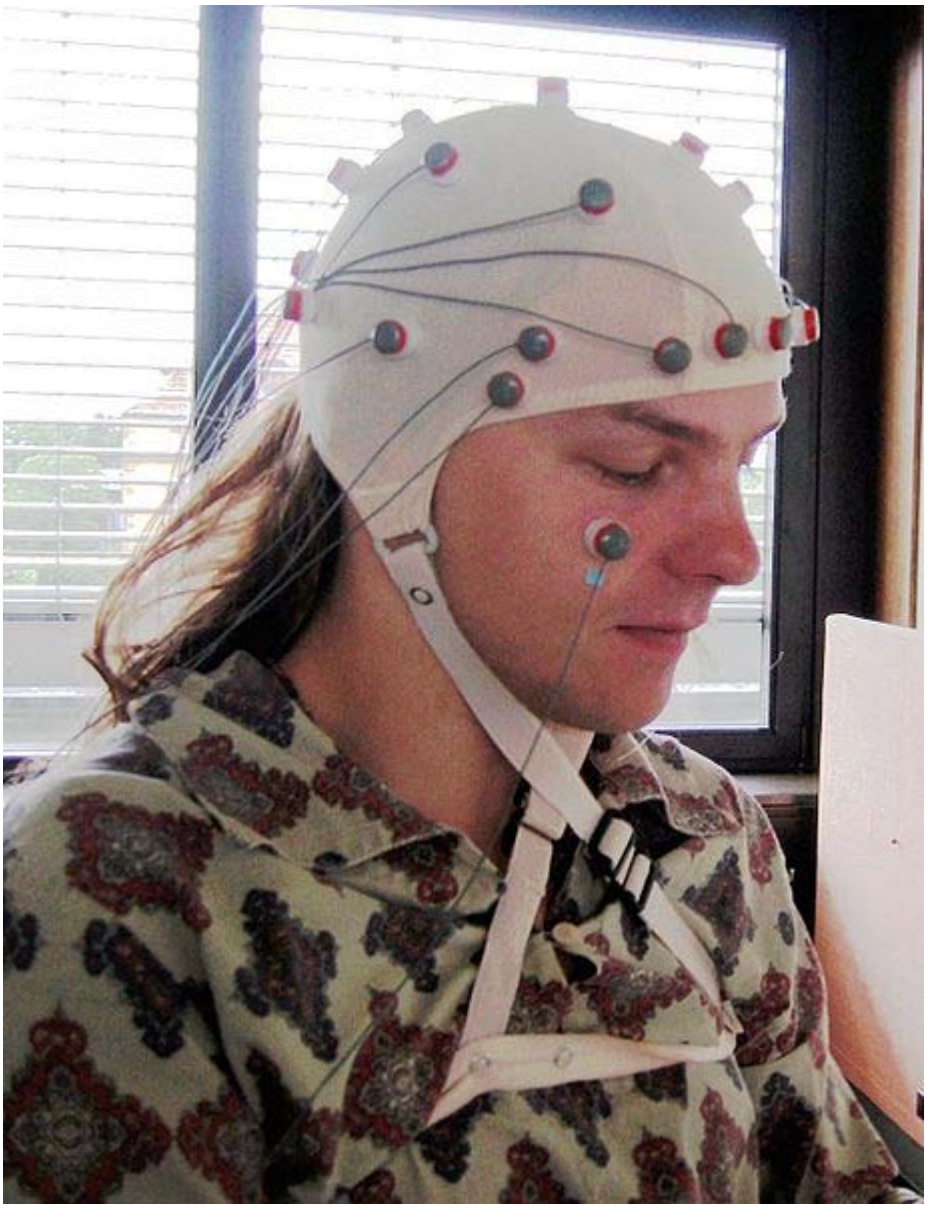
The EEG has been used for many purposes besides the conventional uses of clinical diagnosis and conventional cognitive neuroscience. Long-term EEG recordings in epilepsy patients are used for seizure prediction. Neurofeedback remains an important extension, and in its most advanced form is also attempted as the basis of brain computer interfaces. The EEG is also used quite extensively in the field of neuromarketing. There are many commercial products substantially based on the EEG.

Honda is attempting to develop a system to move its Asimo robot using EEG, a technology it eventually hopes to incorporate into its automobiles.

EEGs have been used as evidence in trials in the Indian state of Maharastra.

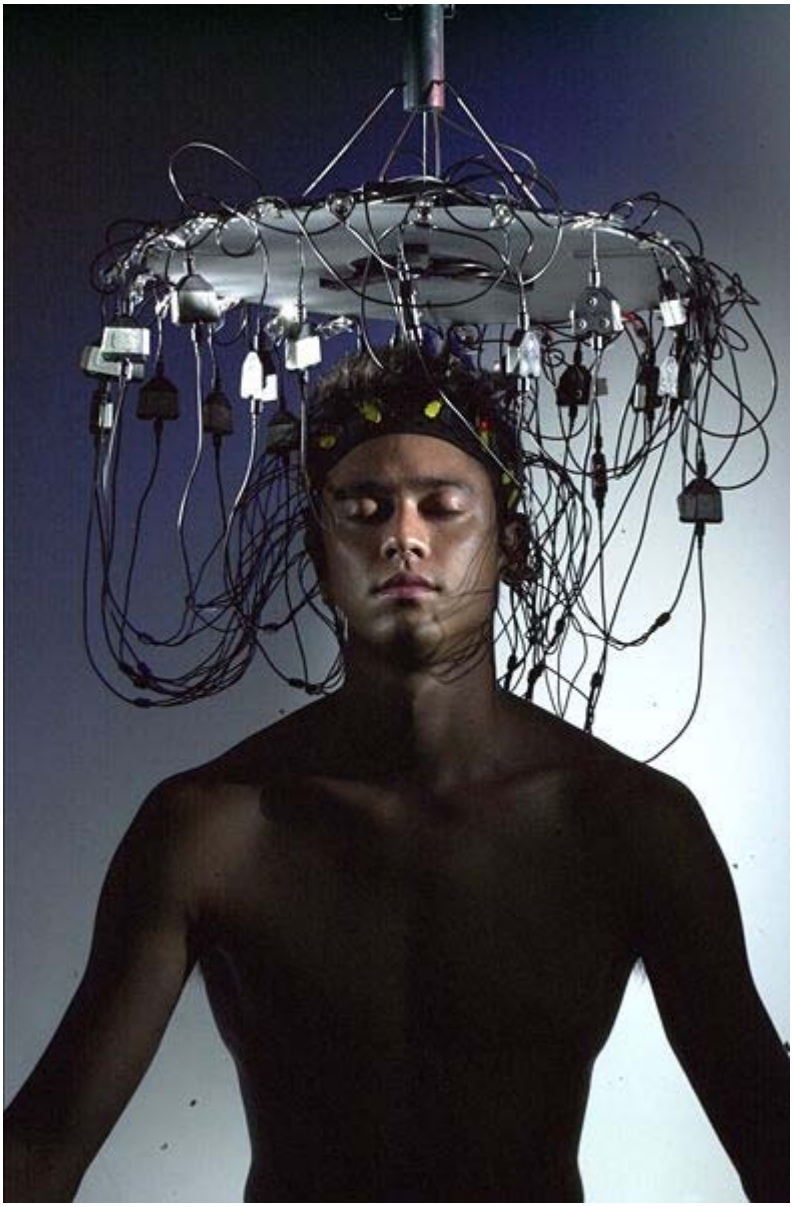
EEG and Telepathy

DARPA budgeted $4 million in 2009 to investigate technology to enable soldiers on the battlefield to communicate via computer-mediated telepathy. The aim is to analyse neural signals that exist in the brain before words are spoken.



Person wearing electrodes for EEG

Portable recording device for EEG



EEG electroencephalophone used during a music performance in which bathers from around the world were networked together as part of a collective musical performance, using their brainwaves to control sound, lighting, and the bath environment

Chapter 17

Electroneuronography

Electroneuronography (ENoG) is a neurological non-invasive test that was first described by Esslen and Fisch in 1979 and is used to examine the integrity and conductivity of a peripheral nerve. It consists of a brief electrical stimulation of the nerve in one point underneath the skin, and at the same time recording the electrical activity (compound action potentials) at another point of the nerve's trajectory in the body. The response is displayed in a cathode ray tube (CRT) or through the video monitor of a computer. The stimulation as well as the recording are carried out by disc electrodes taped to the skin, and the technician may use electrically conducting gel or paste to bolster the signals being input and output. Alternatively, the recording electrodes may also be used to pick up the electrical activity of a muscle innervated by that nerve. In such instances electroneuronography is closely related to electromyography.

Usually, nerves in the limbs (arms and legs) are tested in this way, but one of the most common applications of electroneuronography is the test of the facial nerve, such as in cases of muscle weakness in one side of the face (Bell's palsy). It is performed by an audiologist, who carries out tests to compare the two sides of the face. The stimulation electrode is located at the stylomastoid foramen and the recording electrode is located near the nasolabial fold. The ENoG test is the only objective measure of facial nerve integrity.

Background

In the human body there are twelve pairs of cranial nerves. Audiologists generally focus their expertise on the seventh and eighth nerves, which are known as the facial nerve and vestibulocochlear nerve, respectively. Electroneuronography is typically concerned with the amount of degradation in the facial nerves, each of which consists of thousands of fibers. Motor and sensory fibers are typically found in a 2:1 ratio, and it has been proposed that only half of the motor units need to be functional for normal nerve conduction to take place. The facial nerves originate in the brainstem, cross through the auditory canal, exit the skull at the stylomastoid foramen, and terminate face in 2 main branches on each side of the face. These control muscle contractions and facial expressions.

Facial nerve paralysis can impact a several aspects of a person’s life, ranging from emotional or psychological effects to the actual physical limitations themselves. People

who have been affected by such conditions often have difficulty speaking, drinking, eating, and showing the simplest of facial expressions. All of these combine to limit socialization and active involvement in the public domain. The proper assessment of facial nerve integrity is, therefore, vital to the detection and treatment of such disorders. Electroneuronography is used as a basis for a physician's course of action in managing disease. A doctor may opt for continued observation of the patient following initial testing, or they may recommend surgery to deal with the damage.

Facial nerve disorders may stem from a myriad of contributing factors: Bell's palsy, injury resulting from surgical error, trauma to the temporal bone, otitis media, multiple sclerosis, mumps, chicken pox, and other conditions.

Testing/Mechanism of Operation

Recording Techniques

Electroneuronography tests are performed by audiologists, and have been since their invention in the late 1970s, when they replaced acoustic reflex measurements. Typically, the system calculates the difference between compound muscle action potentials generated near the nose (nasolabial fold) in response to supramaximal electrical stimulation near the ear (stylomastoid foramen). Thus, the electrical stimulus travels along the facial nerve, allowing it to be specifically pinpointed. Increasing sensitivity and specificity of the recordings has been a constant goal, and it is believed that variability arises from the location and pressure of the electrodes, the stimulating current, and skin resistance. Esslen and Fisch placed the electrodes on the nasolabial fold, and this has become the standard, but May and Hughes experimented with electrodes placed on the nasal ala, citing better waveforms. The two positions were compared with respect to supramaximal threshold, waveform shape/amplitude, and repeatability. With regard to the supramaximal threshold, the nasal alae demonstrated a superior biphasic waveform while requiring less input stimulation to yield adequate results. In all other categories, however, there was no statistical difference between taking measurements at the nasolabial fold compared to the nasal alae.

It is common for a general feeling of discomfort to accompany the electrical stimulation of the nerve, but nearly all patients prefer to undergo the procedure in order to effect a treatment for their condition. Measurements are generally taken on the normal, unaffected side of the face first, and then on the abnormal side. Bipolar stimulation is generated at the stylomastoid foramen, while the recording electrodes are attached at the terminal ends of the nerve near the nose. A ground electrode is placed in the center of the patient's forehead, sufficiently far from the facial nerve as to not give an output reading. A variety of stimulation locations may also be employed, to get the best possible results. Audiologists aim to get the most efficient readings possible by optimizing results with a minimal input stimulus. The amount of damage is calculated as a ratio of how much nerve conduction has been retained by the affected side compared to the healthy value. Massive amounts of clinical experience may be required to accurately interpret the data

received from testing, and misreading the results may put the patient at serious risk of developing further damage or creating a problem in otherwise healthy facial nerves.

Analyzing the Results

Amplitude is the key component in the interpretation of electroneuronography tests. The resulting waveforms are analyzed and reported as a percentage using the following formula:

Dysfunctional Side (volts) / Healthy Side (volts) = Percentage of Response

Other forms of recording the output include using a percentage of fibers that are no longer active. This is essentially the same as subtracting the percentage of response from 100%. Either method is clinically accepted, provided the terminology is consistent and not interchanged.

Any responsive level above 10% is regarded as being able to spontaneously recover and does not typically require surgical intervention. Anything beneath the threshold usually requires active and invasive means to correct. To ensure accurate results, and consequently an appropriate course of action, readings may need to be taken every few days until fairly constant values are recorded.

