Surgical Techniques

Textbook for medical students

Edited by Mihály Boros

University of Szeged
Faculty of Medicine
Institute of Surgical Research

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Readership:

Dr. Erzsébet Rőth
Dr. György Lázár
Dr. Csaba Gaál

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Dr. Mihály Boros

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Introduction

“Surgical techniques” is a subject relating to the principles of surgery. Traditionally it discusses instrumentation, tools and sterile techniques used to perform safe operations by generations of surgeons. A relatively new, but continuously expanding element is linked to the development of clinical surgery. This part involves surgical research on the pathophysiology of the perioperative period, and scientific studies on the consequences of invasive procedures on the body functions and on the relationship of surgery and patient care in general. These aspects are of utmost importance for the achievement of good surgical results. In brief, “surgical techniques” is concerned with the methodology of classical surgery, and may also be regarded as the deontology of modern surgery (*deontology* = theory of obligations).

This handbook is based on the topics presented on the graduate courses at the Institute of Surgical Research at the University of Szeged. These courses do not cover all aspects of clinical surgery; the intention is rather to give a general overview of basic techniques which could be used in practice in all major fields and subspecialties. There are a number of conventional surgical techniques that have been in use for some time and the scalpel is the symbolic instrument of these fields. However, it is being replaced by new and more effective surgical tools, sophisticated computer technology and techniques such as laser, robotic or minimally invasive surgery. If we wish to be at the forefront of these advances, the new methods should also be discussed.

The volumes have been compiled by the staff and PhD students of the Institute (Dr. Ágnes Adamicza, Dr. Mihály Boros, Dr. Tamás Jánossy, Dr. József Kaszaki, Dr. Andrea Szabó, Dr. Csilla Torday, Gabriella Varga, Dr. Gábor Erős and Dr. Miklós Czóbel), together with Dr. László Szalay (Department of Ophthalmology), Dr. Zsolt Bella (Department of Oto-Rhino-Laryngology) and Dr. Zoltán Bajory (Department of Urology). The editor wishes to acknowledge the creative illustrations by Drs Miklós Czóbel and László Szalay and Mrs. Kálmánné Csíkszentimrei. The activities of Dr. Miklós Czóbel have made it possible to maintain a highly effective website (http://web.szote.u-szeged.hu/expsur) where the main parts of this book can be found.

The ROP-3.3.1-2005-02-0001/34 project has led to an infrastructure for skills training where specific invasive techniques can be safely practised and mastered. We hope that the new skills laboratory at the Institute of Surgical Research, this handbook and the website (http://web.szote.u-szeged.hu/expsur/rop/index.htm) will stand the test of time, and that many medical students will benefit from them.

Mihály Boros

November 2006, Szeged

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"A man laid on an operating table in one of our surgical hospitals is exposed to more chances of death than was an English soldier on the battlefield of Waterloo"
(Sir James Simpson: Hospitalism: its effects on the results of surgical operations. In: *Edinburgh Med J*, 1869).

1. Historical overview

19th century surgery was faced with four classical difficulties: pain, infection, obsolete technology and the enigmatic pathophysiological changes of the perioperative period. By the end of the "century of surgeons", three of these problems had been solved, and modern clinical surgery has been born.

The first milestone was reached on October 16, 1846, in Boston, when a patient of John Collins Warren (1778–1856) was successfully narcotized with ether by William Morton (1819–1868). According to the inscription in the Ether Dome of the Massachusetts Memorial Hospital: "*On October 16, 1846, in this hall, the former operating theatre occurred the first public demonstration of narcosis, which resulted in analgesia during a major surgical intervention. Aether sulfuricus was applied by William Thomas Green Morton, a dentist from Boston. Gilbert Abbot was the patient and a neoplasm of the jaw was removed by John Collins Warren. The patient declared that he did not feel any pain and he was emitted whole on December 7. This discovery has spread from this room and opened a new era for surgery.*"

John Collins Warren (1778–1856) and William Morton (1819–1868)

Within some weeks, on December 21, 1846, Robert Liston (1794–1847) applied ether narcosis in London and James Simpson soon introduced chloroform narcosis (*On a new anaesthetic agent, more efficient than Sulphuric Ether. Lancet, 21 November 21, 1847: 549-550*). Hungary kept in line with the progress: on January 25, 1847, Lajos Markusovszky (1815–1893) tested the effects of ether on himself in Vienna and then together with János Balassa he performed the first operation involving the use of ether narcosis on February 8, 1847, in Budapest (the creation of the first Hungarian medical periodical *Medical Weekly Journal* (1857) and the Hungarian Medical Publishing Company (in 1863) were also among the merits of Markusovszky).

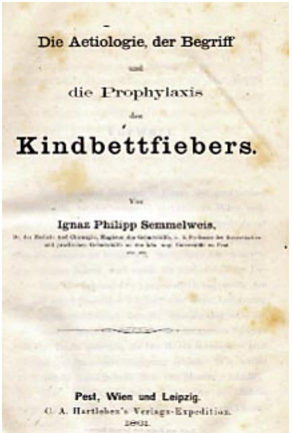
Lajos Markusovszky (1815–1893) and János Balassa (1814–1868)

Narcosis quickly became a relatively safe and generally accepted method of surgery. In 1893, Vilmos Vajna reported on the 3-year statistics of the German Surgical Society; 3098 cases were anesthetized, with only one death.

The initial attempts to prevent wound infection were by no means so successful. Surgical incisions were still followed by *irritative* fever, which sometimes lasted for only a few days and were accompanied by *pus bonum et laudabile* (good and commendable pus, sec. Galen), but even the most brilliant surgeons had to take into account the possibility of fatal postoperative infection. The terms "*hospitalism*" and "*hospital gangrene*" were used to denote postoperative infections. The frequency of these infections is well demonstrated by the incidence of puerperal fever (childbed fever): the average death rate in the First Department of Obstetrics at the Allgemeines Krankenhaus in Vienna was 9.92%, but on occasion the incidence was as high as 29.3% (in October 1842). At that time the mortality rate in hospitals in Edinburgh and Glasgow averaged around 40%, and in Paris it was as high as 59%.

In the 1840s, Ignác Semmelweis (1818–1865), a Hungarian obstetrician and Oliver Wendell Holmes (1809–1894) an American anatomist, came closest to verifying the causes. Finally, Semmelweis unequivocally identified that decomposing organic matter on the doctors' hands propagated infection, leading to the spread of puerperal fever, e.g. sepsis. On May 15 (?), 1847, Semmelweis introduced compulsory hand-washing with chlorinated lime. He issued a directive: "*All students and doctors who enter the wards for the purpose of making an examination must thoroughly wash and scrub their fingers and hands* *in the solution of chlorinated lime placed in basins at the entrance to the wards. One disinfection is sufficient for one visit, but between the examinations of each patient the hands must be washed with soap and water. Semmelweis".* In May 1847, the mortality from puerperal fever was still 14.5% whereas in August, following the institution of these measures, it was 1.2%.

Before the era of bacteriology this was a stroke of genius. Semmelweis had proved the effectiveness of asepsis, but the adverse circumstances prevented the rapid spread of his theory and his discovery did not become generally known.


Die Aetiologie, der Begriff
und
die Prophylaxis
des
Kindbettfiebers.
Von
Ignaz Philipp Semmelweis,
Pest, Wien und Leipzig.
C. A. Hartleben's Verlags-Expedition.

Ignác Semmelweis (1818–1865) *Die Aetiologie, der Begriff und die Prophylaxis des Kindbettfiebers* (1861)

At the beginning of the 1860s Louis Pasteur (1822–1895) elaborated the "*germ theory*" (his motto was *"chance prefers the prepared mind")*. Then, twenty years after Semmelweis, Sir Joseph Lister (1827–1912), a Scottish surgeon described the method of wound disinfection. In the operating theatre Lister sprayed carbolic acid (phenol) onto the instruments, onto the hands of the surgeon and also onto the wound, to kill microorganisms. His publication in 1867 set the trend of antisepsis (*On the Antiseptic Principle in the Practice of Surgery, Lancet*).

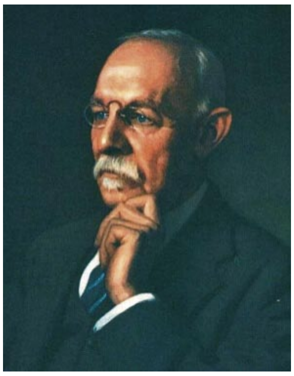
Sir Joseph Lister (1827–1912) and the first antiseptic operation

In 1881, Robert Koch (1843–1910) reported postulates whereby it became possible to verify that infectious diseases are caused by living microorganisms, i.e. bacteria:

1. "After it has been determined that the pathogenic organism is present in the animal body,
2. and after it has been shown that the organism can reproduce in the body,
3. and be transmitted from one individual to another, the most important experiment remains to be done…
4. to determine the conditions necessary for growth and reproduction of the microorganism."

In a further substantial step, Ernst von Bergmann (1836–1907) introduced sublimate antisepsis (1887) and steam sterilization (1886), and Curt Schimmelbusch (1850–1895) then initiated aseptic wound management. At the end of the 1880s, Lister realized that the treatment of wounds with antiseptics has a disadvantageous effect on wound healing. Furthermore, it was shown that the effects of chemicals are only superficial: they are not able to kill bacteria in the deep tissues. Lister later admitted that the aseptic method elaborated by the German school of surgeons was more advantageous than his own.

Surgical gloves were invented by William S. Halsted, chief surgeon at the Johns Hopkins University (1852–1922). In 1890, Halsted requested the Goodyear Rubber Company to prepare thin rubber gloves for the head scrub nurse (his later wife), Caroline Hampton, who suffered from dermatitis caused by the disinfectants. Joseph C. Bloodgood (1867–1935) who succeeded Halsted, used these gloves routinely from 1896, and the method proved to decrease not only the incidence of dermatitis, but also the number of postoperative wound infections.



William S. Halsted (1852–1922)

2. Asepsis and antisepsis in surgical practice

During surgery, the body's major defense against infection, the skin is broken and the inner surfaces of the body are exposed to the environment. Every attempt must therefore be made to prevent bacteria from entering the wound (*asepsis*) and to eliminate them if they have already entered (*antisepsis*).

Definition of asepsis
Asepsis covers all those procedures designed to reduce the risk of bacterial (or other, e.g. fungal or viral) contamination, e.g. through the use of sterile instruments and the gloved "no touch" technique. They include all of those prophylactic methods, working processes and behavioral forms by which microorganisms (bacteria, fungi and viruses) can be kept away from the patient's organism and the surgical wound. The goal of asepsis is to prevent contamination. Asepsis can be ensured by the use of sterile devices, materials and instruments and by creating an environment that is poor in microbes.

Definition of antisepsis
Antisepsis relates to the removal of transient microorganisms from the skin and a reduction in the resident flora. Techniques may be applied to eliminate contamination (bacterial, viral, fungal and others) present on objects and skin by means of sterilization and disinfection. Living surfaces, the skin, the operating field and the surgeon's hands can not be considered sterile.

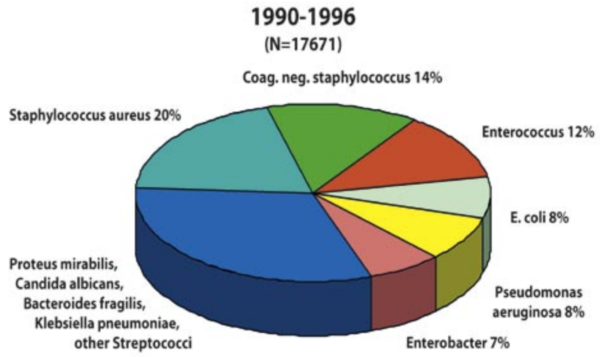
In a wider sense, asepsis concerns an ideal state, in which the instruments, the skin and the surgical wound are free from pathogenic germs, while antisepsis includes all those prophylactic procedures designed to ensure surgical asepsis. Asepsis is what is primarily important. Asepsis is primary prevention.

Definition of sterility
Sterility is a microbiologically germ-free state of materials and items. This means that they are free from all kinds of pathogenic and apathogenic microorganisms, including latent and resting forms, such as spores.

3. Surgical infections, sources of wound contamination, interventions

Disorders appearing during medical care (e.g. allergies against drugs) or caused by medication (e.g. complications of transfusion) are referred to as iatrogenic harms. They include iatrogenic infections (since the Greek word *iatros* is linked to doctors and *hospitalis* reminds us of hospitals, the medical profession uses the word *nosocomial* as an epithet). Nosocomial infections may be manifested in different forms. Some of them are well defined and originate from a single microbiologic cause. However, in most cases a syndrome evolves which is caused by many different pathogens. Surgery is primarily affected by this problem. It is rather paradoxical that, 150 years after the discoveries by Semmelweis and Lister the incidence of nosocomial infections is currently increasing.

The infection of wounds (*surgical site infection;* SSI) is one of the main manifestations of nosocomial infections. In the US, it occurs in approximately 14–16% of the cases and SSI contributes to 77% of the cases of mortality among surgical patients. On the average, SSI increases the relative risk of death 2.2-fold and extends the hospitalization period by 5–15 days. When all surgical complications are considered, the average incidence of SSI is 1–3%, but in colon surgery the level may reach 10%. As nosocomial infections are a source of great expense to the patient, the surgeon, the health care system and the society, an understanding of the etiology and pathomechanism is of the utmost importance.



*Staphylococcus aureus (*20%), Coagulase-negative staphylococcus (14%), Enterococcus (12%), *Escherichia coli (*8%), *Pseudomonas aeruginosa (*8%), *Enterobacter (*7%), *Proteus mirabilis, Klebsiella pneumoniae, Candida albicans, Bacteroides fragilis, and other streptococci (2-3%). (Source: National Nosocomial Infections Surveillance (NNIS) System, Centers for Disease Control and Prevention (CDC), 1996*)

The main cause of postoperative wound infections is the endogenous flora (skin: Staphylococci and Streptococci; mouth: Staphylococci, Streptococci and anaerobes; nasopharynx: Staphylococci, Streptococci, Haemophilus and anaerobes; large bowel: Gram-negative rods, Enterococci and anaerobes; the urinary tract is normally sterile). In direct wound infection, the process is started by residual skin flora, dermal infection, the surgeon's hands or a contaminated device or bandage, or can be transmitted from drains and intravenous catheters. Airborne infections originate from the skin and clothing of other patients and the staff and from the airflow in the hospital room or operating theater. In the case of hematogenic propagation, intravenous devices or a septic process in distant anatomical regions can be the source of SSI (Leaper DJ: *Risk factors for surgical infection. J Hosp Infect, 1999*).