Diagnostic Uses

Alternative Tests

Several alternative procedures exist for testing facial nerve integrity. Electromyography, Acoustic reflex testing (formerly the gold standard), MRI, CT scanning, transcranial magnetic stimulation, blink reflex tests, and maximal/minimal stimulation tests may also be used to asses the viability of the nerves. Currently, however, electroneuronography serves as the only objective test compared to these options, and the test is preferentially performed before the others.

House-Brackmann Facial Grading Scale

The House-Brackmann (HB) scale is the standard used by medical professionals to evaluate facial nerve function. It is a measure of the range of intentional motion the patient's facial muscles have, and is based largely on the observations of the physician. Because of the subjective nature of the scale, there may be discrepancies between assessments by different doctors, but the overall reliability and ease of use has made this scale the most commonly employed by medical professionals.

The scale itself consists of six levels of facial nerve function, ranging from healthy (level 1) to a total lack of movement (level 6). When performing a visual examination, the level at which the patient's facial nerves are functioning is reported as a fraction of the 6 levels. Therefore, someone with normal facial nerve integrity would be reported as "1/6,"

or “level 1 of 6.” Grade two is associated with mild weakening of the facial nerve, and grades three and four have moderate damage, varying only on the basis of the ability to close the eye. The next two levels include severe impairment and total paralysis, respectively. Electroneuronography may only be employed in the most severe instances (5/6 or 6/6) because in the other cases there is clear evidence that the nerve is mostly intact. Even so, it may be helpful to chart a patient’s progress beginning at the lowest levels of damage.

Common Causes of Weakness

Perhaps the most common cause of damage to the facial nerve is Bell’s palsy (BP). It has a reported incidence of about 0.00015% within the world population each year, and in up to approximately 10% of those cases, the disorder will recur. The etiology of this disease is currently unknown, but hypotheses include infections, genetic predisposition, environmental factors, and neuropathy. Among those who develop the disorder, unilateral paralysis of the facial muscles occurs in a day or two, but it is common for the patient to recover on their own over the span of a few weeks. Even if the condition is resolved, the patient still stands a 20% chance of having lifelong weakness in their facial muscles, and 5% of these people will have permanent damage equivalent to a level of 4 or higher on the House-Brackmann scale.

Another possible effect of Bell’s palsy is Wallerian Degeneration (WD), which may take days to become evident. Because of the slow-acting nature of this pathology, a patient may present healthy electroneuronography results despite a lack of volitional control of the facial muscles immediately following the onset of Bell’s palsy. This is because the degeneration has not yet reached completion, and some fibers are still intact. Therefore, it is standard procedure to wait at least three days after symptoms present themselves to perform an electroneuronography test, in order to prevent false negatives. At the other end of the spectrum, tests are generally not recommended after a period of twenty-one days. Typically, electroneuronography recordings are taken on the third day of symptoms and repeated every four days until a plateau is reached.

Facial Nerve Injury

Seddon classified facial nerve injuries into three broad categories: neuropraxia, neurotmesis, and axonotmesis. Neuropraxia is the most common form of injury associated with Bell’s palsy, and it is characterized by paralysis without a degeneration of the peripheral nerve. Electroneuronography would yield a normal or mildly impaired response, as the nerve fibers are still whole but unresponsive to conscious control. Neurotmesis is regarded as the worst possible outcome, with electroneuronography readings equivalent to a flat line, or no response to stimulation. This represents total degradation of the facial nerve. Lastly, axonotmesis consists of damage to the inner nerve fibers while the outer covering remains whole, and also yields a flat line in response to stimulation. Because of their similar recordings, electroneuronography cannot, by itself, distinguish between the latter two forms of nerve injury.

Chapter 18

Colonoscopy

	Intervention: Colonoscopy
ICD-10 code:	
ICD-9 code:	45.23
MeSH	D003113
Other codes:	

Colonoscopy is the endoscopic examination of the colon and the distal part of the small bowel with a CCD camera or a fiber optic camera on a flexible tube passed through the anus. It may provide a visual diagnosis (e.g. ulceration, polyps) and grants the opportunity for biopsy or removal of suspected lesions.

Virtual colonoscopy, which uses 2D and 3D imagery reconstructed from computed tomography (CT) scans or from nuclear magnetic resonance (MR) scans, is also possible, as a totally non-invasive medical test, although it is not standard and still under investigation regarding its diagnostic abilities. Furthermore, virtual colonoscopy does not allow for therapeutic maneuvers such as polyp/tumour removal or biopsy nor visualization of lesions smaller than 5 millimetres. If a growth or polyp is detected using CT colonography, a standard colonoscopy would still need to be performed.

Colonoscopy can remove polyps as small as one millimetre or less. Once polyps are removed, they can be studied with the aid of a microscope to determine if they are precancerous or not.

Colonoscopy is similar to, but not the same as, sigmoidoscopy -- the difference being related to which parts of the colon each can examine. A colonoscopy allows an examination of the entire colon (measuring four to five feet in length). A sigmoidoscopy allows an examination of only the final two feet of the colon.

A sigmoidoscopy is often used as a screening procedure for a full colonoscopy -- done in many instances in conjunction with a fecal occult blood test (FOBT), which can detect the formation of cancerous cells throughout the colon. At other times, a sigmoidoscopy is preferred to a full colonoscopy in patients having an active flare of ulcerative colitis or

Crohn's disease to avoid a perforation of the colon. Additionally, surgeons have lately been using the term pouchoscopy to refer to a colonoscopy of the ileo-anal pouch.

Reasons for procedure

Conditions that call for colonoscopies include gastrointestinal hemorrhage, unexplained changes in bowel habit and suspicion of malignancy. Colonoscopies are often used to diagnose colon cancer, but are also frequently used to diagnose inflammatory bowel disease. In older patients (sometimes even younger ones) an unexplained drop in hematocrit (one sign of anemia) is an indication that calls for a colonoscopy, usually along with an esophagogastroduodenoscopy (EGD), even if no obvious blood has been seen in the stool (feces).

Fecal occult blood is a quick test which can be done to test for microscopic traces of blood in the stool. A positive test is almost always an indication to do a colonoscopy. In most cases the positive result is just due to hemorrhoids; however, it can also be due to diverticulosis, inflammatory bowel disease (Crohn's disease, ulcerative colitis), colon cancer, or polyps. However—since its development by Dr. Hiromi Shinya and Dr. William I. Wolff in the 1960s--polypectomy has become a routine part of colonoscopy, allowing for quick and simple removal of polyps without invasive surgery.

Due to the high mortality associated with colon cancer and the high effectivity and low risks associated with colonoscopy, it is now becoming a routine screening test for people 50 years of age or older. Subsequent rescreenings are then scheduled based on the initial results found, with a five- or ten-year recall being common for colonoscopies that produce normal results. Patients with a family history of colon cancer are often first screened during their teenage years.

A study published in the New England Journal of Medicine (September 18, 2008) has found that among people who have had an initial colonoscopy that found no polyps, the risk of developing colorectal cancer within five years is extremely low. Therefore, there is no need for those people to have another colonoscopy sooner than five years after the first screening.

Procedure

Preparation

The colon must be free of solid matter for the test to be performed properly. For one to three days, the patient is required to follow a low fiber or clear-liquid only diet. Examples of clear fluids are apple juice, chicken and/or beef broth or bouillon, lemon-lime soda, lemonade, sports drink, and water. It is very important that the patient remain hydrated. Sports drinks contain electrolytes which are depleted during the purging of the bowel. Orange juice, prune juice, and milk containing fiber should not be consumed, nor should liquids dyed red, purple, orange, or sometimes brown; however, cola is allowed. In most cases, tea (no milk) or black coffee (no milk) are allowed.

The day before the colonoscopy, the patient is either given a laxative preparation (such as Bisacodyl, phospho soda, sodium picosulfate, or sodium phosphate and/or magnesium citrate) and large quantities of fluid, or whole bowel irrigation is performed using a solution of polyethylene glycol and electrolytes. Often, the procedure involves both a pill-form laxative and a bowel irrigation preparation with the polyethylene glycol powder dissolved into any clear liquid, preferably a sports drink which contain electrolytes.

In this case, a typical procedure regimen then would be as follows: in the morning of the day before the procedure, a 238 g bottle of polyethylene glycol powder should be poured into 64 oz. of the chosen clear liquid, which then should be mixed and refrigerated. Two (2) bisacodyl 5 mg tablets are taken 3 pm; at 5 pm, the patient starts drinking the mixture (approx. 8 oz. each 15-30 min. until finished); at 8 pm, take two (2) bisacodyl 5 mg tablets; continue drinking/hydrating into the evening until bedtime with clear permitted fluids. A common brand name of bisacodyl is Dulcolax, and store brands are available. A common brand name of polyethylene glycol powder is MiraLax. It may be advisable to schedule the procedure early on a given day so the patient need not go without food and only limited fluids the morning of the procedure on top of having to go through the foregoing preparation procedures the preceding day.

Since the goal of the preparation is to clear the colon of solid matter, the patient should plan to spend the day at home in comfortable surroundings with ready access to toilet facilities. The patient may also want to have at hand moist toilettes or a bidet for cleaning the anus. A soothing salve such as petroleum jelly applied after cleaning the anus will improve patient comfort.

The patient may be asked to skip aspirin and aspirin-like products such as salicylate, ibuprofen, and similar medications for up to ten days before the procedure to avoid the risk of bleeding if a polypectomy is performed during the procedure. A blood test may be performed before the procedure.

The investigation

During the procedure the patient is often given sedation intravenously, employing agents such as fentanyl or midazolam. Although meperidine (Demerol) may be used as an alternative to fentanyl, the concern of seizures has relegated this agent to second choice for sedation behind the combination of fentanyl and midazolam. The average person will receive a combination of these two drugs, usually between 25 to 100 µg IV fentanyl and 1–4 mg IV midazolam. Sedation practices vary between practitioners and nations; in some clinics in Norway, sedation is rarely administered.

Some endoscopists are experimenting with, or routinely use, alternative or additional methods such as nitrous oxide and propofol, which have advantages and disadvantages relating to recovery time (particularly the duration of amnesia after the procedure is complete), patient experience, and the degree of supervision needed for safe administration. This sedation is called "twilight anesthesia." For some patients it is not fully effective, so they are indeed awake for the procedure and can watch the inside of

their colon on the color monitor. Substituting propofol for midazolam, which gives the patient quicker recovery, is gaining wider use, but requires closer monitoring of respiration.

A meta-analysis found that playing music improves patient tolerability of the procedure.

The first step is usually a digital rectal examination, to examine the tone of the sphincter and to determine if preparation has been adequate. The endoscope is then passed through the anus up the rectum, the colon (sigmoid, descending, transverse and ascending colon, the cecum), and ultimately the terminal ileum. The endoscope has a movable tip and multiple channels for instrumentation, air, suction and light. The bowel is occasionally insufflated with air to maximize visibility. Biopsies are frequently taken for histology.

In most experienced hands, the endoscope is advanced to the junction of where the colon and small bowel join up (cecum) in under 10 minutes in 95% of cases. Due to tight turns and redundancy in areas of the colon that are not "fixed", loops may form in which advancement of the endoscope creates a "bowing" effect that causes the tip to actually retract. These loops often result in discomfort due to stretching of the colon and its associated mesentery. Manoeuvres to "reduce" or remove the loop include pulling the endoscope backwards while torquing the instrument. Alternatively, body position changes and abdominal support from external hand pressure can often "straighten" the endoscope to allow the scope to move forward. In a minority of patients, looping is often cited as a cause for an incomplete examination. Usage of alternative instruments leading to completion of the examination has been investigated, including use of pediatric colonoscope, push enteroscope and upper GI endoscope variants.

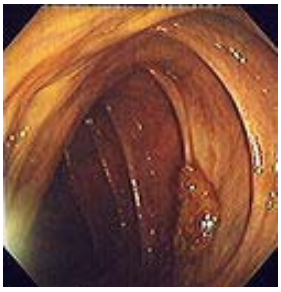
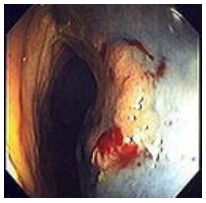
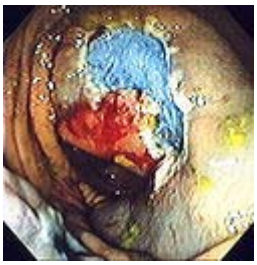
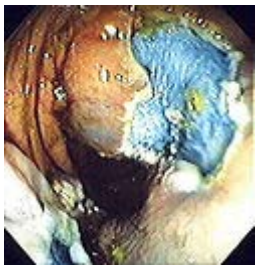
For screening purposes, a closer visual inspection is then often performed upon withdrawal of the endoscope over the course of 20 to 25 minutes. Lawsuits over missed cancerous lesions have recently prompted some institutions to better document withdrawal time as rapid withdrawal times may be a source of potential medical legal liability. This is often a real concern in clinical settings where high caseloads could provide financial incentive to complete colonoscopies as quickly as possible.