4. Types of surgical wound contaminations and their classification

Criteria for defining an SSI as superficial

1. Infection occurs within 30 days after an operation.
2. The infection involves only the skin and the subcutaneous tissue adjacent to the incision.
3. At least one of the following is present:
   - a purulent discharge from the surgical site,
   - at least one of the signs and symptoms of infection (pain, tenderness, localized swelling, redness or heat),
   - spontaneous dehiscence of the wound or deliberate opening of the wound by the surgeon (unless the culture results from the site are negative),
   - an abscess or evidence of infection on direct examination or reoperation, or histopathologic or radiological examination,
   - diagnosis of infection by a surgeon or attending physician.

Deep incisional SSI

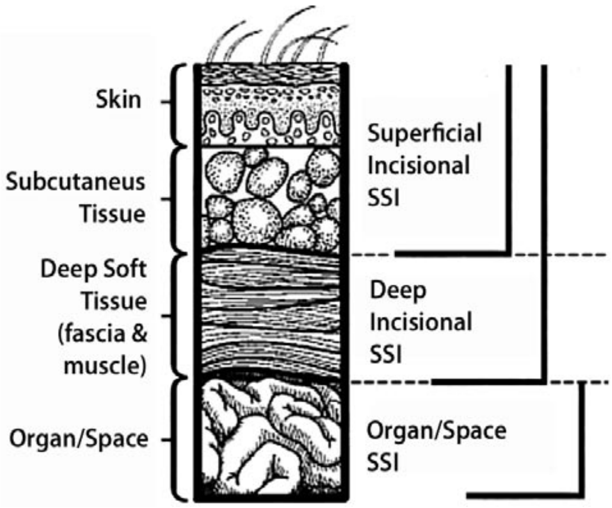
These infections involve deep tissues, such as the fascial and muscle layers. They include infections involving both superficial and deep incision sites and organ/space SSIs draining through incisions. Criteria:

1. They occur within 30 days after surgery with no implant (up to 1 year after surgery if an implant is left in place),
2. The infections involve deep soft tissues, fascia and muscle layers,
3. At least one of the following:
   - Purulent drainage/organism isolated from an aseptically obtained culture.
   - Fascial dehiscence or deliberate opening of the fascia by a surgeon due to signs of inflammation.
   - An abscess or other evidence of infection noted below the fascia during reoperation, radiological examination or histopathology.
   - A surgeon declares that a deep incisional infection is present.

Organ/space SSI

These infections involve any part of the anatomy, in organs and spaces other than the incision, which was opened or manipulated during operation. Criteria needed for the diagnosis:

1. The infection occurs within 30 days after surgery or within 1 year if an implant is present and the infection seems related to the operation.
2. The infection involves a joint/organ/space, or anatomic structures opened or manipulated during the operation.
3. At least one of the following:
   - Purulent drainage from a drain placed into the organ/space.
   - An organism is isolated from a culture sample obtained aseptically from joint fluid or deep tissue.
   - An abscess or other evidence of infection involving a joint, organ or space during reoperation, radiological examination or histopathology.
   - A diagnosis of an organ/space SSI by a surgeon.



5. Prevention of wound contamination

Analysis of the potential sources of infection reveals the following origins of causative agents:

- patients waiting for operation;
- members of the operating team;
- the operating theater (e.g. air, air conditioning, water, etc.);
- devices for operation (e.g. drapes, threads, bandages, etc.).

Rules of asepsis must be kept in connection with all of the above factors as this is the only way to prevent wound infections.

Before the operation

- A careful scrub and preparation of the operative site (cleansing and removal of hair) is necessary.
- Knowledge and control of risk factors (e.g. normalization of the serum glucose level in cases of diabetes mellitus, etc.).
- Perioperative antimicrobial prophylaxis (e.g. antibiotics) in high-risk patients.

During the operation

- Appropriate surgical techniques must be applied (gentle tissue preparation, exact handling of bleedings, use of absorbable sutures, etc.).

- Change of gloves and rescrub if necessary.
- Normal body temperature must be maintained. Narcosis may worsen the thermoregulation. Hypothermia and general anesthesia both induce vasodilatation, and thus the core temperature will decrease.
- The oxygen tension must be maintained and hyperoxygenization should be applied if needed. Oxidative processes play an important role in protection against pathogens. Reactive oxygen radicals (especially superoxide anions) are the frontline of defense against surgery-associated pathogens. The activity of the NADPH-linked oxidase of neutrophils is pO_2-dependent (Km ~ 60 mmHg), and hypoxia therefore transitionally decreases the killing activity of leukocytes.

After the operation

- SSI evolves shortly (within 2 h) after contamination.
- Hand washing is mandatory and the use of sterile gloves is compulsory while handling wound dressings and changing bandages during the postoperative period.

6. Risk factors of wound contamination

Systemic factors

These include age (the elderly or young children), undernourishment, obesity, hypovolemia, impaired tissue perfusion and steroid therapy. Diseases connected to altered immune responses: diabetes mellitus, cirrhoses, uremia and immunosuppressed states are all risk factors. In the majority of these cases, the surgical intervention should be performed exclusively under aseptic circumstances in the sterile operating room. The patients must usually be isolated, and hospitalized in sterile rooms, with strict adherence to the rules of asepsis. Wound management should be performed under "*operating room circumstances*".

Factors related to the wound

These may be dead or devitalized tissue left in the wound, a hematoma, foreign bodies, including drains, sutures, dead space, improper skin scrubbing, disinfection and shaving, or a previously existing infection (local or distant).

Factors related to the operation

These include an incorrect surgical technique, inadequate handling of bleeding, long-lasting surgical interventions (longer than 2 h); intraoperative infections, nonsterile operating room personnel, instruments, improper air-exchange, hypothermia, and a long preoperative stay (hospitalization).

Factors related to the type of the operation

The risk factor may be the type of the operation itself, as in certain operations the risk of wound contamination is higher than average. Surgical wounds can be categorized according to the level of wound contamination as *clean*, *clean–contaminated*, *contaminated* and *dirty-infected* groups.

Classification	Description	Infection risk [%]
Clean (Class I)	An uninfected operative wound without acute inflammation and closed primarily. Respiratory, gastrointestinal, biliary and urinary tracts not entered. No break in the aseptic technique. A closed drainage is used if necessary.	< 2
Clean-contaminated (Class II)	Elective opening of respiratory, biliary, gastrointestinal or urinary tracts and with minimal spillage. No evidence of infection or major break in the aseptic technique. Example: appendectomy.	< 10
Contaminated (Class III)	Non-purulent inflammation is present. Gross spillage from gastrointestinal tract. Penetrating traumatic wounds < 4 h. Major break in the aseptic technique.	Approx. 20
Dirty-infected (Class IV)	Purulent inflammation is present. Preoperative perforation of viscera. Penetrating traumatic wounds > 4 h.	Approx. 40

Source: CDC, 1996

7. Postoperative wound management

The decisive factor is the rigorous maintenance of the rules of asepsis:

- the primarily closed wound is covered with sterile covering bandage for 48 h;
- hygienic hand washing before and after the wound management is mandatory;
- a sterile technique must be applied during change of the covering bandage.

8. Sterilization, elimination and inactivation of pathogens

Definition: this involves the removal of viable microorganisms (pathogenic and apathogenic microorganisms, including latent and resting forms such as spores), which can be achieved by different physical and chemical means and methods or by their combined effects, in killing or inactivating all living microorganisms and their latent and resting forms.

Autoclaves
Autoclaves are highly effective and inexpensive tools of sterilization. Their effectiveness is based on the fact that the temperature of steam under pressure exceeds 100 °C. At 108 kPa, it is 121 °C (vacuum has to be created). When the pressure is 206 kPa, the temperature of steam is 134 °C. The time needed for sterilization at 121 °C is 20 min and at 134 °C is 10 min. To be effective against viruses and spore forming bacteria the steam must be in direct contact with the materials. The effectiveness can be checked via the color change of the indicator tape placed on the packing. *Disadvantage:* autoclaves are unsuitable for heat-sensitive objects.

Gas sterilization by ethylene oxide
This agent is highly penetrative and active against bacteria, spores and viruses. It is suitable for heat-sensitive items. *Disadvantages:* it is flammable, toxic and expensive, and leaves toxic residues on sterilized items. Accordingly, instruments sterilized in this way need to be stored for a prolonged period before use (airing is needed).

Sporicidal chemicals – cold sterilization
Sporicidal chemicals are often used as disinfectants, but can also sterilize instruments if utilized for a prolonged period. *The advantages* of these methods are that they are inexpensive and suitable for heat-sensitive items. *The disadvantages* are that they are toxic and irritants. The most widely used liquid sporicidal chemical is 2% glutaraldehyde (Cidex). It is able to kill most bacteria and viruses within 10 min (spores can survive for 3 h).

Irradiation
Gamma rays and accelerated electrons are excellent for sterilization. They are mostly used for industrial purposes, e.g. the sterilization of disposable items (plastic syringes and needles) and materials (bandages) rather than sterilization in hospitals.

9. Disinfection

Definition: this is the reduction of the number of viable microorganisms by destroying or inactivating them on living or inanimate (nonliving) surfaces. It can be achieved with chemicals (disinfectants) such as glutaraldehyde, formaldehyde, quaternary detergents, etc. Some of these disinfectants are sporicidal, but they should generally not be used for sterilization because most items need a very long time (up to 10 h or more) of soaking in order to render them sterile.

Low-temperature steam
Most bacteria and viruses are killed by exposure to moist heat. This is usually achieved with dry saturated steam at 73 °C, applied for more than 10 min. This procedure is effective, reliable and suitable for instruments with a lumen. It is unsuitable for heat-sensitive items.

Chemical disinfectants
These are suitable for heat-sensitive items, but are less effective than heat. The goal is to destroy microorganisms by chemical or physicochemical means. Different organisms vary in their sensitivity to them:

- Gram-positive bacteria are highly sensitive.
- Gram-negative bacteria are relatively resistant.
- Clostridial and Mycobacterial species are very resistant.
- Slow viruses are highly resistant.

The use of antiseptics (their application, making the solutions, their effective concentration, the time needed for the effective disinfection of the different chemicals, etc.) is strictly regulated in official guidelines (see "*Handout of disinfection and disinfectants*" by the Hungarian National Health Center). The chemicals used include clear soluble phenolics, hypochlorites, alcohols and quaternary ammonium compounds.

10. Asepsis

Asepsis (in a wider sense) has become a fully elaborated routine procedure. The rules of asepsis must be maintained as concerns the patient, the operating room personnel, the operating theater, the operating room devices, the tools and the instruments. Surgical asepsis demands strict precautions, while working in a sterile field presupposes the understanding that violation of the technical rules may cause fatal infections.

10.1. Preparation of the skin before the operation

The skin harbors *resident* flora (these bacteria cause no harm unless drawn into the body through a break in the skin, e.g. *Staphylococcus epidermidis)* and *transient* flora (acquired from a contaminated source); the latter includes any type of bacterium that can live on the skin.

Bathing

It is not unequivocal that bathing lowers the germ count of the skin, but as regards elective surgery preoperative antiseptic showers/baths are compulsory. Special attention is paid to the operative site. This should be bathed with antiseptic soap (chlorhexidine or quaternol) the evening prior the operation.

Shaving

This makes the surgery, the suturing and the dressing removal easier. It must be done immediately prior to the operation, with the least possible cuticular/dermal injury; in this case, the wound infection rate is only 1%. The infection rate rises to > 5% if shaving is performed more than 12 h prior to the surgery (abrasions can cause colonization, which can lead to wound infection). Clippers or depilatory creams reduce infection rates to < 1%.

Preparation of the skin

This is performed immediately before the operation. Disinfectants are applied to the skin:

- 70% isopropanol (this acts by denaturing proteins; it is a bactericidal) short-acting;
- 0.5% chlorhexidine (a quaternary ammonium compound, which acts by disrupting the bacterial cell wall, it is bactericidal, but does not kill spore-forming organisms; it is persistent, with a long duration of action (up to 6 h), and is more effective against Gram-positive organisms);
- 70% povidone–iodine (Betadine, which acts by oxidation/substitution of free iodine; it is bactericidal and active against spore-forming organisms; it is effective against both Gram-positive and Gram-negative organisms, it is rapidly inactivated by organic material such as blood; patient skin sensitivity is occasionally a problem).

Surgical disinfectants can also be grouped according to color (e.g. Betadine, Kodan gefärbt, etc.) or colorless (e.g. Kodan farblos). The advantage of color is that the prepared area is visible, while colorless compounds are used when observation of the skin's own color is important (e.g. discerning the differences between necrotic and viable tissues).

10.2. Disinfection and scrubbing of the skin before the operation

- This is performed after the surgical hand scrub and before dressing (gowning, i.e. putting on sterile gowns). All supplies used (towels, gauze sponges, sponge forceps and gloves) must be sterile.
- Scrubbing is performed outward from the incision site and concentrically (see later). The prepped/disinfected area must be large enough for the lengthening of the incision / insertion of a drain.
- The *classical method*: 1. removal of the fat from the skin surface with petrol (twice); 2. antiseptic paint (1–5% iodine tincture) is applied twice immediately.
- The skin prep must be performed in accordance with the accepted and generally applied rules of the operating room. *Currently,* only antiseptic paint is applied (usually povidone-iodine) at least twice (but usually three times), alcoholic solutions (e.g. Dodesept) could be used in the case of sensitive skin, applied with sterile sponges (gauze balls) mounted in a sponge-holding clamp.
- In aseptic surgical interventions the procedure starts in the line of the planned incision, while in septic, infected operations it starts from the periphery toward the planned area of the operation. Washing with antiseptics is begun at the exact location where the incision will be made, moving outward in a circular motion. A "no touch" technique is used. An area already washed is not returned to with the same sponge.
- The disinfectant collections in body folds must be sponged up after the skin-scrubbing procedure in order to avoid skin inflammation and burns.

10.3. Isolation of the operating area (draping)

- After the skin preparation, the disinfected operating area must be isolated from the nondisinfected skin surfaces and body areas by the application of sterile linen textile (muslin) or sterile water-proof paper (nonwoven) drapes and other sterile accessories/supplements. The isolation prevents contamination originating from the patient's skin. Draping is performed after the surgeon has donned gown and gloves.
- The use of sterile self-attaching synthetic adhesives (affixed to the disinfected operating area) is questionable, because these can help residual bacteria come to the surface, due to the increased perspiration during the operation.
- As the deeper layers of the disinfected skin always contain residual bacteria, the skin can not be touched either by instruments or by hand.
- The isolation can be performed with disposable sterile sheets which are attached to each other where they cross by self-attaching surfaces. Nondisposable, permeable linen textiles are fixed with special Backhaus towel clips; usually four Backhaus clips fix the sheets. In the draping routine, four towels are placed around the immediate surgical site: this is the "*squaring-off*" (isolation) of the site.

- In general surgical operations (e.g. abdominal operations), the scrub nurse and the assistant carry out the draping with the specially folded sheets. The first sheet isolates the patient's leg. The *Mayo* stand is then moved to the end of the operating table. The second sheet is used to isolate the patient's head; this sheet is fixed by a *Jones* or *Schaedel* towel-clip to the guard, which shields the anesthesiologist from the operative field. Placement of the two side-sheets then follows.
- The isolated area is always smaller then the scrubbed area. After being placed on the patient, sheets can not be moved toward the operating area, but only toward the periphery, because pathogens can be transferred from the nondisinfected parts to the surgical area.
- A special full sheet may be applied, too. This is positioned so that a hole incorporated in it lies over the operative site.

11. Basic rules of asepsis in the operating theater

- Only those people whose presence is absolutely necessary should stay in the operating room.
- Activity causing superfluous air flow (talking, laughing, sneezing and walking around) should be avoided. The atmosphere of the operating theater must be quiet and peaceful; movement and talking are kept to a minimum during surgery. Talking releases droplets of moisture laden with harmful bacteria into the air around the sterile field.
- Entry into the operating theater is allowed only in operating room attire and shoes worn exclusively in the operating room. All clothing except the underwear must be changed. This complete change to the garments used in the operating theater should also apply for the patient placed in the holding area. Leaving the operating area in surgical attire is forbidden.
- The doors of the operating room must be closed.
- Movement into the operating room out of the holding area is allowed only in a cap and mask covering the hair, mouth and nose. If the mask becomes wet, it should be replaced.

11.1. Personnel attire in the operating room

- Strict personal hygiene is necessary for the operating room personnel. Taking part in an operation is permitted only after surgical hand washing and scrubbing. The scrubbing person must not wear jewels. Watches and rings should be removed. Fingernails should be clean and short; nail polish is forbidden. Surgical scrubbing must always be performed in accordance with the accepted and generally applied rules of the local operating suite.
- Surgical team members in sterile attire should keep well within the sterile area; the sterile area is the space that includes the patient, the surgical team members, the sterile equipment tables and any other draped sterile equipment.
- Non-scrubbed personnel should not come close to the sterile field or the scrubbed sterile person, they should not reach over sterile surfaces, and they should handle only non-sterile instruments.
- Scrubbed team members should always face each other, and never show their backs to each other. They should face the sterile field at all times.
- Any airway infection or an open excreting wound excludes participation in an operation.

12. Scrubbing, disinfection and gowning in general

Scrub suit

In order to minimize the risk of infection, it is essential that the correct procedure should be followed before entry into the surgical suites and operating areas. All personnel should wear scrub clothes. Surgical attire acts as a barrier that protects patients from exposure to microorganisms that could cause postoperative infections. This barrier includes surgical gloves, caps, masks, gowns, protective eyewear, waterproof aprons, and sturdy footwear. They must all be the right size and properly worn.

Surgical caps and face mask

The hair, mouth and respiratory tract are rich in bacteria. The cap should cover the hair completely. The mask should be tied securely. It must be comfortable to wear, as it will be worn throughout the procedure.

Masks are effective in preventing gross contamination from saliva during talking and coughing. Masks should cover the nose and mouth, fitting snugly across the bridge of the nose, at the edge of the cheeks, and under the chin. Masks should be changed between cases or when they become wet (usually from breath). They should never be worn dangling around the neck. Rubbing ordinary soap on glasses and polishing them is the most satisfactory way to prevent fogging. Positioning of the mask:

Correct

Wrong

The scrub preparation and surgical disinfection

- The surgical hand and arm scrub procedure must be performed in the scrub suite before entry into the surgical suite/operating room. To maintain the asepsis, the hand and arm scrub is performed in accordance with the basic rules of asepsis.
- Hands can not be made sterile. The aim of the scrub is to reduce the number of transient and resident bacteria. The scrub eliminates the transient flora of the skin and blocks the activity of most resident germs located in the deeper layers. The disinfectant forms a thin film layer on the skin, thereby hindering the resident bacteria from reaching the surface from the crypts.

Participation in a surgical intervention requires participation in the complete protocol of scrubbing and disinfection. Scrubbing must be performed in accordance with accepted and generally applied rules of the local surgical suite. Simple scrubbing with ordinary soap is NOT disinfection.

The goal of scrubbing is to reduce the quantity of transient and resident bacterial flora and to inhibit its activity.

- Traditionally, scrubbing is carried out as in the *Ahlfeld-Fürbinger* 2-phase scrub. This consists of mechanical cleansing with a brush for 5 min, and rubbing with a disinfectant hand scrub agent for 5 × 1 min. Today, mechanical cleansing is restricted to the nails.
- Mechanical cleaning is the first phase of scrubbing. This first phase usually lasts for 3 min (5 min maximum).
- The second phase is disinfection. The most commonly used disinfectants include alcohol, phenol, hexachlorophene, iodine or chlorhexidine. Examples of trademarks are Dodesept Hand, Promanum N, Septoderm Hande, Skinman Intensive, Bradoderm, Spitaderm, Betadine, Betaisodona (iodine solution) and Sterillium (alcohol solution). 5 × 5 mℓ should be used, each dose for 1 min.
- Personnel must enter the operating theatre immediately after the scrub. The arms should be flexed at the elbow and the forearms should be up; the touching of nonsterile surfaces should be avoided.

The mechanical phase in detail

- Remove watch, rings, bracelets, etc.
- Cut the nails if necessary and clean the subungual areas with a nail file.
- Turn on the tap and adjust the water to an appropriate temperature and flow rate.
- Wash the hands and forearms thoroughly with liquid or foam soap. Rub each side of each finger, between the fingers, and the back and palm of the hands with soap. After the hands have been scrubbed, the arms are scrubbed. Rub the soap on each side of the forearm from the wrist to the elbow to at least 3 finger-breadths above the elbow, keeping the hand higher than the arm at all times. This prevents bacteria-laden soap and water from contaminating the hand. If at any time the hand touches anything nonsterile object, the scrub must be lengthened by 1 min for the area that has been contaminated.
- Rinse the hands and arms with water, keeping the hands above the level of the elbows, and allow the water to drain off the elbows.
- Take a sterile brush in one hand and the soap in the opposite one. Make a good lather on the brush and brush the nails and finger tips only. The brushing of any other part of the hand is forbidden.
- Finish the scrubbing and put the brush aside.
- Rinse both hands and arms thoroughly with tap water. This rinsing must be thorough, because any soap remaining on the skin may decrease or inhibit the effects of disinfectants.

Phases of scrubbing, 1.

Hygienic hand wash

Exposure of the sterile brushes...

and taking them

Phases of scrubbing, 2.

Mechanical cleaning of the nails

Phases of scrubbing, 3.

Cleaning of the hands and nails with soap

Phases of scrubbing, 4.

Phases of rinsing

This is forbidden!

Disinfection in detail

- Keep the palm below the tubing of the dosing wall-apparatus so that the hand is at the same level as the eye of the photoelectric cell. Do not touch either the apparatus or the tubing. If the hand is held properly, one dose of antiseptic will flow into the palm. The hands and arms are rubbed thoroughly with the antiseptic for 1 min. Repeat the process 4 more times.
- The disinfected area should extend to one finger under the elbow. The unwashed skin should not be touched with the clean hands.
- This process should be repeated four times more, but the affected area will be smaller and smaller. The second time, the dividing line is three fingers under the elbow; the third time, it is on the middle of the forearm. The fifth dose is rubbed only in the hands.
- If the disinfectant contains alcohol, it must not be rinsed. It is allowed to dry on the skin, in order to form a film. This film blocks residual bacteria from reaching the surface and it inactivates those which possibly appear there. If the disinfectant contains detergent, the scrub nurse gives a sterile towel with which to dry the hands.

Phases of disinfection, 1.

Correct

Wrong

Phases of disinfection, 2.

The gowning procedure

The scrubbed personnel enter the surgical suite immediately after the scrub. The hands are held above the elbows, in front of the chest. They go to the *Schimmelbush* container which is on a stand, and open the cover with the foot pedal. The further steps of gowning are as follows:

- Pick up a sterile gown with the right hand using the left hand to prevent others from pulling out. The gown is folded so that the inner surface is exposed to you when you pick it up. If you are gowning yourself, grasp the gown firmly and bring it away from the container. Never touch the outer surface.

- Remain well away from nonsterile objects while dressing, in order to allow a wide margin of safety.
- Hold the gown at the edges of the neck piece, away from your body and the container, and sufficiently high that it will not touch the floor.
- Holding the gown by the inside at the neckline, allow it to unfold gently, ensuring that the gown does not come into contact with anything that is not sterile.
- Gently shake the folds from the gown and insert both arms into the armholes, keeping your arms extended as you do so. Wait for the scrub nurse to assist you by pulling the gown up over the shoulders and tying it.
- The assistant / scrub nurse stands at the back and grasps the inner surface of the gown at each shoulder. The gown is pulled over the shoulders and the sleeves up over the wrist. The scrub nurse assists you by fastening the gown at the back.
- Meanwhile the cuffs of the gown can be adjusted. If there is a band, use it to fix the cuff. The assistant ties the bands at the back of the gown and the longer bands at the waist as well. Do not try to give these bands to the assistant, because you would risk touching a non-sterile person. The only exception is when the bands on the waist are sewn on the front of the gown. In this case you should cross your arms, grasp the contralateral bands and keep them away from you. The assistant then grasps and ties them without touching the gown.

Handling of the sterile gown

Correct Wrong

Pulling out the gown

Wrong

Unfolding the gown

Phases of gowning

Gowning procedure

Correct Wrong

Tying of the gown, 1.

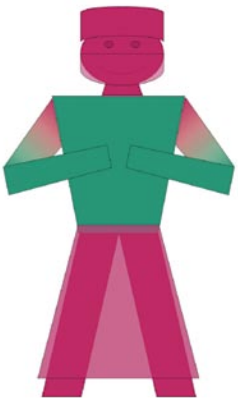
Tying of the gown, 2.

Correct Wrong

Tying of the gown, 3.

Forbidden

Effective ”sterile” area



Certain parts of the gown can not be regarded as sterile (!)

- the back and the armpits;
- the areas lateral to the armpits;
- below the waistline;
- the sleeves above the elbow, 10 cm from the shoulders.

Gloving

- Surgical gloves are made of latex or hypoallergic materials. Gloving is assisted by a scrub nurse already wearing a sterile gown and gloves. Surgical gloves are packed and sterilized in paper bags.
- The sterile nurse holds the left hand glove open with her fingers beneath the cuff so that her glove does not come in contact with your skin. The palm of the glove faces you. The sterile nurse holds the left hand glove open with her fingers beneath the cuff so that her glove does not come in contact with your skin. The palm of the glove faces you. Put two fingers of your right hand into the opening; pull the inner side of the glove toward you so that a wide opening is created. Slip your left hand into the glove so that the glove cuff covers the sleeve cuff.
- When you put on the right hand glove, place the fingers of your gloved left hand under the right glove cuff to widen the opening and thrust your right hand into the glove.
- You may now adjust your gloves so that they fit comfortably on the hands.

Gloving of the left hand

Gloving of the right hand

The gloved hands

To diminish friction between the skin and the glove, sterile talcum powder is used. The gloves have been lightly coated with powder. Powder entering into the abdominal cavity may lead to adhesions. When you are wearing a cap, a mask, a sterile gown and gloves, you are ready to participate in the operation.

Removing gloves

When removing the gloves, you should touch only their outer surface. In this way you can retain the cleanness of your hands if you change gloves during operation and protect yourself from infections. Grasp the cuff of your dirty left-hand glove and pull it down to the middle of the palm so that it hangs down from your finger in inside-out mode, and then repeat the process with the other one. Now you can take off both gloves one at a time without touching the dirty outer surfaces.

Removing the gloves

13. Personnel attire and movement in the operating room

- Sterile personnel should remain well within the sterile area. Operating team members should move about the suite as little as possible. Excessive movement leads to dust and air currents with the resulting spread of bacteria. Sterile team members face each other and also face the sterile field. Their backs are never turned toward the sterile field (it must be remembered that the back of the gown should be considered nonsterile).
- Hands must be kept within the sterile boundary of the gown.
- Sterile hands must not touch the cap, the mask or the nonsterile parts of the gown. Even spectacles must

not be touched; a nonsterile assistant must be asked to adjust them. You should use only sterile instruments and touch only sterile surfaces (e.g. the patient and the table covered with sterile sheets). Contact between sterile devices and objects of unknown sterility involves the risk of contamination.

- You must not stretch out your hand to attempt to catch falling instruments and you are not allowed to pick them up. Do not take any instrument from the instrument stand; ask the scrub nurse to give it to you.

14. Basic rules of asepsis in the operating room

- The operating room personnel must work in accordance with the rules of asepsis so as to ensure an aseptic germ-free wound state.
- Sterile personnel can handle only sterile equipment.
- If the sterility of an item or a person is questionable, this item or person is considered contaminated.
- Sterile tables are sterile at table height only.
- Sterile objects and surfaces in the air become unavoidably contaminated after a while.
- Humid sterile surfaces become contaminated because of capillary activity (e.g. sterile package and sheets become humid). This is called *strikethrough* contamination.
- The edges of boxes and pots can not be considered sterile. This means that the edge of any container that holds sterile supplies is not sterile.
- The skin (e.g. the field of operation) can not be considered sterile; however, it is obligatory to apply aseptic operating techniques.