Suspicious lesions may be cauterized, treated with laser light or cut with an electric wire for purposes of biopsy or complete removal polypectomy. Medication can be injected, e.g. to control bleeding lesions. On average, the procedure takes 20–30 minutes, depending on the indication and findings. With multiple polypectomies or biopsies, procedure times may be longer. As mentioned above, anatomic considerations may also affect procedure times.

After the procedure, some recovery time is usually allowed to let the sedative wear off. Outpatient recovery time can take an estimate of 30–60 minutes. Most facilities require that patients have a person with them to help them home afterwards (again, depending on the sedation method used).

One very common aftereffect from the procedure is a bout of flatulence and minor wind pain caused by air insufflation into the colon during the procedure.

An advantage of colonoscopy over x-ray imaging or other, less invasive tests, is the ability to perform therapeutic interventions during the test. A polyp is a growth of excess of tissue that can develop into cancer. If a polyp is found, for example, it can be removed by one of several techniques. A snare device can be placed around a polyp for removal. Even if the polyp is flat on the surface it can often be removed. For example, the following shows a polyp removed in stages:

Polyp is identified	**A sterile solution is injected under the polyp to lift it away from deeper tissues.**	**A portion of the polyp is now removed.**	**The polyp is fully removed.**
			

Pain

The pain associated with the procedure is not caused by the insertion of the scope but from inflating of the colon in order to do the inspection. The scope is basically a long, flexible tube about a centimeter in diameter, that is, roughly as big around as the little finger. This is less than the diameter of an average stool so just as there is normally no pain from the daily passage of food inside the colon , there should be no pain from a normal insertion.

The colon is wrinkled and corrugated like an accordion, or a clothes-dryer exhaust tube. This gives it the large surface area needed for digestion. But in order to inspect this surface, the doctor must blow it up like a balloon, to get the creases out. This is done using a powered air compressor a lot like the one used to inflate a car's tires.

The stomach, intestines and colon have a "second brain" wrapped around them. This "second brain" has at least sensor nerves, decision processes, and motor nerves, so that it runs the chemical factory of digestion completely by itself, without the person having to think about it. It uses 95% of all serotonin in the body. And it uses other complex hormone signals and nerve signals to communicate with the brain and the rest of the body.

Normally a colon's job is to digest food, and to detect when a person gets sick. Harmful bacteria in rancid food create unexpected gas. So the colon has distension sensors that

can tell when there is unexpected gas pushing the colon walls out. Then the "second brain" tells the person to feel sick — they are having intestinal difficulties. In the case of bad food, this would involve stopping moving around. The person would sit groaning in the bathroom until the body eliminated the food. This is why doctors often recommend a total anesthesia or a partial "twilight" sedative to lessen the brain's awareness of the pain.

Once the colon has been inflated, the doctor inspects it with the scope on the way out, as it is slowly pulled backwards. If any polyps are found, they can be cut out at this point.

Some doctors prefer to work with totally anesthetized patients at this point, since the lack of pain being reported allows a leisurely examination. Whereas a doctor with a twilight sedated patient might hurry the inspection at this point, because of the groaning. However, twilight sedation is safer than general anesthesia. For this reason, it is generally better to request twilight sedation and ask the doctor to take his or her time, even if the patient groans.

The intensity of the pain may be correlated with the pressure of the air inside the colon. Doctors should use an air pump with a constant pressure source, not a constant volume source. Only enough air to maintain a particular pressure should be pumped into the colon.

Most other known physical means of distending the colon without pumping air in, introduces another physical contact into the system, with corresponding substantial increases in the probability of puncture. It is much safer, from a medical standpoint, to distend the colon with air, even if it does cause pain. The pain is transitory and can be borne.

Tens of millions of adults need to have colonoscopies each year, and yet many don't, because they are afraid of the pain.

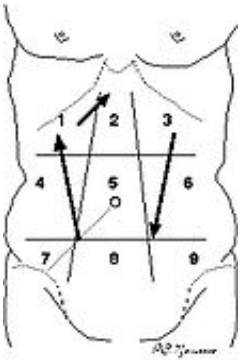
If pain is truly an issue, the patient can always request a general anesthetic. In the meantime, knowing that the pain comes from the colon being inflated, and not from the scope itself, makes the pain understandable and possibly more bearable. However, when the patient is under light anesthesia and unable to fully communicate his or her concerns or move, the intense, inescapable pain can be traumatizing, regardless of its source. It can also inhibit willingness to undergo future procedures.

It is worth noting that in many hospitals (for instance St. Mark's Hospital, London, which specialises in intestinal and colorectal medicine) colonoscopies are carried out without any sedation. This allows the patient to shift their body position to help the doctor carry out the procedure and significantly reduces recovery time and side-effects. Although there is some discomfort when the colon is distended with air this is not usually particularly painful and it passes relatively quickly. Patients can then be released from hospital on their own very swiftly without any feelings of nausea.

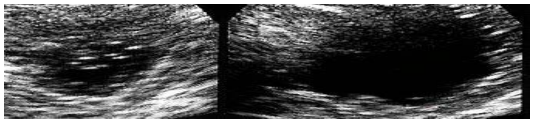
Ultrasound duodenography and ultrasound colonography

Duodenography and colonography are performed like a standard abdominal examination using B-mode and color flow Doppler ultrasonography using a low frequency transducer for example a 2.5 MHz and a high frequency transducer for example a 7.5 MHz probe. Detailed examination of duodenal walls and folds, colonic walls and haustra was performed using a 7.5 MHz probe. Deeply located abdominal structures were examined using 2.5 MHz probe. All ultrasound examinations are performed after overnight fasting (for at least 16 hours) using standard scanning procedure. Subjects are examined with and without water contrast. Water contrast imaging is performed by having adult subjects take at least one liter of water prior to examination. Patients are examined in the supine, left posterior oblique, and left lateral decubitus positions using the intercostal and subcostal approaches. The liver, gall bladder, spleen, pancreas, duodenum, colon, and kidneys are routinely evaluated in all patients. With patient lying supine, the examination of the duodenum with *high frequency ultrasound duodenography* is performed with 7.5 MHz probe placed in the right upper abdomen, and central epigastric successively; for *high frequency ultrasound colonography*, the ascending colon, is examined with starting point usually midway of an imaginary line running from the iliac crest to the umbilicus and proceeding cephalid through the right mid abdomen; for the descending colon, the examination begins from the left upper abdomen proceeding caudally and traversing the left mid abdomen and left lower abdomen, terminating at the sigmoid colon in the lower pelvic region. Color flow Doppler sonography is used to examine the localization of lesions in relation to vessels. All measurements of diameter and wall thickness are performed with built-in software. Measurements are taken between peristaltic waves.

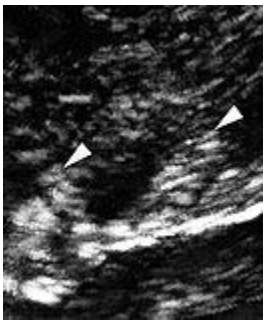
The abdominal quadrants scanned in the order.



The duodenal tri-band wall with folds of Kerckring, showing floaters with water contrast.



A high resolution view of colonic haustration.



Risks

This procedure has a low (0.35%) risk of serious complications.

According to a study published in the Annals of Internal Medicine, for which researchers reviewed colon cancer screening data from 1966 to 2001 the most severe complications from colonoscopy are perforation (that occurred in 0.38% of cases), heavy bleeding (occurring in 1.4% of colonoscopies) and death (occurring in 0.016% of colonoscopy patients).

The most serious complication generally is the gastrointestinal perforation, which is life-threatening and requires immediate major surgery for repair. An analysis of the relative risks of sigmoidoscopy and colonoscopy, published in the February 5, 2003 issue of the Journal of the National Cancer Institute brought into attention that the risk of perforation after colonoscopy is approximately double that after sigmoidoscopy, even though this difference appeared to be decreasing.

Bleeding complications may be treated immediately during the procedure by cauterization via the instrument. Delayed bleeding may also occur at the site of polyp removal up to a week after the procedure and a repeat procedure can then be performed to treat the bleeding site. Even more rarely, splenic rupture can occur after colonoscopy because of adhesions between the colon and the spleen.

As with any procedure involving anaesthesia, other complications would include cardiopulmonary complications such as a temporary drop in blood pressure, and oxygen saturation usually the result of overmedication, and are easily reversed. Anesthesia can also increase the risk of developing blood clots and lead to pulmonary embolism or deep venous thrombosis. (DVT) In rare cases, more serious cardiopulmonary events such as a heart attack, stroke, or even death may occur; these are extremely rare except in critically ill patients with multiple risk factors. In very rare cases, coma associated with anesthesia may occur. Virtual colonoscopies carry risks that are associated with radiation exposure.

Severe dehydration caused by the laxatives that are usually administered during the bowel preparation for colonoscopy also may occur. Therefore, patients must drink large amounts of fluids during the days of colonoscopy preparation to prevent dehydration. Loss of electrolytes or dehydration is potential risk that can even get deadly. In rare cases, severe dehydration can lead to kidney damage or renal dysfunction under the form of phosphate nephropathy.

Colonoscopy preparation and colonoscopy procedure can cause inflammation of the bowels and diarrhea or even bowel obstruction.

During colonoscopies where a polyp is removed (a polypectomy), the risk of complications has been higher, although still very uncommon, at about 2.3 percent. One of the most serious complications that may arise after colonoscopy is the postpolypectomy syndrome. This syndrome occurs due to potential burns to the bowel wall when the polyp is removed. It is however a very rare complication and as a result patients may experience fever and abdominal pain. The condition is treated with intravenous fluids and antibiotics while the patient is recommended to rest.

Bowel infections are a potential colonoscopy risk, although very rare. The colon is not a sterile environment as many bacteria live in the colon to assure the well-functioning of the bowel and therefore the risk of infections is very low. Infections can occur during biopsies when too much tissue is removed and bacteria protrude in areas they do not belong to or in cases when the lining of the colon is perforated and the bacteria get into the abdominal cavity. Infection may also be transmitted between patients if the colonoscope is not cleaned and sterilized properly between tests, although the risk of this happening is very low.

Minor colonoscopy risks may include nausea, vomiting or allergies to the sedatives that are used. If medication is given intravenously, the vein may become irritated. Most localized irritations to the vein leave a tender lump lasting a number of days but going away eventually. The incidence of these complications is less than 1%.

On very rare occasions, intracolonic explosion may occur.

High frequency ultrasound duodenography and colonography carry no risks associated with the procedures.

Although complications after colonoscopy are uncommon, it is important for patients to recognize early signs of any possible complications. They include severe abdominal pain, fevers and chills, or rectal bleeding (more than half a cup).

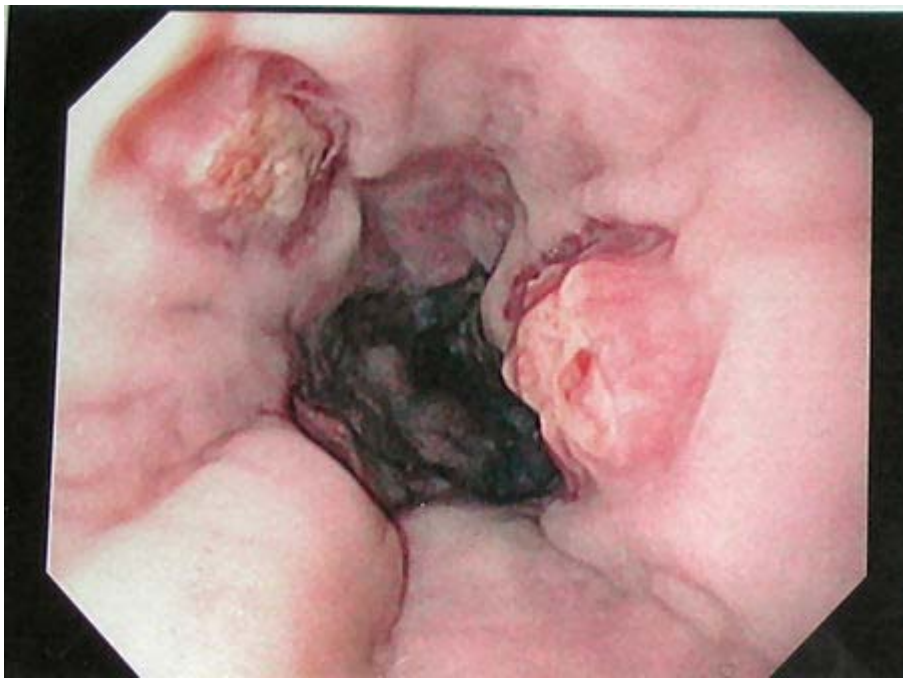
Results

A recent study published in the *Annals of Internal Medicine* implies that colonoscopy screening prevents approximately two thirds of the deaths due to colorectal cancers on the left side of the colon, and is not associated with a significant reduction in deaths from right-sided disease. This study examined people with colon cancer diagnosed between 1996 and 2001 in Ontario who died of colon cancer by 2003, and hence studied colonoscopies done in the early to mid 1990s. (Since the procedure continues to evolve, more recent colonoscopies may be more effective). The summary result, according to table 3 of the report, show approximately a 37% reduction in the death rate from colorectal cancer, with a significantly lower reduction in death for "incomplete" colonoscopies.