15. Further important items to ensure asepsis and to avoid wound contamination

- During certain operations (e.g. after the opening of the bowel) the gloves are presumably contaminated by pathogenic microorganisms and must be changed. The gloves must also be replaced if they become damaged during sustained operations, and naturally between two operations. In the latter case, repeated disinfection or a new scrubbing procedure too is needed.
- Potentially contaminated instruments must be dropped at once into the waste bucket (e.g. scalpels used to incise the skin or to open a bowel) and must be replaced by new, sterile instruments.
- The surgical wound must be covered with a sterile wound cover.
- Closed circuit drainage must be applied for the drainage of oozing blood or confluent fluid collected in the wound.
- Easily cleanable and sterilizable metal instruments or disposable instruments and suture materials, plastic cannulas, drains and vascular prostheses must be used.
- Aseptic and septic operations must be separated in both time and space, and particularly in time. Aseptic operations (e.g. hernia operations, thyroidectomy or varix operations) must be carried out in a sterile (aseptic) operating room, and septic operations (colon surgery, appendectomy, hemorrhoidectomy and fistulas) in a septic operating theater. If these can not be separated spatially, aseptic operations must be carried out first and the septic cases only later. After these surgical interventions have been completed, the operating theater must be cleaned up and disinfected.

16. Duties related to asepsis in the postoperative period

- Bandages should be changed only when this is indicated.
- Bandages are changed first on aseptic patients.
- Bandages are changed with sterile instruments.
- Before and after bandage change hand washing is mandatory with antiseptic soap and new sterile gloves should be used for every case.

17. Surgical antisepsis

The basis of antisepsis is the killing or inactivation of pathogenic germs which have gained access to the wound. This is much less effective than prophylaxis. Antiseptic solutions (hydrogen peroxide or Betadine) or powders (boric acid, etc.) can be used locally, or antibiotics can be applied locally or systemically. The prophylactic use of antibiotics is not indicated in clean cases (except when implantation is performed), whereas in cases of contamination or dirty-infected operations antibiotic prophylaxis or treatment is mandatory (see Ministry of Health directives).

II. The operating room

1. Furniture, basic technical background

- The operating complex consists of many areas: dressing rooms, scrub suite, preparing rooms, and operating theaters. The floor area of an operating room is usually 50–70 square meters; it is well lighted and artificially ventilated. There is air-conditioning, and there is generally no window. The operating complex must be architecturally separated from the wards and intensive care unit.
- The temperature is normal ambient; the relative humidity is between 30% and 60%. In modern operating rooms, higher atmospheric pressure is created by *laminar air flow* equipment, which makes a nonturbulent inflow of clean air. Air movement is from clean to less clean areas.
- The walls are covered with tiles up to the ceiling, and the floor is gap-free. The wall and floor are easy to clean and disinfect.
- Doors are automatic. Personnel enter though a lock system. The staff change clothes and wear surgical attire and shoes worn exclusively in the operating room, or shoe covers when entering.
- All items of furniture have wheels. The operating room is supplied with a central or portable vacuum system and pipes for gases (compressed air, oxygen and narcotic gas).

2. Standard equipment

Operating lamp
This lamp provides cold, convergent light and can be positioned in any required position. It is supplied with a sterile handle via which the surgeon can himself adjust the lamp during the operation.

Operating table
- This is fully adjustable for height and degree of tilt in all directions; the surface is covered with a firm pad that can be removed for cleaning. Many accessories are used to meet the needs of different types of surgery. The table top is sectioned in several places and may be reflexed or extended, or flexed at one or more hinged sections. The table may be tilted laterally or horizontally, and raised or lowered from its hydraulic base. Sections of the table such as the headboard or footboard may be removed as needed.
- The position and height of the table are dictated by the situation of the organ to be exposed and by the surgeon's comfort. The ideal height of the operating table places the operative field approximately at the level of the surgeon's elbow when his arm is at his side. Positioning is very important.
- For operations performed in the abdominal region or under the umbilicus a pillow 10 cm in height should be placed under the patient's hip.
- A metal frame is to be found at the headboard of the table for the fixation of isolation sheets. This "*ether screen*" is a border, which separates the sterile surgical area and the nonsterile area of the anesthesiologists. It is strictly forbidden to lean an elbow on the frame or to reach above it.

Small instrument stand (*Mayo* stand): This is a special type of instrument table that is placed directly over (but not in contact with) the patient's leg. The most frequently used instruments are situated on it.

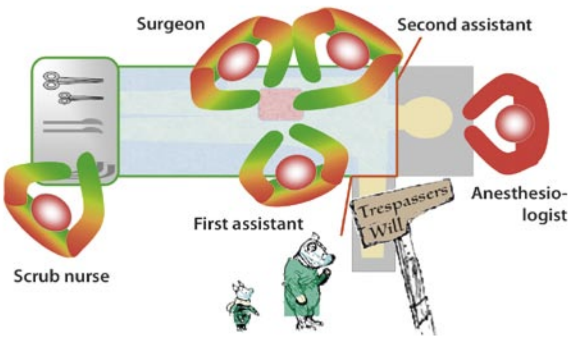
Back table (large instrument stand)
Extra supplies and additional instruments, except those in immediate use, are located here during surgery.

Kick bucket
Soiled (spilled) sponges and some instruments, e.g. the sponge-holding clamp used for the scrub preparation, should be dropped into these containers at the side of the table.

Anesthesia apparatus and other devices required by the anesthesiologist
The anesthesiologist and the assistant take their places behind the headboard of the operating table. They observe the patient throughout the operation. Major hemodynamic and vital parameters (e.g. blood pressure (BP), heart rate (HR), cardiac output (CO), intravascular volume, electrocardiogram (ECG), frequency of respiration, body temperature, etc.) are registered by a monitor with several channels. This is the area where devices required for airway securing and respiration are located: tubes, masks, laryngeal masks, Ambu balloon, portable respirator and instruments for endotracheal intubation (tubes, guiding wires, *Magill* forceps for nasotracheal intubation, laryngoscope, bite-blocking devices (*Guedel* tube or a short tube made of rubber) and a catheter for removing excretion). Other instruments too can be found here: braunules, "butterfly" needles (intravenous cannulas), central venous catheters, arterial catheters, infusion kits, ECG patches, a urine container sack and urine catheters of different sizes.

3. The operating room personnel

The positions of the operating team at the table will vary, depending upon the individual circumstances, and the situation of the organ. The surgeon stands on one side of the operating table. The first assistant is usually opposite the surgeon. On the other side of the table, beside the first assistant, opposite the operator, stands the scrub nurse. The second assistant stands on the left or right of the operator.



Positions of the sterile operating personnel around the operating table. A green line marks the sterile area; red colors show the border of this field. Stepping behind this line is forbidden.

3.1. Organization of the operating room personnel and their duties

Surgeon: This person ultimately guides the flow and scope of what happens in the surgical suite. He/she is primarily responsible for maintaining the asepsis, and also controlling all the activities in the surgical suite during the procedure.

Scrub nurse: She assists in the sterile gowning and gloving of the surgeon and his/her assistant. She is responsible for the maintenance of an orderly surgical field; she prevents contamination of the surgical field by the strict practice of aseptic techniques; she must call the attention of the surgeon and all members of the operating team to any error she perceives in the maintenance of asepsis.

First assistant: He/she works under the direct supervision of the surgeon and assists in such duties as hemostasis, suturing and wound dressing. The first assistant's responsibility is to position the operating table and the light, so that the field will be properly illuminated.

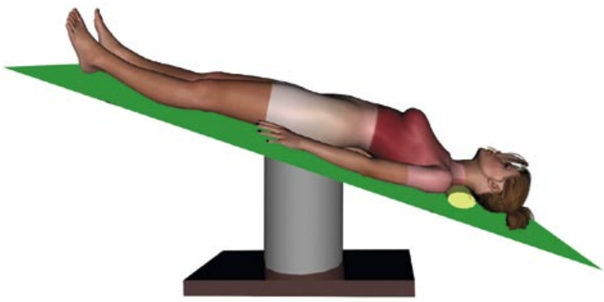
Second assistant: He/she ensures exposure of the operative field. He/she carries out the instructions of the surgeon or the first assistant. He/she should restrict his/her activities to holding instruments and retractors as instructed by either the surgeon or the first assistant;

Circulator / surgical technologist: This is a surgical team member who does not perform a surgical hand scrub or don sterile attire, and thus does not work within the sterile field; he/she is responsible for the nonsterile fields. It is his/her duty to deliver the patient to the operating room, safely position the patient, and to keep the operating room clean.

4. Positioning of the surgical patient

The surgical patient can be positioned on his/her back (standard positioning, e.g. abdominal operation), on his/her side (e.g. thoracic surgery), or on the abdomen (e.g. pylonidal cyst operation). Some types of positioning must be mentioned separately.

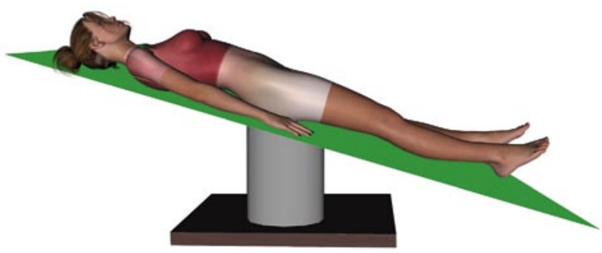
Trendelenburg position



This position was described by the German surgeon *Friedrich Trendelenburg* (1844–1924) in 1881. It is an upside down (45° head-down) position.

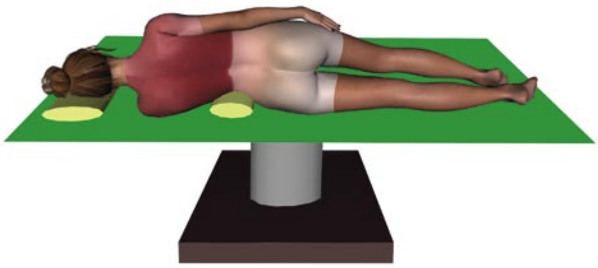
Indications: Depression of venous pressure (varicose vein surgery), or restraining of the small intestine from the pelvis (e.g. gynecology or laparoscopic surgery). Physiological effects of the Trendelenburg position: An elevated venous reflow, raised intracranial and intraocular pressure, and increased intragastric pressure. This leads to reflux of the gastric contents, and venous stagnation on the face and neck.

Reverse (or anti–Trendelenburg) position



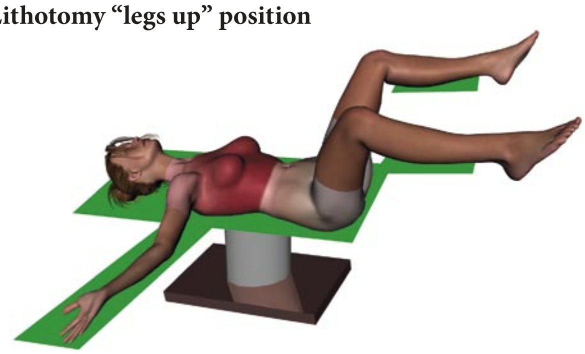
The head is above the horizontal plane. Physiological effects: A reduced venous reflow leads to a CO fall, a mean arterial BP decrease, and an improvement in the functional residual capacity (FRC) of the lung.

Lateral and lateral decubitus position



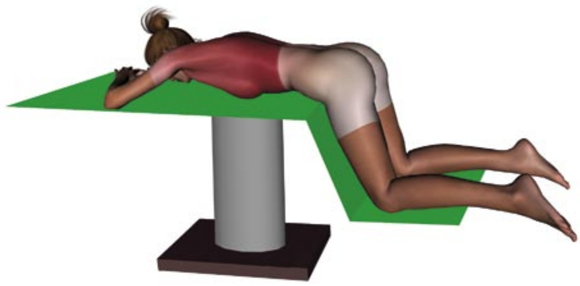
Indications: Thoracotomies, renal, shoulder surgery and hip operations. This position can cause problems because it may change the respiratory conditions. In the lateral decubitus position (in addition to the lateral position), the table is flexed in the center, and a support is also applied. *Indication:* Nephrectomy. *Problems:* Direct caval compression leads to a decreased venous return and hypotension.

Lithotomy "legs up" position



Potential problems: Autotranfusion from the leg vessels will increase the preload (the effect on CO will depend on the patient's volume status), and the vital capacity is decreased**;** The effect on CO will depend on the patient's volume status. The risk of aspiration is increased: anesthesia should never be induced in this position!

Kraske (jackknife or "knee-chest") position



This is a modification of the prone position (lying on the abdomen). The patient lies in the prone position, with the table broken at its midsection so that the head and feet are lower than the midsection. *Indications:* Procedures in the perianal area, proctology and rectal and coccygeal surgery.

III. Surgical instrumentation. Basic surgical instruments and their use

Surgical instruments are precisely designed and manufactured tools. The nondisposable instruments must be durable, and easy to clean and sterilize. They should withstand various kinds of physical and chemical effects: body fluids, secretions, cleaning agents, and sterilization methods (high temperature and humidity). For this reason, most of them are made of high-quality stainless steel; chromium and vanadium alloys ensure the durability of edges, springiness and resistance to corrosion. Due to the constant improvements by surgeons and manufacturers, the number of instruments is so great that only their basic categories and the main representatives can be surveyed. Depending on their function, basic surgical instruments are categorized into four groups.

1. Cutting and dissecting instruments.
2. Grasping, clamping and occluding instruments.
3. Retracting and exposing instruments.
4. Tissue unification, wound-closing instruments and materials.

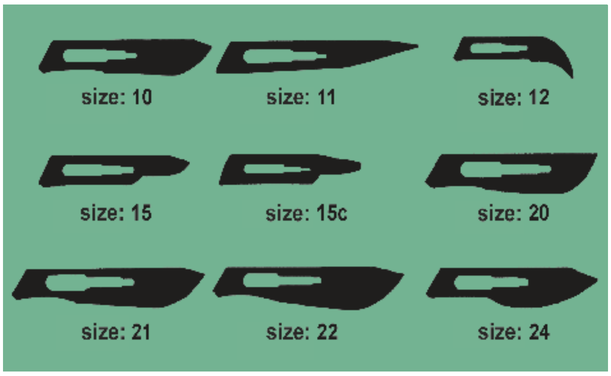
The groups of special instruments include dilators, suctioning-rinsing instruments, electric devices, dermatomes, endoscopes, fiberoptic devices, ultrasonic tissue destructors, cryotomes, laser devices, etc., some of which will be discussed below.

1. Cutting and dissecting instruments

The function of these instruments is to divide tissues, sutures, bandages, etc. These instruments have a sharp surface, either a blade or a point. This category includes knives, scissors, saws, osteotomes, drills, chisels, raspatories (used for the separation of the periosteum), *Volkmann* curettes, biopsy needles, diathermy pencils, etc.

Surgical knives – scalpels

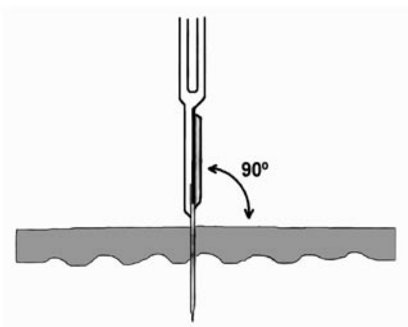
During the dissection of tissues, scalpels cause the minimum of trauma. Instead of the conventional scalpel, disposable scalpels with a plastic handle or scalpels with a detachable blade are nowadays most commonly used. A disposable blade is attached to the stainless steel handle before the operation. A #3 handle is used with the smaller #10-15 blades, and a #4 handle with the larger #20-23 blades.



Wide-bladed scalpels with a curved cutting edge are used for the incision of skin and subcutaneous tissues. Thin-bladed sharp-tipped knives serve for the opening of blood vessels, ducts and abscesses. A bistoury blade looks like a hook and can be applied as a meniscus knife.

The use of scalpels

- The incision is started with the tip of the knife and continued with the cutting edge as soon as possible. Cutting is usually made from left to right or toward the surgeon.
- In long straight incisions, the scalpel is held like a fiddle bow: the knife is gripped horizontally between the thumb, index and middle fingers; the ring and little fingers can hold the end of the handle.



- In the case of skin and other tough tissues which are hard to cut, the handle of the knife is held between the thumb and middle and ring fingers and the index finger is placed on the back of the blade; this makes possible a strong and well-controlled incision.
- In short or fine incisions, the scalpel is held like a pencil, and cutting is made mostly with the tip. Neither the blade nor the handle far from the blade is grasped during the incision (see on page 78.).

Amputating knives
Amputating knives of different sizes are manufactured with a one- or two-sided cutting edge for limb amputations.

Scissors
Next to the scalpel scissors are most often used to divide tissues. Threads and bandages are also cut with scissors. Scissors are made in different sizes; their blades can be straight or curved (*Cooper* scissors). There are special angular scissors which are angled at the joint (e.g. *Lister* scissors). The tips of the blades can be blunt (like those of the *Mayo* and the finer *Metzenbaum* scissors with longer shanks, both of which can be used for the preparation of tissues) or sharp (like those of the iris scissors used in ophthalmology, or the vascular scissors that

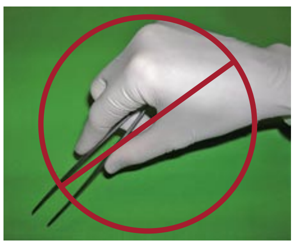
serve for the opening of vessels), but the tips can also be combined (i.e. one is sharp and one is blunt).

The use of scissors
The thumb and the ring finger are put into the finger rings. The index finger is placed on the distal part of the shanks, thereby stabilizing the instrument. In contrast with the scalpel, the cut is made from left to right or away from the surgeon. When cutting from left to right, the wrist is superextended. The cut is usually made close to the tips of the blades. Scissors are suitable for blunt dissection and also for the preparation of tissues. In this case, the scissors are introduced into the tissues with their tips closed, then opened, and dissection is carried out with the lateral blunt edges of the blades.

2. Grasping instruments

These instruments are used to grasp, pick up, hold and manipulate tissues, tools and materials. They can be applied for retraction, blunt dissection and hemostasis or occlusion of tubular structures - such as bowels or ducts – to prevent leakage of their contents.

Non-locking grasping instruments: thumb forceps
These are the simplest grasping tools. Forceps are made in different sizes, with straight, curved or angled blades (dental forceps). They can have blunt (dressing forceps), sharp (splinter forceps or eye dressing forceps) or ring tips. Forceps are used to hold tissues during cutting and suturing, retract them for exposure, grasp vessels for cautery, pack sponges and gauze strips in the case of bleeding, soak up blood and extract foreign bodies. Forceps should be held like a pencil; they grip when compressed between the thumb and index finger. This makes possible the most convenient holding, the finest handling and free movements. Forceps must never be held in the palm.



The teeth of tissue forceps prevent tissues from slipping; accordingly, only a small pressure is required to grasp tissues firmly. Thus, to grip skin and subcutaneous tissues, the tissue forceps is used most frequently. However, vessels, hollow viscera must not be grasped with them (risk of bleeding or perforation). For these purposes, or for holding sponges or bandages, dressing forceps should be chosen. These have blunt ends, with coarse cross-striations to give them additional grasping power. Skin gripped firmly with dressing forceps for a prolonged period can necrotize.

Locking grasping instruments: surgical clamps
For clamping, these tools have a locking mechanism which may be springy handles alone (e.g. a towel clip or a *Doyen* clamp) or combined with ratchet catches (e.g. hemostatic forceps). The design of clamps with a ratchet lock is similar to that of scissors: they have finger rings at one ends of the springy shanks, which are joined with a joint and jaws at their other ends. The ratchet catches interlocking the two shanks can be found before the finger rings. The opposing surfaces of the jaws vary, depending on the specific purpose for which the instrument has been designed: they can be smooth (e.g. *Klammer* intestinal clamp) or serrated (e.g. *Péan, Kocher* and *Lumnitzer* hemostatic forceps), and may (*Kocher* and *Lumnitzer*) or may not (*Péan* clamp) have teeth. Accordingly, traumatic (artery forceps) and atraumatic clamps (e.g. *Dieffenbach* serrafine, *Satinsky* artery forceps and intestinal clamp) can be distinguished. They should be held like scissors: the thumb and ring finger should be put into the finger rings, and the clamp is stabilized with the index finger. The lock can be opened by pressing down one of the finger rings while elevating the other one with the ring finger; in this way, the interlocking teeth are moved from one another.

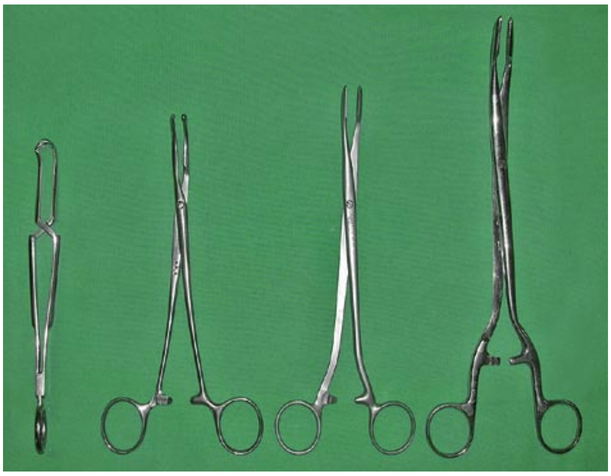
Hemostatic forceps
These instruments are the main means of establishing hemostasis during an operation (also called hemostats): they are used to stop bleeding by grasping and clamping the ends of cut vessels or for preventive hemostasis by applying them before cutting the vessel.

Traumatic hemostatic forceps (crushing hemostats)
Péan, mosquito, *Kocher, Lumnitzer* (*Kocher* with long shanks). The jaws can be straight or curved, while the tips are blunt. The dissector has long shanks and the ends of the jaws are curved at 90°. Hemostatic forceps can be used to grasp and clamp tissues and materials (e.g. threads and sponges) and also for blunt dissection (*Péan*, mosquito and dissector).

Atraumatic hemostatic forceps (non-crushing hemostats)
These are applied if the damage to the vessels or tissues must be avoided because their function is expected later, e.g. if the circulation is to be restored after their removal. The *Dieffenbach* serrafine (bulldog) belongs in this group; its rubber-coated jaws are closed by springy shanks. The *Satinsky* tangential occlusion clamp permits a partial occlusion of the lumen of larger blood vessels. While an anastomosis is made, the blood flow below the clamp is undisturbed.

Instruments used for grasping and clamping other tissues and textiles
Towel-holding clamps: These serve to fix the draping towels to the ether screen, to one another and to the skin of the patient (*Jones* and *Schaedel* towel clips, and *Backhaus* towel clamp).

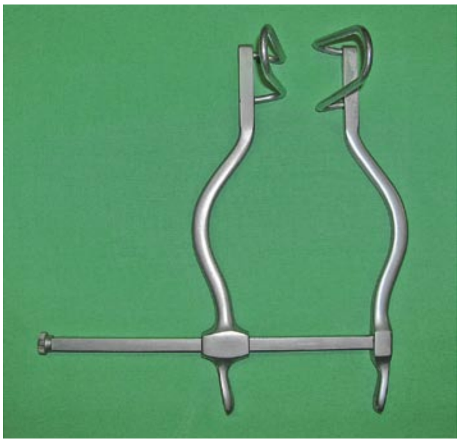
Doyen towel clamps are used to fasten wound towels to the edges of a skin incision. The *Mikulitz* peritoneum clamp is applied to grasp and hold the edges of the opening during draping and suturing. A cervix-holding or sponge-holding clamp is used to grasp the cervix of the uterus during gynecological operations, or to hold sponges for the scrub preparation of the surgical site or to soak up blood from the wound.



Needle holders
In modern surgery suturing is performed almost exclusively with curved needles that are held with needle holders designed for the grasping and guiding of needles. The needle holders grip the needle between the jaws, specially developed for this purpose; they usually have a ratchet lock. The *Mathieu* needle holder has curved shanks with a spring and a locking mechanism. It should be held in the palm. The *Hegar* needle holder resembles a hemostatic forceps, but the shanks are longer and the relatively short jaws are made of a hard metal. The serrations are designed to grip needles. During suturing in deep layers, needle holders with long shanks should be used.

3. Retracting instruments

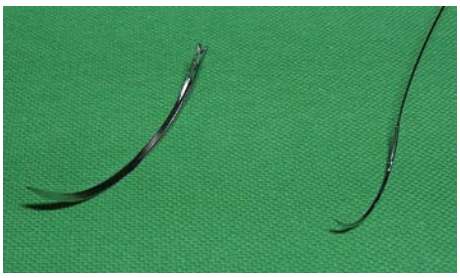
Retractors are used to hold tissues and organs aside in order to improve the exposure and hence the visibility and accessibility of the surgical field. Hand-held retractors (rake retractors, plain retractors, e.g. *Roux, Langenbeck*, or visceral retractors*)* are held by the assistant. They cause minimal tissue damage because the assistant maintains tension on the tissues only as long as necessary. When applied properly, self-retaining retractors (*Weilander* self-retractor, *Gosset* self-retaining retractor, etc.) are of great help, but care should be taken not to damage the tissues when they are placed and removed.



4. Wound-closing instruments and materials

Surgical needles
Needles are classified according to the type of the eye, shaft (body) and point.

The eye of the needle is designed to cause minimal trauma to the tissue. Needle eyes may be conventional, closed or French-eyed, and there are also eyeless needles (atraumatic needles). French-eyed needles are the least traumatic of the eyed needles. Thread is pulled through the minute spring in the head, which locks it into the eye.

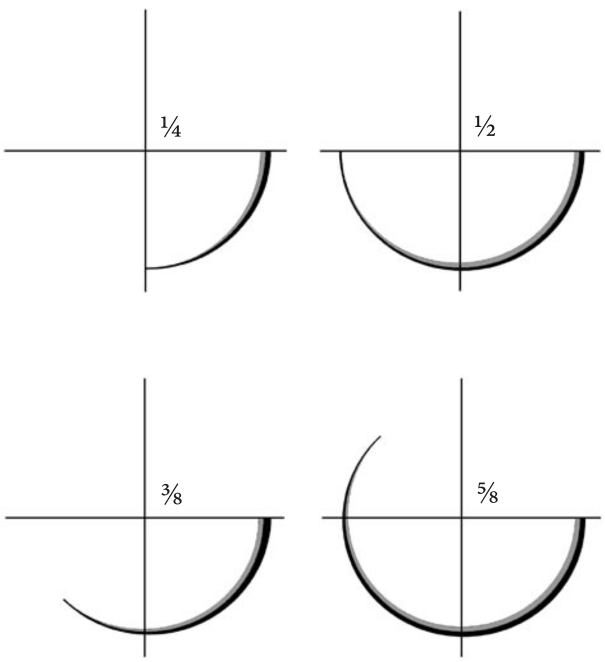


Atraumatic needles cause the least tissue trauma. They are manufactured with suture material already inserted. Needles are also produced that release the thread from the head if it is pulled sharply (controlled release needles).

The shape of its body can be triangular (and cutting) or curved/oval in its cross-section. In traditional cutting-edged needles, the tip of the triangle faces upward, while in reverse cutting needles, the tip of the triangle is to be found at the bottom.

The basic types of the needle points are cutting, taper and blunt.

Depending on their curvature, 1/4 circle (skin, eye or tendon sutures), 1/2 circle (muscle or fascia sutures), 3/8 circle (skin, fascia or gastrointestinal sutures), and 5/8 circle needles (muscle or urogenital sutures) are discerned. Needles are made in different sizes. Curved conventional cutting needles are used to suture firm, tough tissues (skin, subcutaneous, tissues, muscles and fascia). Round-bodied taper-point needles cause the smallest possible hole and the minimum damage in the tissues and blood vessels, the heart and the intestines are therefore sewn with such needles.



Suture materials
Suture materials are used to sew (approximate) wound edges and to ligate bleeding vessels. Surgical threads must meet different requirements: small caliber, high tensile strength, easy handling properties, sterilizability, inertness (causing minimum tissue trauma and reaction), good absorption characteristics or complete removability. They should hold securely when knotted, without fraying and cutting. Suture selection should be based on the knowledge of the physical and biological characteristics of the material, the healing rates of various tissues and factors present in the particular patient (infection, obesity, etc.). The most important properties of suture materials are as follows.

Important physical properties:
- caliber,
- tensile strength,
- elasticity,
- capillarity,
- structure (monofilament or multifilament),
- absorbent capacity,
- sterilizability.

Application properties:
- flexibility,
- slipping in tissues,
- knotting properties,
- knot security.

Biological properties:
- tolerance of tissues,
- tissue reaction.

The tissue reaction depends on the material: it is very strong in the cases of chromic catgut and catgut, moderate to linen, silk and polyamide, mild to Teflon and polyester, and minimal to polypropylene, polyglycolic acid, polydioxanone, steel and tantalum.