Chapter 19

Esophagogastroduodenoscopy

Intervention:
Esophagogastroduodenoscopy



Endoscopic still of esophageal ulcers seen after banding of esophageal varices, at time of esophagogastroduodenosocopy

ICD-10 code:
ICD-9 code: 45.13
MeSH D016145
Other codes:

In medicine (gastroenterology), **esophagogastroduodenoscopy** is a diagnostic endoscopic procedure that visualizes the upper part of the gastrointestinal tract up to the duodenum. It is considered a minimally invasive procedure since it does not require an incision into one of the major body cavities and does not require any significant recovery after the procedure (unless sedation or anesthesia has been used). A sore throat is also common.

Alternative names

Esophagogastroduodenoscopy may be abbreviated **EGD**, or **OGD** if one uses the British spelling **oesophagogastroduodenoscopy**. It is also called **upper GI endoscopy** (UGIE), **gastroscopy** or simply endoscopy (since it is the most commonly performed type of endoscopy, the ambiguous term 'endoscopy' refers to EGD by default).

Indications

Diagnostic

- Unexplained anemia (usually along with a colonoscopy)
- Upper gastrointestinal bleeding as evidenced by hematemesis or melena
- Persistent dyspepsia in patients over the age of 40–45 years
- Heartburn and chronic acid reflux - this can lead to a precancerous lesion called Barrett's esophagus
- Persistent vomiting
- Dysphagia - difficulty in swallowing
- Odynophagia - painful swallowing

Surveillance

- Surveillance of Barrett's esophagus
- Surveillance of gastric ulcer or duodenal ulcer
- Occasionally after gastric surgery

Confirmation of diagnosis/biopsy

- Abnormal barium swallow or barium meal
- Confirmation of celiac disease (via biopsy)

Therapeutic

- Treatment (banding/sclerotherapy) of esophageal varices
- Injection therapy (e.g. epinephrine in bleeding lesions)
- Cutting off of larger pieces of tissue with a snare device (e.g. polyps, endoscopic mucosal resection)
- Application of cautery to tissues
- Removal of foreign bodies (e.g. food) that have been ingested
- Tamponade of bleeding esophageal varices with a balloon
- Application of photodynamic therapy for treatment of esophageal malignancies
- Endoscopic drainage of pancreatic pseudocyst
- Tightening the lower esophageal sphincter
- Dilating or stenting of stenosis or achalasia
- Percutaneous endoscopic gastrostomy (feeding tube placement)

- Endoscopic retrograde cholangiopancreatography (ERCP) combines EGD with fluoroscopy
- Endoscopic ultrasound (EUS) combines EGD with 5–12 MHz ultrasound imaging

Newer interventions

- Endoscopic trans-gastric laparoscopy
- Placement of gastric balloons in bariatric surgery

Equipment

- Endoscope
  - Non-coaxial optic fiber system to carry light to the tip of the endoscope
  - A chip camera at the tip of the endoscope - this has now replaced the coaxial optic fibers of older scopes that were prone to damage and consequent loss of picture quality
  - Irrigation channel to clean the lens
  - Suction/Insufflation/Working channels - these may be in the form of one or more channels
  - Control handle - this houses the controls
- Stack
  - Light source
  - Insufflator
  - Suction
  - Electrosurgical unit
  - Video recorder/photo printer
- Instruments
  - Biopsy forceps
  - Snares
  - Injecting needles

Procedure

The patient is kept NPO (Nil per os) or NBM (Nothing By Mouth) that is, told not to eat, for at least 4–6 hours before the procedure. Most patients tolerate the procedure with only topical anesthesia of the oropharynx using lidocaine spray. However, some patients may need sedation and the very anxious/agitated patient may even need a general anesthetic. Informed consent is obtained before the procedure. The main risks are bleeding and perforation. The risk is increased when a biopsy or other intervention is performed.

The patient lies on his/her left side with the head resting comfortably on a pillow. A mouth-guard is placed between the teeth to prevent the patient from biting on the endoscope. The endoscope is then passed over the tongue and into the oropharynx. This is the most uncomfortable stage for the patient. Quick and gentle manipulation under vision guides the endoscope into the esophagus. The endoscope is gradually advanced down the esophagus making note of any pathology. Excessive insufflation of the stomach

is avoided at this stage. The endoscope is quickly passed through the stomach and through the pylorus to examine the first and second parts of the duodenum. Once this has been completed, the endoscope is withdrawn into the stomach and a more thorough examination is performed including a J-maneuver. This involves retroflexing the tip of the scope so it resembles a 'J' shape in order to examine the fundus and gastroesophageal junction. Any additional procedures are performed at this stage. The air in the stomach is aspirated before removing the endoscope. Still photographs can be made during the procedure and later shown to the patient to help explain any findings.

In its most basic use, the endoscope is used to *inspect* the internal anatomy of the digestive tract. Often inspection alone is sufficient, but biopsy is a very valuable adjunct to endoscopy. Small biopsies can be made with a pincer (biopsy forceps) which is passed through the scope and allows sampling of 1 to 3 mm pieces of tissue under direct vision. The intestinal mucosa heals quickly from such biopsies.

Biopsy allows the pathologist to render an opinion on later histologic examination of the biopsy tissue with light microscopy and/or immunohistochemistry. Biopsied material can also be tested on urease to identify *Helicobacter pylori*.

Complications

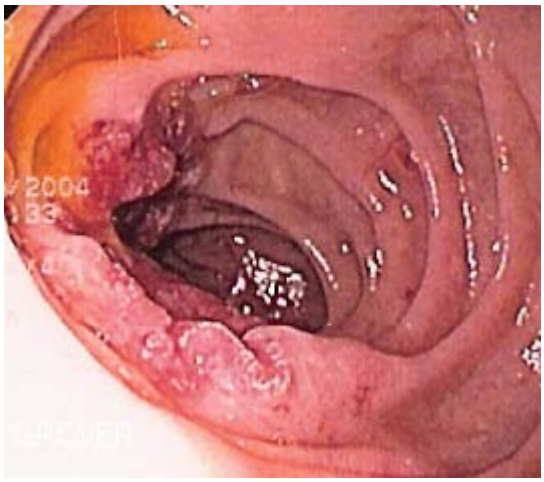
The complication rate is about 1 in 1000. They include:

- aspiration, causing aspiration pneumonia
- bleeding
- perforation
- cardiopulmonary problems

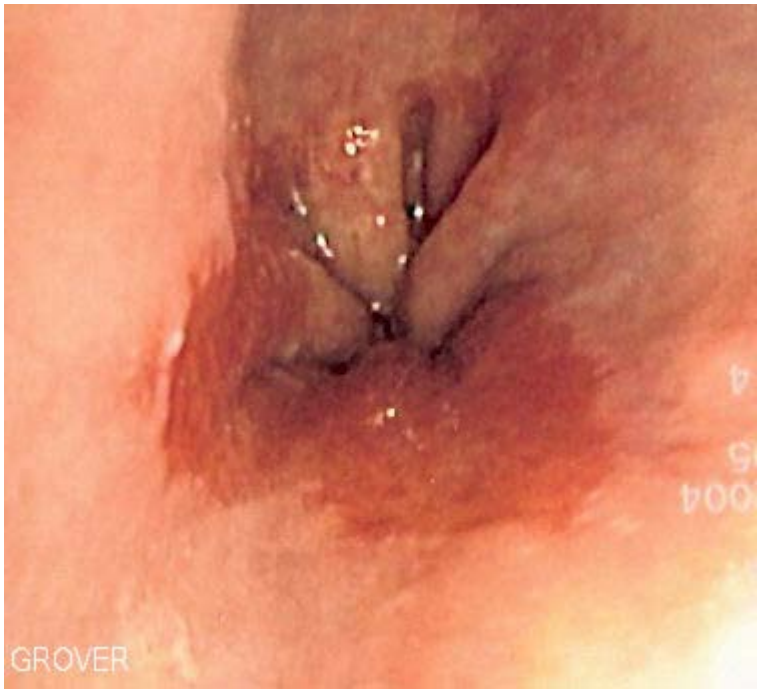
Limitations

Problems of gastrointestinal *function* are usually not well diagnosed by endoscopy since *motion* or *secretion* of the gastrointestinal tract are not easily inspected by EGD. Nonetheless, findings such as excess fluid or poor motion of gut during endoscopy can be suggestive of disorders of function. Irritable bowel syndrome and functional dyspepsia is not diagnosed with EGD, but EGD may be helpful in excluding other diseases that mimic these common disorders.

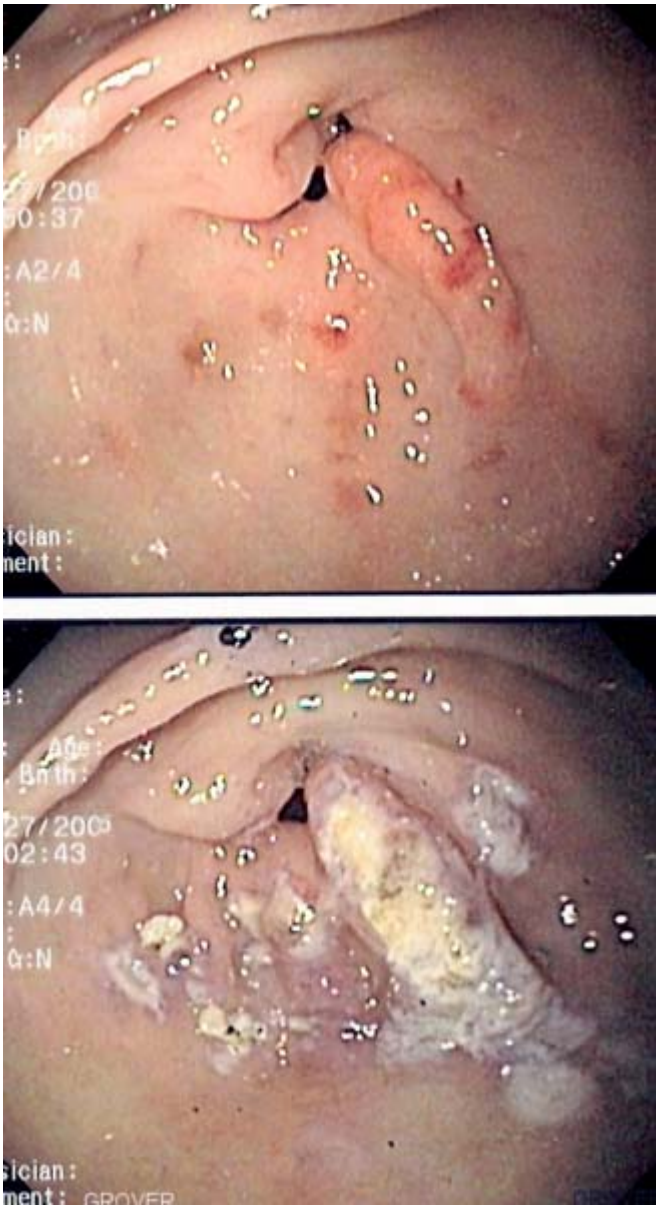
Additional images



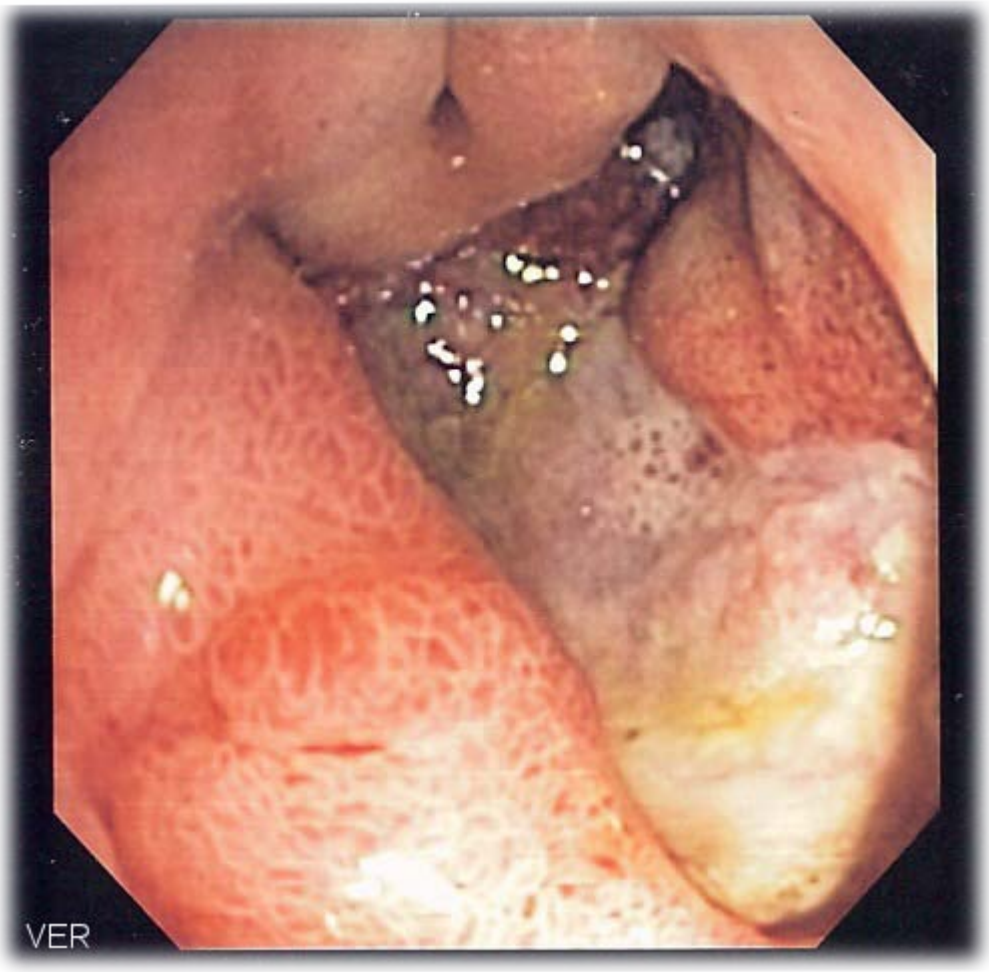
Endoscopic image of adenocarcinoma of duodenum seen in the post-bulbar duodenum