Threads are classified according to *absorbability* (absorbable or nonabsorbable), the *origin of the material* (natural or synthetic), and the *structure* (monofilament or multifilament: braided or twisted). Absorbable sutures are broken down in the body by enzymatic digestion or by hydrolysis. In multifilament threads, several strands of fiber are twisted or braided to make one strand; they are therefore stronger than monofilament threads. Multifilament threads are easy to handle, and can be knotted securely; however, due to their capillarity they facilitate the migration and proliferation of bacteria among the strands, and thus propagate infections. For this reason, it is reasonable to sew with monofilament threads in an infected field. In pseudo-monofilament threads, a multifilament thread is coated with a homogeneous smooth layer (e.g. with polybutylate), due to which the capillarity is lost. Coated threads combine the advantages of monofilament and multifilament threads: they are strong, easy to handle, and noncapillary.

According to the European Pharmacopoeia, the thicknesses of threads are given in metric units, 1/10 mm. For absorbable sutures, size #1 means a thread 0.1 mm in diameter (the diameter of threads can lie in the interval 0.001-0.9 mm); according to the United States Pharmacopoeia (USP), this is a 6-0 thread. For non-absorbable and synthetic threads, this corresponds to size 5-0. The cause of the discrepancy is that catgut is thicker when stored in alcohol than dry thread. The higher the size number, the thicker the thread; the more 0s in the number, the smaller the size. The size ranges from #7 to 12-0. On the Brown and Sharpe (B & S) sizing scale: #20 = 5, #25 = 1, #26 = 0, #28 = 2-0, #32 = 4-0, #35 = 5-0, #40 = 6-0, etc. The length of the thread is also standardized.

SUTURE DIAMETER AND SIZE			
USP		DIAMETER LIMIT (mm)	METRIC SIZE
ABSORBABLE (Catgut Chromic and Plain)	NON-ABSORBABLE AND SYNTHETIC ABSORBABLE		
–	6–0	0.070 – 0.099	0.7
6–0	5–0	0.100 – 0.149	1
5–0	4–0	0.150 – 0.199	1.5
4–0	3–0	0.200 – 0.249	2
3–0	2–0	0.300 – 0.339	3
2–0	0	0.350 – 0.399	3.5
0	1	0.400 – 0.499	4
1	2	0.500 – 0.599	5
2	3.4	0.600 – 0.699	6
–	5	0.700 – 0.799	7

“Sutures are assigned a size which is based on a combination of diameter, tensile strength and knot security. The precise criteria vary depending on whether the suture is natural or synthetic fiber, absorbable, or nonabsorbable sutures” (USP, 1937).

The tensile force should be adjusted to the tensile strength of the thread. If it is too great, the thread is weakened, or broken. If the thread is pulled on a sharp surface (e.g. if it is pulled through the French eye of the needle), it becomes weaker. The thread should be cut where it was grasped with an instrument. Guiding the thread during suturing is the role of the assistant.

A. ABSORBABLE SUTURES

These are broken down in the body and eventually absorbed by digestion by lysosomal enzymes of white blood cells or by hydrolysis (synthetic absorbable sutures). Many of them are no longer in clinical use (e.g. catgut).

Natural materials

Today, the use of natural materials is very restricted.

Surgical gut (catgut)

This is made of collagen processed from the submucosal layer of the bovine or ovine intestine. Catgut is absorbed relatively quickly. Its tensile strength remains unchanged for 7–10 days; it is absorbed in 70 days. Treatment with chromium salt solution prolongs the absorption time. In this case, the tensile strength is retained for 10–14 days; the absorption time is 90 days. It is made in monofilament and multifilament form. It can be applied in an infected field. Plain catgut is used for the ligation of superficial blood vessels and the suturing of mucous membranes or subcutaneous tissues; chromic catgut is applied to sew the fascia and peritoneum.

Collagen

This is produced from the collagen fibers from the bovine flexor tendon in both plain and chromic form, and can be applied in the same fields as surgical gut.

Synthetic materials

These are extremely inert, and have great tensile strength. They can be used to suture and ligate in nearly all tissues (peritoneum, fascia, subcutaneous tissue and joints). One of their disadvantages is that they tend to drag through tissue rather than passing through smoothly. They are rigid and slippery, and they therefore need extra knots (up to 6 half hitches) to obtain a secure ligature.

Polyglycolic acid

Dexon is a braided suture made of polyglycolic acid and coated with polycaprolate. It has an excellent tensile strength (remaining unchanged for about 3 weeks) and excellent knot security. It is completely absorbed in 60-90 days.

Polyglactin

Vicryl is a braided suture manufactured from polyglactin 910 (and coated with polyglactin 370 copolymer) which is similar to Dexon. Its tensile strength is 65% on day 14; absorption is minimal up to 40 days, and complete after 56–70 days. It can be used to ligate or suture tissues, except where approximation under stress is needed (soft tissue surgery or vessel ligation).

Poly-p-dioxanone

PDS II is made of poly-p-dioxanone. It is a monofilament thread. The tissue reaction is minimal. The tensile strength on day 14 is 70%. Absorption is minimal up to 90 days, but complete within 6 months. It is applied in soft tissue, pediatric, plastic and gastrointestinal (colon) surgery.

B. NONABSORBABLE SUTURES

The material of these sutures effectively resists enzymatic digestion. They can be monofilament or multifilament, coated or uncoated threads. They are used in tissues that heal more slowly, or if a very secure tightening is required. They are either left in the body, where they become embedded in the scar tissue, or they are removed when healing is complete.

Natural substances

(Today, silk, linen and cotton are no longer used in human surgical practice!)

Silk

A braided thread made of the protein fibers spun by the silkworm. Silk is strong and easy to handle. It can be applied in most tissues. It should be used dry. It and causes a significant tissue reaction. Its tensile strength is preserved for more than 1 year; it is absorbed by proteolysis within 2 years.

Linen

This is a twisted thread, which is weaker than silk; however, it is straightened when wet. Therefore, it must be dipped into saline solution before use. Its tensile strength is 50% up to 6 months, and 30–40% for 2 years. Linen can also be applied in most tissues. It is sized from thick to thin as follows: #25 (0.4 mm), #40 (0.25 mm), #60 (0.167 mm), #80 (0.125 mm), #100 (0.1 mm), and #120 (0.083 mm).

Cotton

This is made from twisted cotton fibers. It should also be dipped into saline solution. Its applications are identical to those of silk and linen.

Stainless (surgical) steel

This causes almost no tissue reaction. It is manufactured in monofilament and twisted forms. It is rarely used because it is difficult to handle, it may break up and it can easily cut tissues. It can be used for tendon and bone repair, nerve and retention sutures, and skin closure. It is numbered according to Brown and Sharpe.

Synthetic materials

Polyesters

These can be monofilament (Miralene or Mirafil), but are mostly braided, either uncoated (Dacron, Mersilene or Dagrofil), or coated with Teflon (Ethiflex or Synthofil) or polybutylate (Ethibond). They give the strongest sutures, apart from surgical steel. They can be used in a wide variety of tissues, primarily in cardiovascular surgery.

Polyamide (Nylon)

This is manufactured in monofilament (Ethilon, Dermalon) or in braided, coated form (Surgilon, Nurolon or Supramid). Braided nylon can be used in all tissues where a multifilament nonabsorbable suture is acceptable (general closure or microsurgery). Its tensile strength for 1 year is 80%, for two 2 years is 70% and for 11 years 66% and it causes only a minimal inflammatory response.

Polypropylene

This is a monofilament suture material (Prolene or Surgilen). It does not adhere to tissues, it causes only a minimal tissue reaction, it has a high tensile strength (100% for 2 years) and it holds knots better than most other synthetic materials. It is used in general, cardiovascular (blood vessel sutures) and plastic surgery. It can also be applied in an infected fields.

IV. Basic wound-closing methods: sutures and clips

Motto: *"Not too many—not too tight, not too wide—and get them out!"*

At the end of the operation, wounds are closed with sutures or clips. During suturing, tissues are approximated with stitches, and threads are then knotted. The basic prerequisites of wound healing are that tissues should be precisely approximated without tension, no dead space must be left, and the optimal blood supply of the wound should be ensured. As few sutures should be applied as possible, and only as many as necessary. Sutures can be used to stop bleeding (see later).

1. Types of sutures

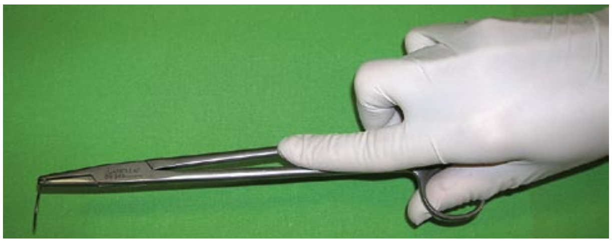
Sutures can be classified according to the *number of the layers*: one layer (only 1 layer is sewn), or 2 or multiple layers (retention suture); according to the *number of rows*: 1 or 2 rows (seldom multiple rows); and according to the type of *technique*: interrupted or continuous.

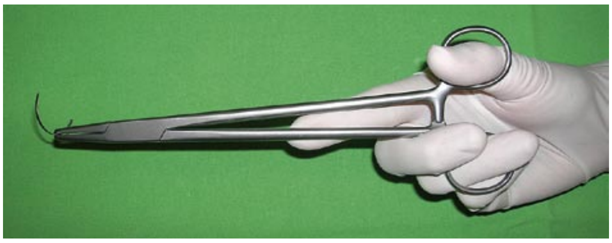
2. Rules of wound closure

- Sutures must not be placed too close to the wound edges, as otherwise the thread can tear them. Stitches should be placed 0.5–1 cm from the wound edges on both sides. (Suturing is usually made toward the person carrying out the procedure.)
- Stitches should be placed at equal distances (approximately 1–1.5 cm).
- Knots should be on one side of the wound and never on the wound line.
- Stitches should be placed opposite each other, so that no wrinkling and gaps occur.
- During suturing, the curvature of the needle should be followed.
- Wound edges must not be inverted (inverted wound edges heal with a thick scar).
- In the case of superficial wounds, stitches should be inserted to the base of the wound, not leaving dead space, in which blood and wound secretion may accumulate (wound infection and other complications).
- Threads must not be stretched too much, to avoid ischemia.
- Deep wounds should be closed in several layers.
- When skin is sutured, the stitches must be wider at the bottom of the wound (including more tissue) than in the superficial layer.

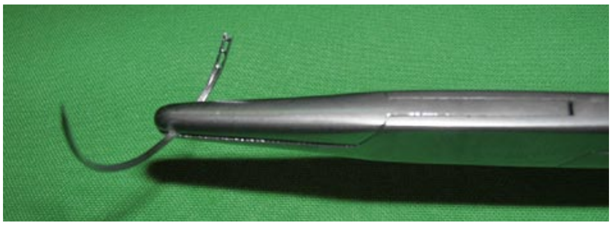
3. Correct position of the needle holder

- The correct position of the needle.





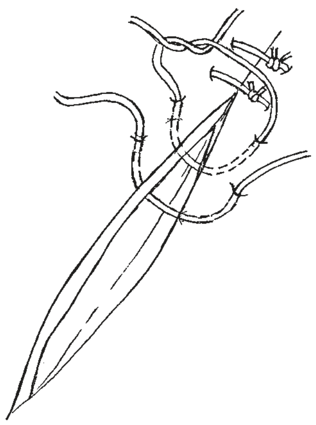
- 1/3–2/3 ratio, with approximately 70° deflection.



4. Interrupted sutures

4.1. Simple interrupted suture (*sutura nodosa*)

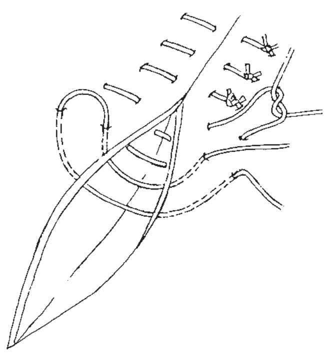
This is frequently used to suture skin, fascia and muscles. After each stitch, a knot should be tied. All sutures must be under equal tension.



The advantage is that the remaining sutures still ensure an appropriate closure and the wound will not open if one suture breaks or is removed. The disadvantage is that it is time-consuming since each individual suture must be knotted.

4.2. Vertical mattress suture (*sec. Donati*)

This is named after Mario Donati (1879–1946), an Italian surgeon. The Anglosaxon terminology (erroneously) is *Blair-Donati* suture (Lyman C. Blair described the "upside-down, continuous, subcuticular" suture in 1964).



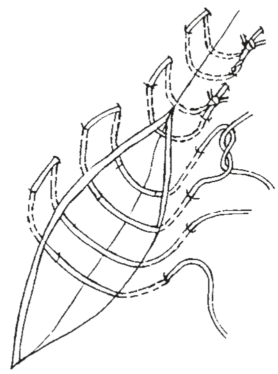
The *Donati* suture is used most often for skin closure. It is a 2-row suture: a simple interrupted stitch is placed wide and deep into the wound edge, and a second, more superficial interrupted stitch is placed closer to the wound edge and in the opposite direction. Finally, it consists of a deep suture that involves the skin and the subcutaneous layer (this closes the wound) and of a superficial back stitch placed into the wound edge (this approximates the skin edges). The two stitches are in a vertical plane perpendicular to the wound line.

4.3. Vertical mattress suture *sec. Allgöwer*

The *Allgöwer* suture was described in 1963 by Martin Allgöwer (1917–) at the University of Basel. It is a special form of vertical mattress suture: on one side of the wound, the thread does not come out from the skin, but runs intracutaneously. In this case, a thin scar is formed.

4.4. Horizontal mattress suture

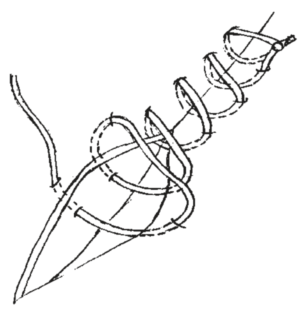
This is a double suture: the back stitch is 1 cm from the first one, parallel to it in the same layer.



5. Continuous sutures

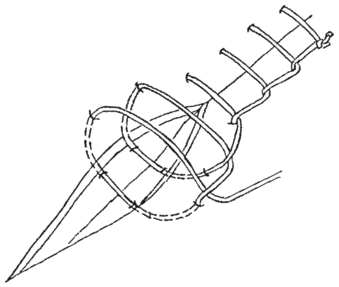
5.1. Simple continuous suture (furrier suture, *sutura pellionum*)

This can be applied to suture tissues without tension, the wall of inner organs, the stomach, the intestines and the mucosa.