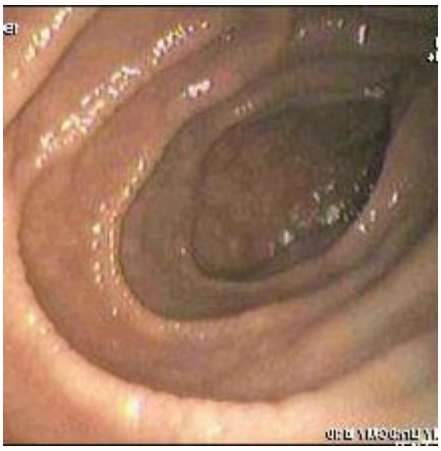
Endoscopic image of Barrett's esophagus, which is the area of red mucosa projecting like a tongue.



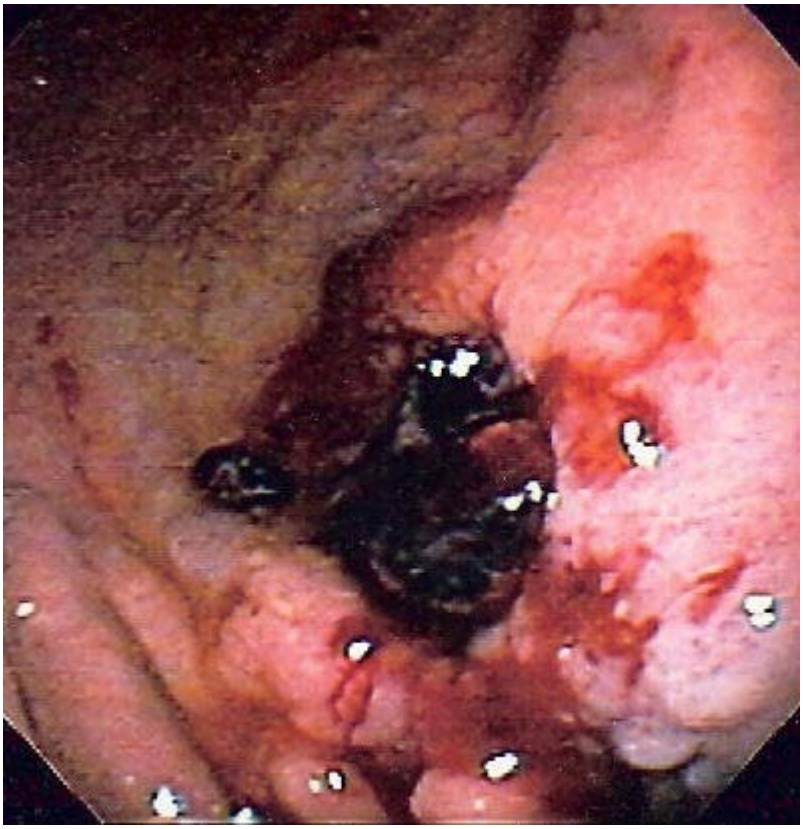
Endoscopic image of gastric antral vascular ectasia seen as a radial pattern around the pylorus before (top) and after (bottom) treatment with argon plasma coagulation



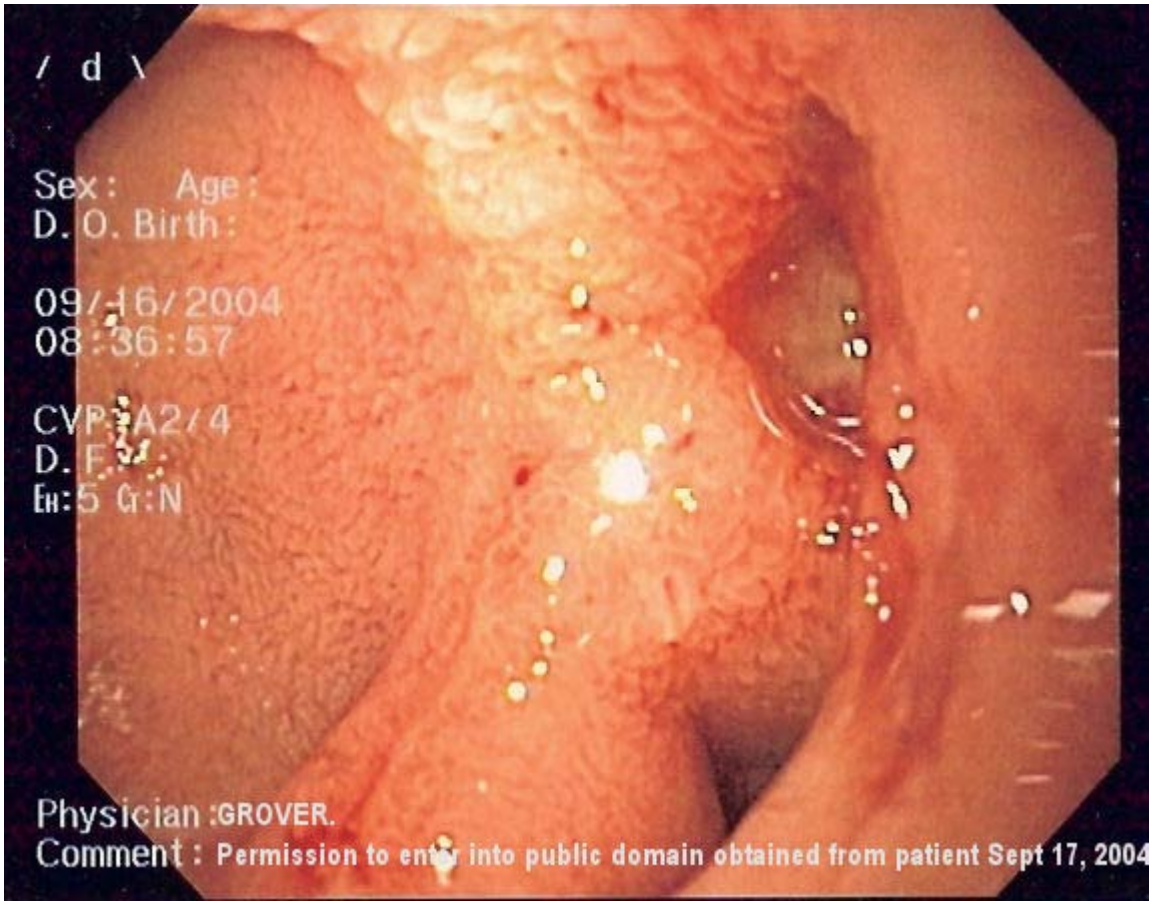
Deep gastric ulcer



Endoscopic still of duodenum of patient with celiac disease showing scalloping of folds



Gastric ulcer in antrum of stomach with overlying clot due to gastric lymphoma



Endoscopic image of a posterior wall duodenal ulcer with a clean base, which is a common cause of upper GI hemorrhage.

Chapter 20

Evoked Potential

An **evoked potential** (or "evoked response") is an electrical potential recorded from the nervous system of a human or other animal following presentation of a stimulus, as distinct from spontaneous potentials as detected by electroencephalography (EEG) or electromyography (EMG).

Evoked potential amplitudes tend to be low, ranging from less than a microvolt to several microvolts, compared to tens of microvolts for EEG, millivolts for EMG, and often close to a volt for ECG. To resolve these low-amplitude potentials against the background of ongoing EEG, ECG, EMG and other biological signals and ambient noise, signal averaging is usually required. The signal is time-locked to the stimulus and most of the noise occurs randomly, allowing the noise to be averaged out with averaging of repeated responses.

Signals can be recorded from cerebral cortex, brain stem, spinal cord and peripheral nerves. Usually the term "evoked potential" is reserved for responses involving either recording from, or stimulation of, central nervous system structures. Thus evoked compound motor action potentials (CMAP) or sensory nerve action potentials (SNAP) as used in nerve conduction studies (NCS) are generally not thought of as evoked potentials, though they do meet the above definition.

Sensory evoked potentials

Sensory evoked potentials (SEP) are recorded from the central nervous system following stimulation of sense organs (for example, visual evoked potentials elicited by a flashing light or changing pattern on a monitor; auditory evoked potentials by a click or tone stimulus presented through earphones) or by tactile or somatosensory evoked potential (SSEP) elicited by tactile or electrical stimulation of a sensory or mixed nerve in the periphery. They have been widely used in clinical diagnostic medicine since the 1970s, and also in intraoperative neurophysiology monitoring (IONM), also known as surgical neurophysiology.

There are three kinds of evoked potentials in widespread clinical use: auditory evoked potentials, usually recorded from the scalp but originating at brainstem level; visual evoked potentials, and somatosensory evoked potentials, which are elicited by electrical stimulation of peripheral nerve.

Long and Allen reported the abnormal BAEPs in an alcoholic woman who recovered from Ondine's curse. These investigators hypothesized that their patient's brainstem was poisoned, but not destroyed, by her chronic alcoholism.

Steady-state evoked potential

An evoked potential is the electrical response of the brain to a sensory stimulus. Regan constructed an analogue Fourier series analyzer to record harmonics of the evoked potential to flickering (sinusoidally modulated) light but, rather than integrating the sine and cosine products, fed them to a two-pen recorder via lowpass filters. This allowed him to demonstrate that the brain attained a steady-state regime in which the amplitude and phase of the harmonics (frequency components) of the response were approximately constant over time. By analogy with the steady-state response of a resonant circuit that follows the initial transient response he defined an idealized steady-state evoked potential (SSEP) as a form of response to repetitive sensory stimulation in which the constituent frequency components of the response remain constant with time in both amplitude and phase. Although this definition implies a series of identical temporal waveforms, it is more helpful to define the SSEP in terms of the frequency components that are an alternative description of the time-domain waveform, because different frequency components can have quite different properties For example, the properties of the high-frequency flicker SSEP (whose peak amplitude is near 40–50 Hz) correspond to the properties of the subsequently discovered magnocellular neurons the retina of the macaque monkey, while the properties of the medium-frequency flicker SSEP (whose amplitude peak is near 15–20 Hz) correspond to the properties of parvocellular neurons. Since a SSEP can be completely described in terms of the amplitude and phase of each frequency component it can be quantified more unequivocally than an averaged transient evoked potential.

It is sometimes said that SSEPs are elicited only by stimuli of high repetition frequency, but this is not generally correct. In principle, a sinusoidally modulated stimulus can elicit a SSEP even when its repetition frequency is low. Because of the high-frequency rolloff of the SSEP, high frequency stimulation can produce a near-sinusoidal SSEP waveform , but this is not germane to the definition of a SSEP. By using zoom-FFT to record SSEPs at the theoretical limit of spectral resolution ΔF (where ΔF in Hz is the reciprocal of the recording duration in seconds) Regan and Regan discovered that the amplitude and phase variability of the SSEP can be sufficiently small that the bandwidth of the SSEP's constituent frequency components can be at the theoretical limit of spectral resolution up to at least a 500 second recording duration (0.002 Hz in this case). Repetitive sensory stimulation elicits a steady-state magnetic brain response that can be analysed in the same way as the SSEP.

The "simultaneous stimulation" technique

This technique allows several (e.g. four) SSEPs to be recorded simultaneously from any given location on the scalp. Different sites of stimulation or different stimuli can be tagged with slightly different frequencies that are virtually identical to the brain, but

easily separated by Fourier series analyzers. For example, when two unpatterned lights are modulated at slightly different frequencies (F1 and F2) and superimposed, multiple nonlinear cross-modulation components of frequency (mF1 ± nF2) are created in the SSEP, where m and n are integers. These components allow nonlinear processing in the brain to be investigated. By frequency-tagging two superimposed gratings, spatial frequency and orientation tuning properties of the brain mechanisms that process spatial form can be isolated and studied. Stimuli of different sensory modalities can also be tagged. For example, a visual stimulus was flickered at Fv Hz and a simultaneously-presented auditory tone was amplitude modulated at Fa Hz. The existence of a (2Fv + 2Fa) component in the evoked magnetic brain response demonstrated an audio-visual convergence area in the human brain, and the distribution of this response over the head allowed this brain area to be localized. More recently, frequency tagging has been extended from studies of sensory processing to studies of selective attention and of consciousness.

The “sweep” technique

The sweep technique is a hybrid frequency domain/time domain technique. A plot of, for example, response amplitude versus the check size of a stimulus checkerboard pattern plot can be obtained in 10 seconds, far faster than when time-domain averaging is used to record an evoked potential for each of several check sizes. In the original demonstration of the technique the sine and cosine products were fed through lowpass filters (as when recording a SSEP) while viewing a pattern of fine checks whose black and white squares exchanged place six times per second. Then the size of the squares was progressively increased so as to give a plot of evoked potential amplitude versus check size (hence “sweep”). Subsequent authors have implemented the sweep technique by using computer software to increment the spatial frequency of a grating in a series of small steps and to compute a time-domain average for each discrete spatial frequency. A single sweep may be adequate or it may be necessary to average the graphs obtained in several sweeps with the averager triggered by the sweep cycle. Averaging 16 sweeps can improve the signal-to-noise ratio of the graph by a factor of four. The sweep technique has proved useful in measuring rapidly-adapting visual processes and also for recording from babies, where recording duration is necessarily short. Norcia and Tyler have used the technique to document the development of visual acuity and contrast sensitivity through the first years of life. They have emphasized that, in diagnosing abnormal visual development, the more precise the developmental norms, the more sharply can the abnormal be distinguished from the normal, and to that end have documented normal visual development in a large group of infants. For many years the sweep technique has been used in paediatric ophthalmology (electrodiagnosis) clinics Worldwide.

Evoked potential feedback

This technique allows the SSEP to directly control the stimulus that elicits the SSEP without the conscious intervention of the experimental subject. For example, the running average of the SSEP can be arranged to increase the luminance of a checkerboard stimulus if the amplitude of the SSEP falls below some predetermined value, and to

decrease luminance if it rises above this value. The amplitude of the SSEP then hovers about this predetermined value. Now the wavelength (colour) of the stimulus is progressively changed. The resulting plot of stimulus luminance versus wavelength is a plot of the spectral sensitivity of the visual system.

Visual evoked potential

Visual evoked potentials (VEPs) are described by O'Shea et al. (2009). They are caused by sensory stimulation of a subject's visual field and are observed using electroencephalography. Commonly used visual stimuli are flashing lights, or checkerboards on a video screen that flicker between black on white to white on black (invert contrast). The resulting waveform includes the C1 and P1 followed by the visual N1.

Visual evoked potentials are very useful in detecting blindness in patients that cannot communicate, such as babies or animals. If repeated stimulation of the visual field causes no changes in EEG potentials, then the subject's brain is probably not receiving any signals from his/her eyes. Other applications include the diagnosis of optic neuritis, which causes the signal to be delayed. Such a delay is also a classic finding in Multiple Sclerosis. Visual evoked potentials are furthermore used in the investigation of basic functions of visual perception. VEPs are also sometimes used to determine if someone is fraudulently alleging blindness.

The term "visual evoked potential" is used interchangeably with "visually evoked potential". It usually refers to responses recorded from the occipital cortex. Sometimes, the term "visual evoked cortical potential" (VECP) is used to distinguish the VEP from retinal or subcortical potentials.

The **multifocal VEP** is used to record separate responses for visual field locations.

Some specific VEPs are:

- Sweep visual evoked potential
- Binocular visual evoked potential
- Chromatic visual evoked potential
- Hemi-field visual evoked potential
- Flash visual evoked potential
- LED Goggle visual evoked potential
- Motion visual evoked potential
- Multifocal visual evoked potential
- Multi-channel visual evoked potential
- Multi-frequency visual evoked potential
- Stereo-elicited visual evoked potential

Auditory evoked potential

Auditory evoked potential can be used to trace the signal generated by a sound through the ascending auditory pathway. The evoked potential is generated in the cochlea, goes through the cochlear nerve, through the cochlear nucleus, superior olivary complex, lateral lemniscus, to the inferior colliculus in the midbrain, on to the medial geniculate body, and finally to the cortex.

Auditory evoked potentials (AEPs) are a subclass of event-related potentials (ERP)s. ERPs are brain responses that are time-locked to some “event”, such as a sensory stimulus, a mental event (such as recognition of a target stimulus), or the omission of a stimulus. For AEPs, the “event” is a sound. AEPs (and ERPs) are very small electrical voltage potentials originating from the brain recorded from the scalp in response to an auditory stimulus, such as different tones, speech sounds, etc.

Somatosensory evoked potential

Somatosensory Evoked Potentials (SSEPs) are used in neuromonitoring to assess the function of a patient's spinal cord during surgery. They are recorded by stimulating peripheral nerves, most commonly the tibial nerve, median nerve or ulnar nerve, typically with an electrical stimulus. The response is then recorded from the patient's scalp.

Because of the low amplitude of the signal once it reaches the patient's scalp and the relatively high amount of electrical noise caused by background EEG, scalp muscle EMG or electrical devices in the room, the signal must be averaged. The use of averaging improves the signal-to-noise ratio. Typically, in the operating room, over 100 and up to 1,000 averages must be used to adequately resolve the evoked potential.

The two most looked at aspects of an SSEP are the amplitude and latency of the peaks. The most predominant peaks have been studied and named in labs. Each peak is given a letter and a number in its name. For example, N20 refers to a negative peak (N) at 20ms. This peak is recorded from the cortex when the median nerve is stimulated. It most likely corresponds to the signal reaching the somatosensory cortex. When used in intraoperative monitoring, the latency and amplitude of the peak relative to the patient's post-intubation baseline is a crucial piece of information. Dramatic increases in latency or decreases in amplitude are indicators of neurological dysfuncion.

During surgery, the large amounts of anesthetic gases used can affect the amplitude and latencies of SSEPs. Any of the halogenated agents or nitrous oxide will increase latencies and decrease amplitudes of responses, sometimes to the point where a response can no longer be detected. For this reason, an anesthetic utilizing less halogenated agent and more intravenous hypnotic and narcotic is typically used.

Intraoperative monitoring

Somatosensory evoked potentials provide monitoring for the dorsal columns of the spinal cord. Sensory evoked potentials may also be used during surgeries which place brain structures at risk. They are effectively used to determine cortical ischemia during carotid endarterectomy surgeries and for mapping the sensory areas of the brain during brain surgery.

Electrical stimulation of the scalp can produce an electrical current within the brain that activates the motor pathways of the pyramidal tracts. This technique is known as transcranial electrical motor potential (TcMEP) monitoring. This technique effectively evaluates the motor pathways in the central nervous system during surgeries which place these structures at risk. These motor pathways, including the lateral corticospinal tract, are located in the lateral and ventral funiculi of the spinal cord. Since the ventral and dorsal spinal cord have separate blood supply with very limited collateral flow, an anterior cord syndrome (paralysis or paresis with some preserved sensory function) is a possible surgical sequela, so it is important to have monitoring specific to the motor tracts as well as dorsal column monitoring.

Transcranial magnetic stimulation versus electrical stimulation is generally regarded as unsuitable for intraoperative monitoring because it is more sensitive to anesthesia. Electrical stimulation is too painful for clinical use in awake patients. The two modalities are thus complementary, electrical stimulation being the choice for intraoperative monitoring, and magnetic for clinical applications.

Motor evoked potentials

Motor evoked potentials (MEP) are recorded from muscles following direct stimulation of exposed motor cortex, or transcranial stimulation of motor cortex, either magnetic or electrical. Transcranial magnetic MEP (TCmMEP) potentially offer clinical diagnostic applications. Transcranial electrical MEP (TCeMEP) has been in widespread use for several years for intraoperative monitoring of pyramidal tract functional integrity.

During the 1990s there were attempts to monitor "motor evoked potentials", including "neurogenic motor evoked potentials" recorded from peripheral nerves, following direct electrical stimulation of the spinal cord. It has become clear that these "motor" potentials were almost entirely elicited by antidromic stimulation of sensory tracts—even when the recording was from muscles (antidromic sensory tract stimulation triggers myogenic responses through synapses at the root entry level). TCMEP, whether electrical or magnetic, is the most practical way to ensure pure motor responses, since stimulation of sensory cortex cannot result in descending impulses beyond the first synapse (synapses cannot be backfired).

Chapter 21

Magnetoencephalography

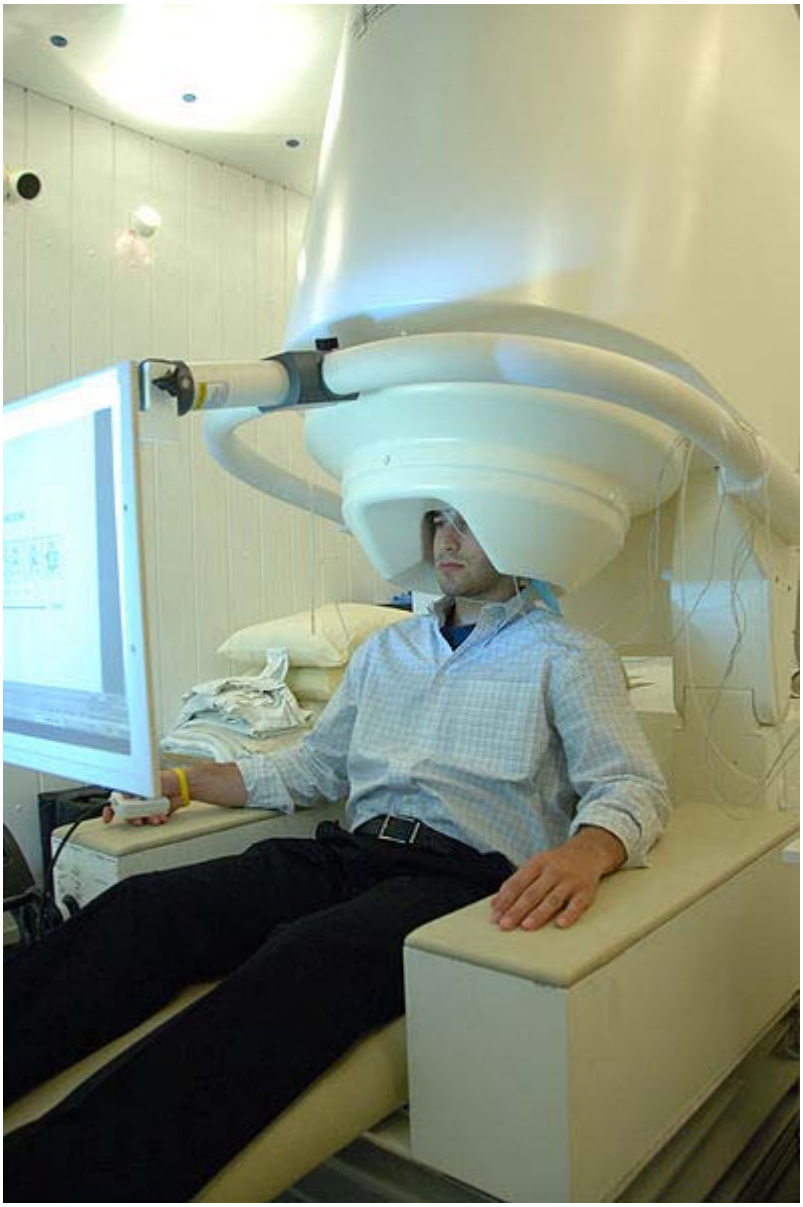
Magnetoencephalography (**MEG**) is a technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain, using arrays of SQUIDs (superconducting quantum interference devices). Applications of MEG include basic research into perceptual and cognitive brain processes, localizing regions affected by pathology before surgical removal, determining the function of various parts of the brain, and neurofeedback.

History of MEG

MEG signals were first measured by University of Illinois physicist David Cohen in 1968, before the availability of the SQUID, using a copper induction coil as the detector. To reduce the magnetic background noise, the measurements were made in a magnetically shielded room. The coil detector was barely sensitive enough, resulting in poor, noisy MEG measurements that were difficult to use. Later, Cohen built a better shielded room at MIT, and used one of the first SQUID detectors, just developed by James E. Zimmerman, a researcher at Ford Motor Company, to again measure MEG signals. This time the signals were almost as clear as those of EEG. This stimulated the interest of physicists who had been looking for uses of SQUIDs. Subsequently, various types of spontaneous and evoked MEGs began to be measured.