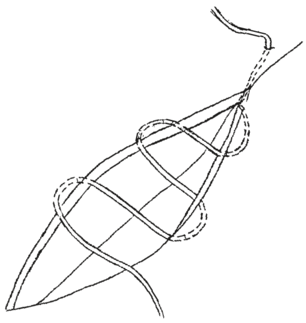


Advantages: 1. It can be performed quickly, since a knot should be tied only at the beginning and the end of the suture (here, only a part of the thread is pulled through and the strands of the opposite sides are knotted). 2. The tension is distributed equally along the length of the suture. During suturing, the assistant should continuously hold and guide the thread (with hands or forceps) to prevent it from becoming loose.

5.2. Locked continuous suture



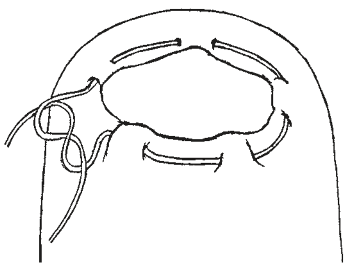
5.3. Subcuticular continuous suture



This runs in the subcuticular plane parallel to the skin surface; it enters the skin at the beginning and comes out at the end (no sutures are visible). It is used in skin with minimal wound tension and produces a fine scar. Starting from one end of the incision, insert the needle through the dermis, taking small bites alternately on one side and then the other. At both ends, the thread can be tied or taped to the skin.

5.4. Purse-string suture

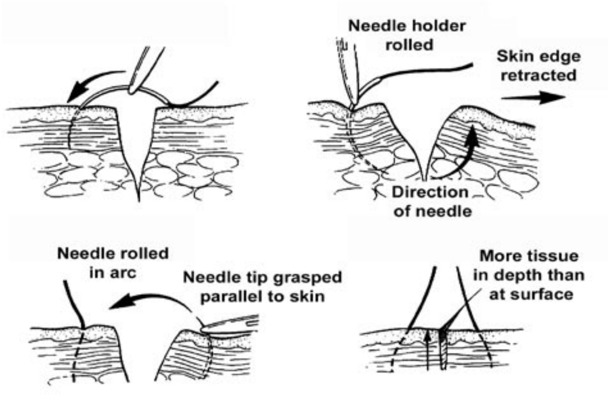
The openings of the gastrointestinal tract are closed with this suture; an atraumatic needle and thread are used. It is a suture for a circular opening, running continuously around it. The wound edges are then inverted into the opening with dressing forceps and the threads are pulled and knotted.



6. Methods of wound closure

6.1. Suturing with simple interrupted knotted stitches (skin and subcutis closure)

- For simple interrupted stitches, a needle holder, a curved needle (a 1/2 circle cutting needle) and 30-35 cm of thread are needed.
- The subcutaneous tissue must be stabilized by gently grasping it with tissue forceps 0.5 cm deep on the far side of the wound. The surgeon should insert the needle toward him- or herself, obliquely downward, 1–2 cm deep.
- Suturing should be started with the hand pronated, and the needle should be driven following its curvature by progressively supinating the hand until the point of the needle appears. The needle should exit the tissue perpendicular to the wound. With deep stitches, it can occur that the needle should be released and regrasped. The surgeon must always see the point of the needle when possible.
- When the point of the needle exits the tissue, the needle should be grasped and stabilized with the forceps, then released and regrasped with the needle holder under the forceps and removed from the tissues. The point of the needle must never be grasped.
- The free end of the thread is held by the assistant, and the thread is pulled out from the needle. The needle closed in the jaws of the needle holder is passed to the scrub nurse.
- The distance from one suture to the next should be approximately 1–1.5 cm. The elevation of tissues with knotted sutures by the assistant may provide help toward insertion of the next suture.
- All the stitches are cut just above the knots, only after the last one has been tied.



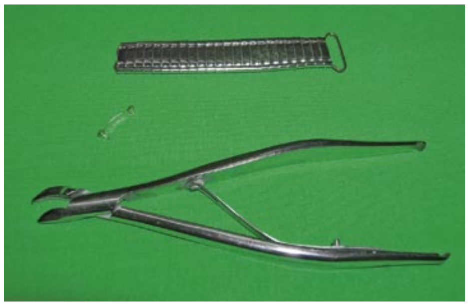
6.2. Suturing with *Donati* stitches (skin closure)

- For in vitro training and non-human practice #40 linen thread or nylon thread and a skin needle (a 3/8 or 1/4 cutting needle) are used.
- The stitch takes both deep and superficial bites and is useful for closing deeper wounds. The superficial bite allows for a more exact apposition of the skin edges, and the inversion of wound edges can be avoided. The wound edge is grasped and stabilized with tissue forceps on the far side, and the needle is inserted ~ 1 cm from the edge, close beside the forceps. The stitch is continued on the other side. The needle should exit the other skin edge at the same distance (1 cm) from the wound.
- The needle should be removed from the skin and the point is turned into the opposite direction to make a back-handed stitch (the inner curvature of the needle and the point are up). The needle is then grasped with the needle holder again. During these steps, the position of the needle holder remains unchanged.
- The closer wound edge is elevated with the tissue forceps, and a back-handed stitch is inserted 1–2 mm from the edge. The needle should leave the tissues between the cutis and subcutis. The stitch is repeated in the far side wound edge, from inside to outside.
- The thread is removed from the needle. The stitches must be tied just tight enough to appose the edges without causing ischemia, taking into account that edema will occur during the next few days. The threads are cut after complete closure of the wound, but ~ 0.5–1 cm is left above the knots.
- The wound should be disinfected with povidone-iodine or iodine tincture and covered with a bandage.

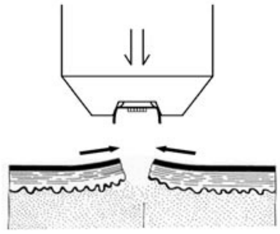
6.3. Wound closure with metal clips (*agrafe*)

Metal clips made of stainless steel or titanium can also be used for the approximation of tissues. They can be applied to close skin wounds and, for example to make gastrointestinal sutures. In the case of skin, they can be used on fields without wound tension and where wounds tend to heal quickly (e.g. after appendectomy, strumectomy or hernia repairs). Clips can be applied to close the lumen of different tissues and organs (vessels, ducts, etc.). This method is also used in video-endoscopic surgery.

1. Clips fit into the jaws of a special grasping instrument designed for their handling, the *Michel* clip applicator and remover. The clip is grasped with the



forceps-like part of the applicator. The assistant approximates and lifts up the opposite wound edges with two tissue forceps. The surgeon inserts the clip with the applicator between the two tissue forceps, perpendicular to the incision, with a definite movement. When compressed, the toothed tips of the clip are closed with the instrument. The distance between the clips is 1–1.5 cm. Clips are removed with the other end of the instrument. It is forbidden to close wounds of the hand or the hairy skin of the head with clips.
2. Skin wounds can also be closed with a modern, clip applicator.

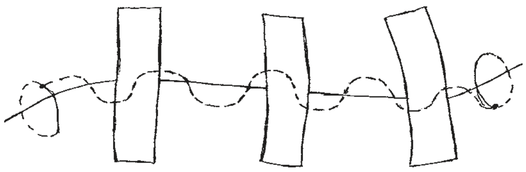


3. Staplers: These approximate tissues with staples in one or two rows. The metal clips are pressed by the apparatus into the anvil of the opposite side, where they become crooked and are closed without crushing the tissues.
   - Linear stapler: This closes tissues with double rows of staples in a straight line; it can also cut the tissues between the two rows (gastrointestinal and lung surgery).

   - Circular staplers: These can be used to approximate tubular structures (esophagus or intestinal surgery).
   - Staplers are suitable for making purse-string sutures (intestinal surgery).
   - Vascular staplers use special 3-row clips for the complete occlusion of vessels.

6.4. Other wound-closing methods

1. Surgical adhesives: These are usually produced from fibrin, collagen or thrombin and induce the last phase of blood coagulation, so that a firm fibrin mesh is produced. Application fields: Anastomosis, securing vascular and nerve sutures, fixation of skin transplants and stopping bleeding (see later).
2. Wound closure with self-adhesive strips (*Steri-Strip*): These can be applied if the wound edges can be easily and well approximated in the case of smaller wounds not requiring suturing. They are also used to fasten subcuticular sutures.



Disadvantages: Less precision is attained than with suturing; body parts with secretions (armpits, palms or soles) are difficult areas; areas with hair are not suitable for taping.

7. Sutures in different tissues

Skin
Usually, nonabsorbable sutures (synthetic materials) are used. Suture types applied: Simple interrupted suture, vertical mattress suture (*Donati, Allgöwer* suture) or subcuticular continuous suture. Metal clips, a clip-applying machine, self-adhesive strips (*Steri-Strips*) (small children and supplementary fastening of subcuticular sutures), or surgical steel (in the case of delayed wound healing) can also be utilized.

Mucosa
Thin absorbable sutures (earlier catgut) are used.

Gastrointestinal tract
The danger of suture insufficiency is great. *Lembert* sutures (involving the seromuscular layer on both sides), *Albert* sutures (passing through all layers), or *Czerny* sutures (a double row: *Albert* suture followed by a *Lembert* suture) can be applied. Different staplers are often used (see above).

Muscles
In most cases, muscles are closed with absorbable (earlier catgut) sutures, together with the fascia.

Fascia
This is closed with simple interrupted stitches, using synthetic suture materials.

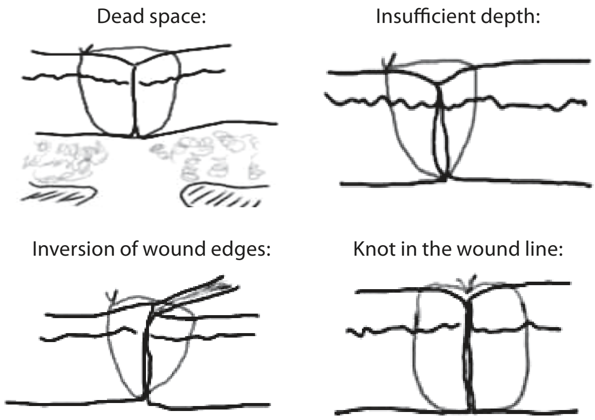
Tendons
Surgical steel or other nonabsorbable monofilament sutures are applied.

Blood vessels
These are sewn with nonabsorbable synthetic thread (e.g. Prolene), often by using microsurgical techniques.

Nerves
These are approximated with microsurgical techniques, using nonabsorbable monofilament threads.

Parenchymal organs (liver, spleen and kidney)
These are sewn with absorbable material and mattress sutures.

7.1. Failures of suturing technique



7.2. Removing sutures

The saying "*without inflammation, there is no healing*" is the clue to the readiness of the wound for suture removal (there should be pink, raised healing ridge). The time of removal (usually within 3–14 days) depends on the location of the suture (sutures are removed later from a field which is under tension), the blood supply of the operative field (sutures can be removed earlier from an area that has good circulation) and the general condition of the patient. Sutures on the face can be removed after 3–5 days, those on the skin of the head and the abdominal wall after 7–10 days, those on the trunk and the joints after 10–14 days, those on the hand and arm after 10 days, and those on the leg and foot after 8–14 days.

Removing simple interrupted, continuous sutures and wound clips

- After careful disinfection of the wound site, the suture is grasped and gently lifted up with a thumb forceps. The thread should be divided as close to the skin as possible so that no thread which was outside the skin should be pulled through the wound. In this way, infection of the wound can be avoided.
- In the case of continuous subcuticular sutures, one end of the suture is cut above the skin and the other end is pulled out in the direction of the wound.

- *Michel* clips are removed with the *Michel* clip applicator and remover. The ring of one end of the clip is grasped with a tissue forceps, the edge of the remover is placed between the clip and the wound line, beneath the apex of the clip. The instrument is closed, the clip will open and the teeth of the clip will come out of the skin.

8. Surgical knots

In surgery, the ends of threads used for sutures or ligatures are tied with surgical knots. The basic requirements for tying knots are that they can be ligated quickly, the knots should hold securely and they should be safe. Incorrectly tied knots may cause serious postoperative complications: loose knots can result in thicker scar formation. Too tight knots can decrease or stop the local blood circulation which slows down wound healing and can lead to the loosening of sutures and even suture insufficiency. The knot must be as small as possible so as to prevent a tissue reaction when absorbable sutures are used, or to minimize the foreign body reaction to nonabsorbable sutures. The two ends of the threads should be cut as short as possible, just above the knots (except for skin sutures, where longer threads are left, facilitating the removal of the sutures).

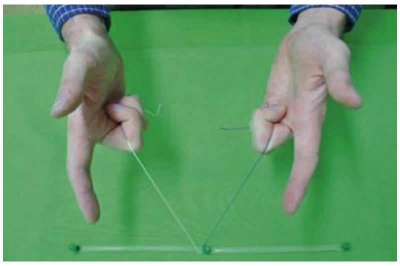
8.1. Types of surgical knots

- There are different types of knots. The *granny knot* used in everyday life consists of two identical simple half-hitches tied above each other: in the second half-hitch, the direction of the ends of the thread is identical with that in the first one. As it has the tendency to slip and can open up spontaneously, it must not be used in surgery.
- The common knot used in surgery is the *square* (or *reef*) knot, a symmetrical knot which consists of at least two half-hitches, one placed on the other: the base half-hitch and then the second half-hitch which is the mirror image of the first one. A half-hitch is one revolution of one end of a thread around the other. The first half-hitch is made by crossing the segments, and the second half-hitch is in the opposite direction to that of the first one, so the knot has two mirror image half-hitches. The number of half-hitches depends on the nature of the surgical materials (synthetic monofil threads require extra knots – 5 or 6 knots).
- Techniques of tying knots in surgery: two-handed knots, one-handed knots (one hand is active, while the other only holds the thread, and the knot is then tightened with both hands) and an instrument tie.