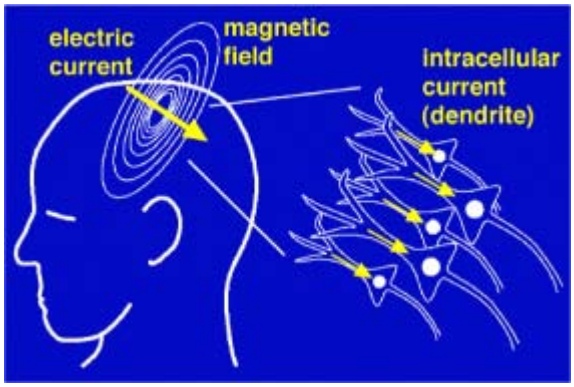
At first, a single SQUID detector was used to successively measure the magnetic field at a number of points around the subject's head. This was cumbersome, and in the 1980s, MEG manufacturers began to arrange multiple sensors into arrays to cover a larger area of the head. Present-day MEG arrays are set in helmet-shaped dewar that typically contain 300 sensors, covering most of the head. In this way, MEGs of a subject or patient can now be accumulated rapidly and efficiently.

The basis of the MEG signal



Patient undergoing an MEG

Synchronized neuronal currents induce weak magnetic fields. At 10 femtotesla (fT) for cortical activity and 10^3 fT for the human alpha rhythm, the brain's magnetic field is considerably smaller than the ambient magnetic noise in an urban environment, which is on the order of 10^8 fT or 0.1 μT. The essential problem of biomagnetism is thus the weakness of the signal relative to the sensitivity of the detectors, and to the competing environmental noise.



Origin of the brain's magnetic field. The electric current also produces the EEG signal.

The MEG (and EEG) signals derive from the net effect of ionic currents flowing in the dendrites of neurons during synaptic transmission. In accordance with Maxwell's equations, any electrical current will produce an orthogonally oriented magnetic field. It is this field which is measured. The net currents can be thought of as electric dipoles, i.e. currents with a position, orientation, and magnitude, but no spatial extent. According to the right-hand rule, a current dipole gives rise to a magnetic field that flows around the axis of its vector component.

To generate a signal that is detectable, approximately 50,000 active neurons are needed. Since current dipoles must have similar orientations to generate magnetic fields that reinforce each other, it is often the layer of pyramidal cells, which are situated perpendicular to the cortical surface, that give rise to measurable magnetic fields. Bundles of these neurons that are orientated tangentially to the scalp surface project measurable portions of their magnetic fields outside of the head, and these bundles are typically located in the sulci. Researchers are experimenting with various signal processing methods in the search for methods that detect deep brain (i.e., non-cortical) signal, but no clinically useful method is currently available.

It is worth noting that action potentials do not usually produce an observable field, mainly because the currents associated with action potentials flow in opposite directions and the magnetic fields cancel out. However, action fields have been measured from peripheral nerves.

Magnetic shielding

Since the magnetic signals emitted by the brain are on the order of a few femtoteslas, shielding from external magnetic signals, including the Earth's magnetic field, is necessary. Appropriate magnetic shielding can be obtained by constructing rooms made of aluminium and mu-metal for reducing high-frequency and low-frequency noise, respectively.

Entrance to MSR, showing the separate shielding layers

Magnetically shielded room (MSR)

A magnetically shielded room (MSR) model consists of three nested main layers. Each of these layers is made of a pure aluminium layer, plus a high permeability ferromagnetic layer, similar in composition to molybdenum permalloy. The ferromagnetic layer is supplied as 1 mm sheets, while the innermost layer is composed of four sheets in close contact, and the outer two layers are composed of three sheets each. Magnetic continuity is maintained by overlay strips. Insulating washers are used in the screw assemblies to ensure that each main layer is electrically isolated. This helps eliminate radio frequency radiation, which would degrade SQUID performance. Electrical continuity of the aluminium is also maintained by aluminium overlay strips to ensure AC eddy-current shielding, which is important at frequencies greater than 1 Hz. The junctions of the inner layer are often electroplated with silver or gold to improve conductivity of the aluminium layers.

Active shielding system

Active systems are designed for three dimensional noise cancellation. To implement an active system, low-noise fluxgate magnetometers are mounted at the center of each surface and oriented orthogonally to it. This negatively feeds a DC amplifier through a low-pass network with a slow falloff to minimize positive feedback and oscillation. Built into the system are shaking and degaussing wires. Shaking wires increase the magnetic permeability, while the permanent degaussing wires are applied to all surfaces of the inner main layer to degauss the surfaces. Moreover, noise cancellation algorithms can reduce both low-frequency and high-frequency noise. Modern systems have a noise floor of around 2–3 $fT/Hz^{0.5}$ above 1 Hz.

Source localization

The inverse problem

The challenge posed by MEG is to determine the location of electric activity within the brain from the induced magnetic fields outside the head. Problems such as this, where model parameters (the location of the activity) have to be estimated from measured data (the SQUID signals) are referred to as *inverse problems* (in contrast to *forward problems* where the model parameters (e.g. source location) are known and the data (e.g. the field at a given distance) is to be estimated.) The primary difficulty is that the inverse problem does not have a unique solution (i.e., there are infinite possible "correct" answers), and the problem of defining the "best" solution is itself the subject of intensive research. Possible solutions can be derived using models involving prior knowledge of brain activity.

The source models can be either over-determined or under-determined. An over-determined model may consist of a few point-like sources ("equivalent dipoles"), whose locations are then estimated from the data. Under-determined models may be used in cases where many different distributed areas are activated ("distributed source solutions"): there are infinitely many possible current distributions explaining the measurement results, but the most likely is selected. Localization algorithms make use of given source and head models to find a likely location for an underlying focal field generator.

Localization algorithms using overdetermined models operate by expectation-maximization: the system is initialized with a first guess. A loop is started, in which a forward model is used to simulate the magnetic field that would result from the current guess. The guess is adjusted to reduce the discrepancy between the simulated field and the measured field. This process is iterated until convergence.

The extent to which the constraint-free MEG inverse problem is ill-posed cannot be overemphasized. If one's goal is to estimate the current density within the human brain with say a 5mm resolution then it is well established that the vast majority of the information needed to perform a unique inversion must come not from the magnetic field measurement but rather from the constraints applied to the problem. Furthermore, even when a unique inversion is possible in the presence of such constraints said inversion can be unstable. These conclusions are easily deduced from published works.

Magnetic source imaging

The estimated source locations can be combined with magnetic resonance imaging (MRI) images to create magnetic source images (MSI). The two sets of data are combined by measuring the location of a common set of fiducial points marked during MRI with lipid markers and marked during MEG with electrified coils of wire that give off magnetic fields. The locations of the fiducial points in each data set are then used to define a

common coordinate system so that superimposing the functional MEG data onto the structural MRI data ("coregistration") is possible.

A criticism of the use of this technique in clinical practice is that it produces colored areas with definite boundaries superimposed upon an MRI scan: the untrained viewer may not realize that the colors do not represent a physiological certainty, because of the relatively low spatial resolution of MEG, but rather a probability cloud derived from statistical processes. However, when the magnetic source image corroborates other data, it can be of clinical utility.

Dipole model source localization

A widely accepted source-modeling technique for MEG involves calculating a set of equivalent current dipoles (ECDs), which assumes the underlying neuronal sources to be focal. This dipole fitting procedure is non-linear and over-determined, since the number of unknown dipole parameters is smaller than the number of MEG measurements. Automated multiple dipole model algorithms such as MUSIC (MUltiple SIgnal Classification) and MSST (MultiStart Spatial and Temporal) modeling are applied to the analysis of MEG responses. The limitations of dipole models for characterizing neuronal responses are (1) difficulties in localizing extended sources with ECDs, (2) problems with accurately estimating the total number of dipoles in advance, and (3) dependency on dipole location, especially depth in the brain.

Distributed Source Models

Unlike multiple-dipole modeling, distributed source models divide the source space into a grid containing a large number of dipoles. The inverse problem is to obtain the dipole moments for the grid nodes. As the number of unknown dipole moments is much greater than the number of MEG sensors, the inverse solution is highly underdetermined, so additional constraints are needed to reduce ambiguity of the solution. The primary advantage of this approach is that no prior specification of the source model is necessary. However, the resulting distributions may be difficult to interpret, because they only reflect a "blurred" (or even distorted) image of the true neuronal source distribution. The matter is complicated by the fact that spatial resolution depends strongly on several parameters such as brain area, depth, orientation, number of sensors etc.

Independent component analysis (ICA)

Independent component analysis (ICA) is another signal processing solution that separates different signals that are statistically independent in time. It is primarily used to remove artifacts such as blinking, eye muscle movement, facial muscle artifacts, cardiac artifacts, etc. from MEG and EEG signals that may be contaminated with outside noise. However, ICA has poor resolution of highly correlated brain sources.

MEG use in the field

In research, MEG's primary use is the measurement of time courses of activity. MEG can resolve events with a precision of 10 milliseconds or faster, while functional MRI (fMRI), which depends on changes in blood flow, can at best resolve events with a precision of several hundred milliseconds. MEG also accurately pinpoints sources in primary auditory, somatosensory and motor areas. For creating functional maps of human cortex during more complex cognitive tasks, MEG is most often combined with fMRI, as the methods complement each other. Neuronal (MEG) and hemodynamic (fMRI) data do not necessarily agree, in spite of the tight relationship between local field potentials (LFP) and blood oxygenation level dependent (BOLD) signals. MEG and BOLD signals may originate from the same source (though the BOLD signals are filtered through the hemodynamic response).

Recent studies have reported successful classification of patients with multiple sclerosis, Alzheimer's disease, schizophrenia, Sjögren's syndrome, chronic alcoholism, and facial pain. MEG can be used to distinguish these patients from healthy control subjects, suggesting a future role of MEG in diagnostics.

Focal epilepsy

The clinical uses of MEG are in detecting and localizing pathological activity in patients with epilepsy, and in localizing eloquent cortex for surgical planning in patients with brain tumors or intractable epilepsy. The goal of epilepsy surgery is to remove the epileptogenic tissue while sparing healthy brain areas. Knowing the exact position of essential brain regions (such as the primary motor cortex and primary sensory cortex, visual cortex, and areas involved in speech production and comprehension) helps to avoid surgically induced neurological deficits. Direct cortical stimulation and somatosensory evoked potentials recorded on ECoG are considered the gold standard for localizing essential brain regions. These procedures can be performed either intraoperatively or from chronically indwelling subdural grid electrodes. Both are invasive.

Noninvasive MEG localizations of the central sulcus obtained from somatosensory evoked magnetic fields show strong agreement with these invasive recordings. MEG studies assist in clarification of the functional organization of primary somatosensory cortex and to delineate the spatial extent of hand somatosensory cortex by stimulation of the individual digits. This agreement between invasive localization of cortical tissue and MEG recordings shows the effectiveness of MEG analysis and indicates that MEG may substitute invasive procedures in the future.

Fetal MEG

MEG has been used to study cognitive processes such as vision, audition and language processing in fetuses and newborns.

Comparison with related techniques

MEG has been in development since the 1960s but has been greatly aided by recent advances in computing algorithms and hardware, and promises improved spatial resolution coupled with extremely high temporal resolution (better than 1 ms). Since the MEG signal is a direct measure of neuronal activity, its temporal resolution is comparable with that of intracranial electrodes.

MEG complements other brain activity measurement techniques such as electroencephalography (EEG), positron emission tomography (PET), and fMRI. Its strengths consist in independence of head geometry compared to EEG (unless ferromagnetic implants are present) and non-invasiveness, as opposed to PET.

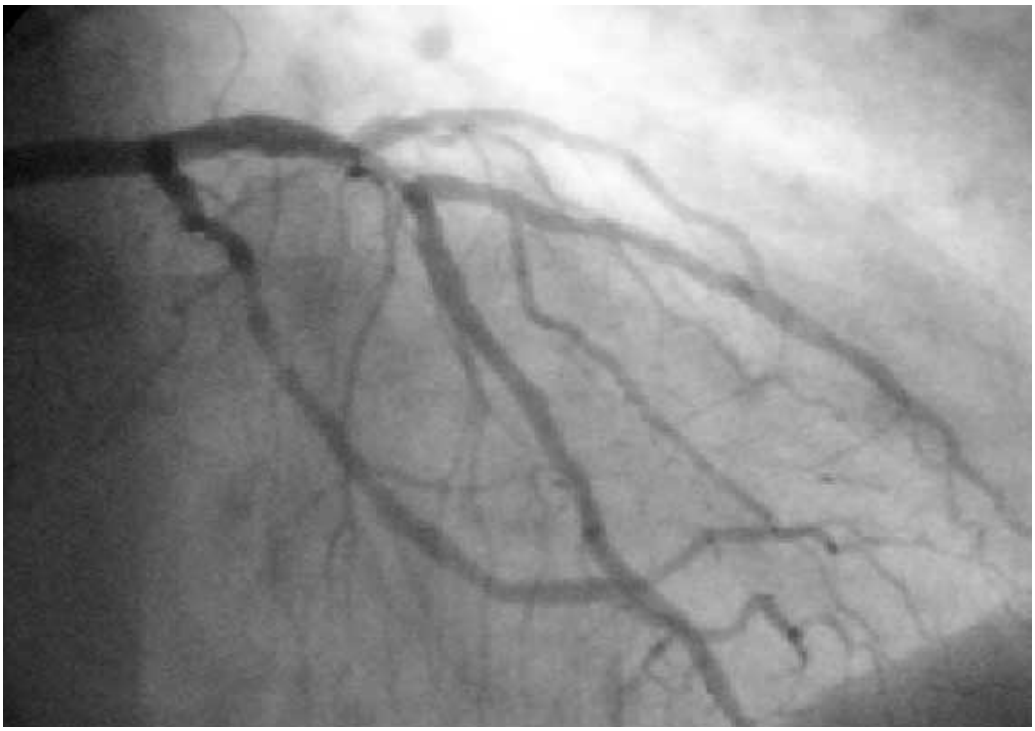
MEG vs. EEG

Although EEG and MEG signals originate from the same neurophysiological processes, there are important differences. Magnetic fields are less distorted than electric fields by the skull and scalp, which results in a better spatial resolution of the MEG. Whereas scalp EEG is sensitive to both tangential and radial components of a current source in a spherical volume conductor, MEG detects only its tangential components. MEG therefore measures activity in the sulci selectively, whereas scalp EEG measures activity both in the sulci and at the top of the cortical gyri. EEG is therefore sensitive to activity in more brain areas, but activity that is visible in MEG can also be localized with more accuracy.

Scalp EEG is sensitive to extracellular volume currents produced by postsynaptic potentials. MEG primarily detects intracellular currents associated with these synaptic potentials because the field components generated by volume currents tend to cancel out in a spherical volume conductor The decay of magnetic fields as a function of distance is more pronounced than for electric fields. MEG is therefore more sensitive to superficial cortical activity, which makes it useful for the study of neocortical epilepsy. Finally, MEG is reference-free, while scalp EEG relies on a reference that, when active, makes interpretation of the data difficult.

Chapter 22

Coronary Catheterization



A coronary angiogram (an X-ray with radio-opaque contrast in the coronary arteries) that shows the left coronary circulation. The distal left main coronary artery (LMCA) is in the left upper quadrant of the image. Its main branches (also visible) are the left circumflex artery (LCX), which courses top-to-bottom initially and then toward the centre/bottom, and the left anterior descending (LAD) artery, which courses from left-to-right on the image and then courses down the middle of the image to project underneath of the distal LCX. The LAD, as is usual, has two large diagonal branches, which arise at the centre-top of the image and course toward the centre/right of the image.

A **coronary catheterization** is a minimally invasive procedure to access the coronary circulation and blood filled chambers of the heart using a catheter. It is performed for both diagnostic and interventional (treatment) purposes.

Coronary catheterization is one of the several cardiology diagnostic tests and procedures. Specifically, coronary catheterization is a visually interpreted test performed to recognize occlusion, stenosis, restenosis, thrombosis or aneurysmal enlargement of the coronary artery lumens; heart chamber size; heart muscle contraction performance; and some aspects of heart valve function. Important internal heart and lung blood pressures, not measurable from outside the body, can be accurately measured during the test. The relevant problems that the test deals with most commonly occur as a result of advanced atherosclerosis – atheroma activity within the wall of the coronary arteries. Less frequently, valvular, heart muscle, or arrhythmia issues are the primary focus of the test.

Coronary artery luminal narrowing reduces the flow reserve for oxygenated blood to the heart, typically producing intermittent angina. Very advanced luminal occlusion usually produces a heart attack. However, it has been increasingly recognized, since the late 1980s, that coronary catheterization does not allow the recognition of the presence or absence of coronary atherosclerosis itself, only significant luminal changes which have occurred as a result of end stage complications of the atherosclerotic process.

History

The technique of angiography was first developed in 1927 by the Portuguese physician Egas Moniz to provide contrasted x-ray in order to diagnose nervous diseases, such as tumors, coronary heart disease and arteriovenous malformations. He is recognized as one of the pioneers in this field.

Coronary catheterization was further explored in 1929 when the German physician Werner Forssmann inserted a plastic tube in his cubital vein and guided it to the right chamber of the heart. He took an x-ray to prove his success and published it on November 5 1929 with the title "Über die Sondierung des rechten Herzens" (About probing of the right heart). The coronarography of the left heart was introduced in 1953 with the report by a Portuguese group, published in Cardiologia, International Archives of Cardiology volume 22, pages 45–61, by E. Coelho et al., entitled L'artériographie des coronaires chez l'homme vivant. They were the first to non-selectively inject radiocontrast in the coronary arteries.

In 1960 F. Mason Sones, a pediatric cardiologist at the Cleveland Clinic, accidentally injected radiocontrast in a coronary artery instead of the left ventricle. Although the patient had a reversible cardiac arrest, Sones and Shirey developed the procedure further, and are credited with the discovery (Connolly 2002); they published a series of 1,000 patents in 1966 (Proudfit *et al.*).

Since the late 1970s, building on the pioneering work of Charles Dotter in 1964 and especially Andreas Gruentzig starting in 1977, coronary catheterization has been extended to therapeutic uses: (a) the performance of less invasive physical treatment for angina and some of the complications of severe atherosclerosis, (b) treating heart attacks before complete damage has occurred and (c) research for better understanding of the pathology of coronary artery disease and atherosclerosis.

In the early 1960s, cardiac catheterization frequently took several hours and involved significant complications for as many as 2–3% of patients. With multiple incremental improvements over time, simple coronary catheterization examinations are now commonly done more rapidly and with significantly improved outcomes.

Patient participation

The patient being examined or treated is usually awake during coronary catheterization, ideally with only local anaesthesia such as lidocaine and minimal general sedation, throughout the procedure. Performing the procedure with the patient awake is safer as the patient can immediately report any discomfort or problems and thereby facilitate rapid correction of any undesirable events. Medical monitors fail to give a comprehensive view of the patient's immediate well-being; how the patient feels is often a most reliable indicator of procedural safety.

Death, myocardial infarction, stroke, serious ventricular arrhythmia, and major vascular complications each occur in less than 1% of patients undergoing catheterization. However, though the imaging portion of the examination is often brief, because of setup and safety issues the patient is often in the lab for 20–45 minutes. Any of multiple technical difficulties, while not endangering the patient (indeed added to protect the patient's interests) can significantly increase the examination time.

Equipment

Coronary catheterization is performed in a cardiac catheterization lab, usually located within a hospital. With current designs, the patient must lay relatively flat on a narrow, minimally padded, radiolucent (transparent to X-ray) table. The X-Ray source and imaging camera equipment are on opposite sides of the patient's chest and freely move, under motorized control, around the patient's chest so images can be taken quickly from multiple angles. More advanced equipment, termed a bi-plane cath lab, uses two sets of X-Ray source and imaging cameras, each free to move independently, which allows two sets of images to be taken with each injection of radiocontrast agent.

The equipment and installation setup to perform such testing typically represents a capital expenditure of US$2–5 million (2004), sometimes more, partially repeated every few years.

Diagnostic procedures

During coronary catheterization (often referred to as a **cath** by physicians), blood pressures are recorded and X-Ray motion picture shadow-grams of the blood inside the coronary arteries are recorded. In order to create the X-ray pictures, a physician guides a small tube-like device called a catheter, typically ~2.0 mm (6-French) in diameter, through the large arteries of the body until the tip is just within the opening of one of the coronary arteries. By design, the catheter is smaller than the lumen of the artery it is

placed in; internal/intraarterial blood pressures are monitored through the catheter to verify that the catheter does not block blood flow.

The catheter is itself designed to be radiodense for visibility and it allows a clear, watery, blood compatible radiocontrast agent, commonly called an X-ray dye, to be selectively injected and mixed with the blood flowing within the artery. Typically 3–8 cc of the radiocontrast agent is injected for each image to make the blood flow visible for about 3–5 seconds as the radiocontrast agent is rapidly washed away into the coronary capillaries and then coronary veins. Without the X-ray dye injection, the blood and surrounding heart tissues appear, on X-ray, as only a mildly-shape-changing, otherwise uniform water density mass; no details of the blood and internal organ structure are discernible. The radiocontrast within the blood allows visualization of the blood flow within the arteries or heart chambers, depending on where it is injected.

If atheroma, or clots, are protruding into the lumen, producing narrowing, the narrowing may be seen instead as increased haziness within the X-ray shadow images of the blood/dye column within that portion of the artery; this is as compared to adjacent, presumed healthier, less stenotic areas.

For guidance regarding catheter positions during the examination, the physician mostly relies on detailed knowledge of internal anatomy, guide wire and catheter behavior and intermittently, briefly uses fluoroscopy and a low X-ray dose to visualize when needed. This is done without saving recordings of these brief looks. When the physician is ready to record diagnostic views, which are saved and can be more carefully scrutinized later, he activates the equipment to apply a significantly higher X-ray dose, termed cine, in order to create better quality motion picture images, having sharper radiodensity contrast, typically at 30 frames per second. The physician controls both the contrast injection, fluoroscopy and cine application timing so as to minimize the total amount of radiocontrast injected and times the X-Ray to the injection so as to minimize the total amount of X-ray used. Doses of radiocontrast agents and X-ray exposure times are routinely recorded in an effort to maximize safety.

Though not the focus of the test, calcification within the artery walls, located in the outer edges of atheroma within the artery walls, is sometimes recognizable on fluoroscopy (without contrast injection) as radiodense halo rings partially encircling, and separated from the blood filled lumen by the interceding radiolucent atheroma tissue and endothelial lining. Calcification, even though usually present, is usually only visible when quite advanced and calcified sections of the artery wall happen to be viewed on end tangentially through multiple rings of calcification, so as to create enough radiodensity to be visible on fluoroscopy.

Therapeutic procedures

By changing the diagnostic catheter to a guiding catheter, physicians can also pass a variety of instruments through the catheter and into the artery to a lesion site. The most

commonly used are 0.014-inch-diameter (0.36 mm) guide wires and the balloon dilation catheters.

By injecting radiocontrast agent through a tiny passage extending down the balloon catheter and into the balloon, the balloon is progressively expanded. The hydraulic pressures are chosen and applied by the physician, according to how the balloon within the stenosis responds. The radiocontrast filled balloon is watched under fluoroscopy (it typically assumes a "dog bone" shape imposed on the outside of the balloon by the stenosis as the balloon is expanded), as it opens. As much hydraulic brute force is applied as judged needed and visualized to be effective to make the stenosis of the artery lumen visibly enlarge.

Typical normal coronary artery pressures are in the <200 mmHg range (27 kPa). The hydraulic pressures applied within the balloon may extend to as high as 19000 mmHg (2,500 kPa). Prevention of over-enlargement is achieved by choosing balloons manufactured out of high tensile strength clear plastic membranes. The balloon is initially folded around the catheter, near the tip, to create a small cross-sectional profile to facilitate passage though luminal stenotic areas and designed to inflate to a specific pre-designed diameter. If over inflated, the balloon material simply tears and allows the inflating radiocontrast agent to simply escape into the blood.

Additionally, several other devices can be advanced into the artery via a guiding catheter. These include laser catheters, stent catheters, IVUS catheters, Doppler catheter, pressure or temperature measurement catheter and various clot and grinding or removal devices. Most of these devices have turned out to be niche devices, only useful in a small percentage of situations or for research.

Stents, which are specially manufactured expandable stainless steel mesh tubes, mounted on a balloon catheter, are the most commonly used device beyond the balloon catheter. When the stent/balloon device positioned within the stenosis, the balloon is inflated which, in turn, expands the stent and the artery. The balloon is removed and the stent remains in place, supporting the inner artery walls in the more open, dilated position. Current stents generally cost around $1,000 to 3,000 each (US 2004 dollars), the drug coated ones being the more expensive.

Advances in catheter based physical treatments

Interventional procedures have been plagued by restenosis due to the formation of endothelial tissue overgrowth at the lesion site. Restenosis is the body's response to the injury of the vessel wall from angioplasty and to the stent as a foreign body. As assessed in clinical trials during the late 1980 and 1990s, using only balloon angioplasty (POBA, plain old balloon angioplasty), up to 50% of patients suffered significant restenosis but that percentage has dropped to the single to lower two digit range with the introduction of drug-eluting stents. Sirolimus, paclitaxel and everolimus are the three drugs used in coatings which are currently FDA approved in the United States. As opposed to bare metal, drug eluting stents are covered with a medicine that is slowly dispersed with the

goal of suppressing the restenosis reaction. The key to the success of drug coating has been (a) choosing effective agents, (b) developing ways of adequately binding the drugs to the stainless surface of the stent struts (the coating must stay bound despite marked handling and stent deformation stresses) and (c) developing coating controlled release mechanisms that release the drug slowly over about 30 days. One of the newest innovations in coronary stents is the development of a dissolving stent. Abbott laboratories has used a dissolvable material, polylactic acid, that will completely absorb within 2 years of being implanted.