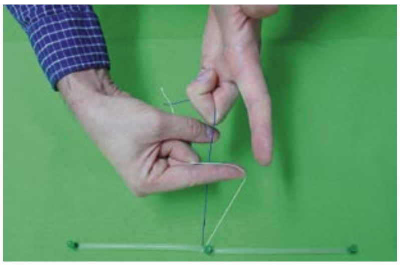
8.2. Two-handed knots

Both hands take an active part in the formation of the knot. These knots are mostly applied on tissues under tension. The most important types of two-handed knots: the two-handed square knot (reef knot or sailor's knot), the surgeon's knot and the Viennese knot.

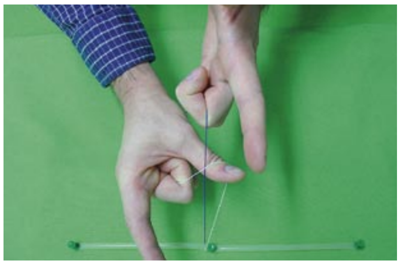
8.2.1. Reef knot or sailor's knot



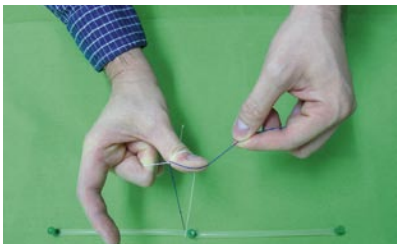
1. The two strands of the thread are crossed; the upper (white) strand is held in the right hand. The ends of the thread are held firmly against the palm with the last three fingers; the thumbs and the index fingers are free.



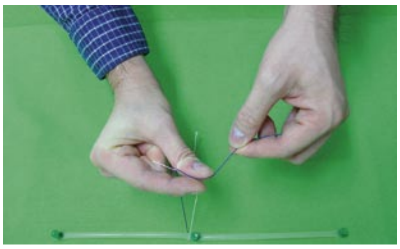
2. With the right index finger, the upper strand is pushed to the left side, over the blue strand.



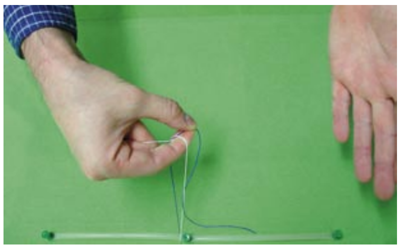
3. The right thumb is inserted between the strands, upward from below.



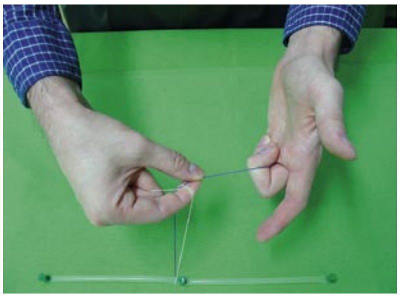
4. The left-hand strand is placed on the pulp of the right thumb.

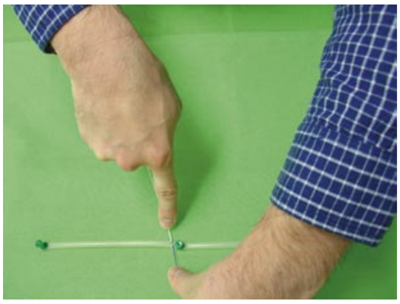


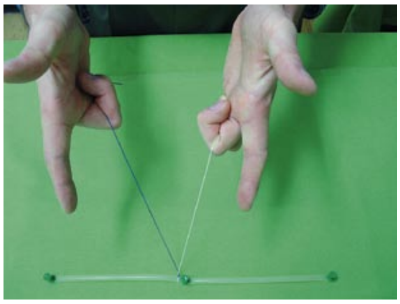
5. The thread is grasped with the right thumb and index finger.

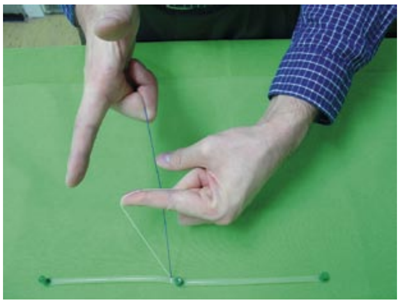


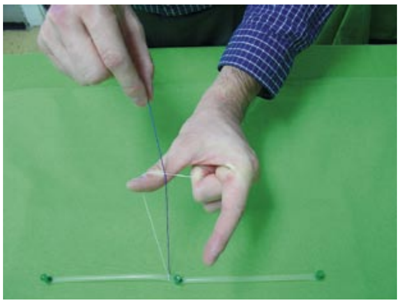
6. The thread is released from the left hand and transferred with the two fingers through the loop.

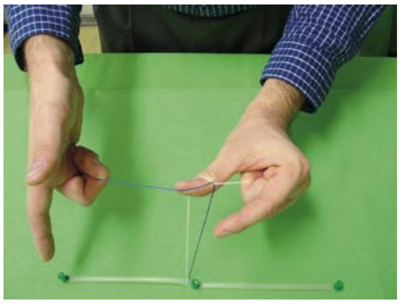

7. The thread is grasped with the left hand again.

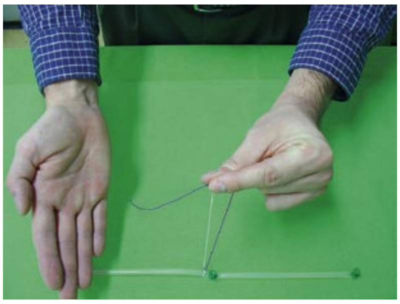

8. The base half-hitch is tightened with the two hands.

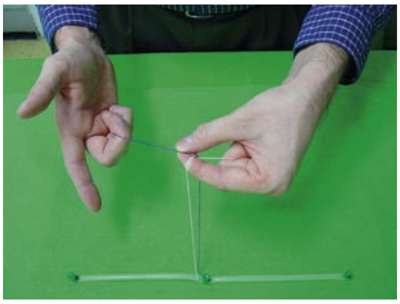

9. The two strands are crossed (exchanged between the two hands) in the opposite direction: the upper (white) strand is held in the left hand.

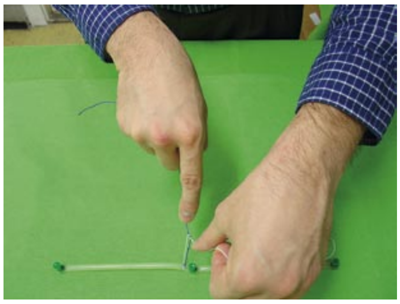

10. With the left index finger, the upper strand is pushed to the right side, over the blue strand.


11. The right thumb is inserted between the strands, upward from below.


12. The right-hand strand is placed on the pulp of the left thumb.

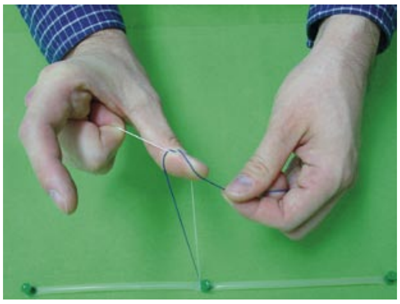

13. The thread is grasped with the left thumb and index finger and released from the right hand.

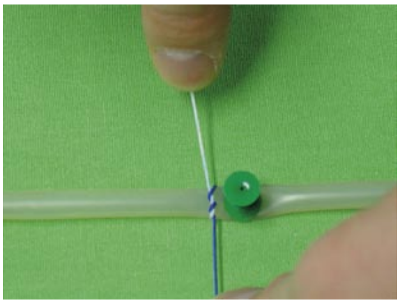

14. The thread is transferred through the loop with the two fingers and grasped with the right hand again.


15. The second half-hitch is tightened with two hands.

8.2.2. Surgeon's knot

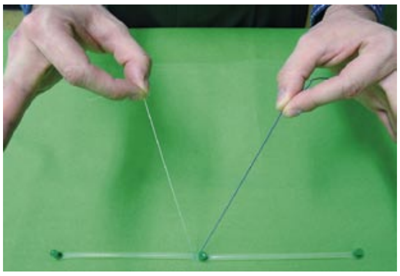
The technique of tying this knot is identical with that for the reef knot (section 8.2.1), but during the tying of the base half-hitch the thread is transferred through the loop twice, and then, similarly as for the reef knot, the base half-hitch is secured with a second half-hitch in the opposite direction. This results in a strong, safe knot that is used mainly in tissues under tension (skin and fascia).


7. The thread is grasped again with the left hand.

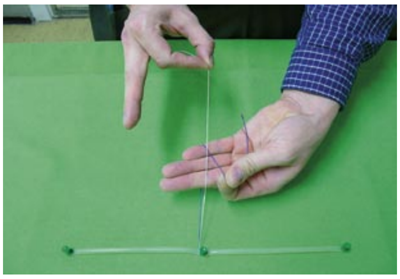

8. The base half-hitch is tightened with the two hands, and then the second half-hitch is tied.

8.2.3. Viennese knot

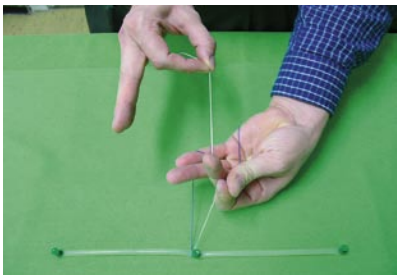
The technique of tying this knot is different, but it results in the same knot as the reef knot. However, it is faster and more elegant; it can be applied well in tissues under minimal tension (e.g. subcutaneous tissues or skin).



1. The two strands of the thread are crossed; the lower (blue) strand is in the left hand. The ends of the thread are held between the tips of the thumbs and the index fingers.

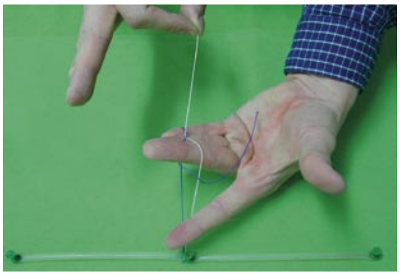


2. The left hand is placed over the thread, the ulnar side of the small finger is laid on the thread and the wrist is supinated so that the small finger rolls along the strand. The left palm faces upward.

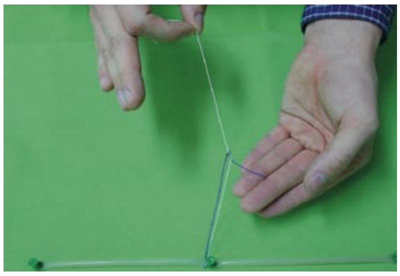


3. The right-hand (white) strand is placed on the pulp of the extended left middle finger, and the distal phalanx is then flexed and pulled beneath the left-hand strand.

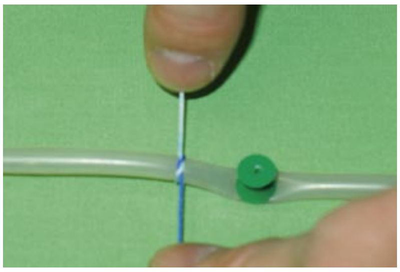
4. The left-hand strand is situated between the middle and index fingers.



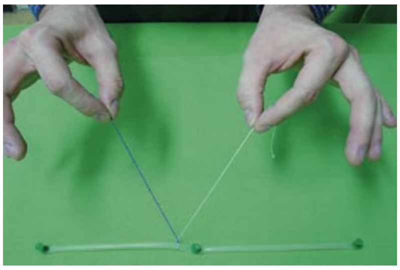
5. The two fingers are closed and the thread is grasped by them. The end is then released by the thumb and index finger.



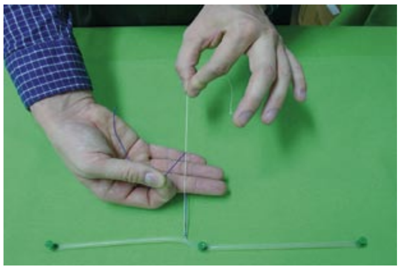
6. The thread is brought through the loop with the two fingers.



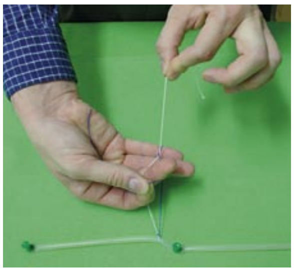
7. With the two strands of the thread held in the palms, the tips of the index fingers are placed on them, and the half-hitch is tightened.



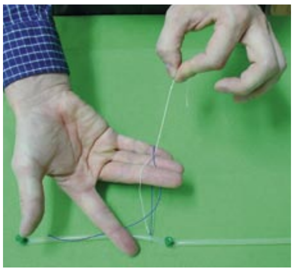
8. The two strands of the thread are crossed (exchanged between the two hands) in the opposite direction (from left to right). The lower (blue) strand is held between the right thumb and index finger.



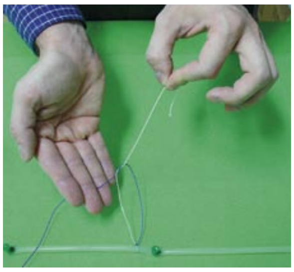
9. The right hand is placed over the thread, the ulnar side of the small finger is laid on the thread and the wrist is supinated so that the small finger rolls along the strand. The right palm faces upward.



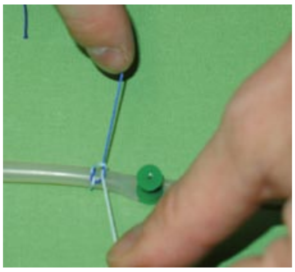
10. The left-hand (white) strand is placed on the pulp of the extended right middle finger, and the distal phalanx is then flexed and pulled beneath the right-hand strand.



11. The two fingers are closed and the thread is grasped by them. The end is then released by the thumb and index finger.



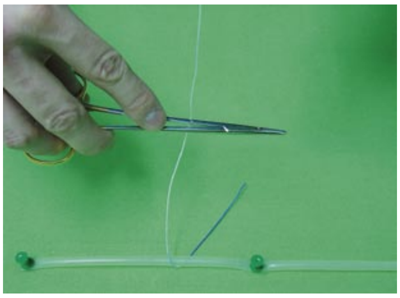
12. The thread is brought through the loop with the two fingers.



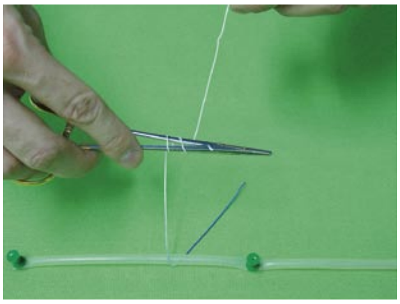
13. Finally, the second half-hitch is tightened.

8.2.4. Instrument tie

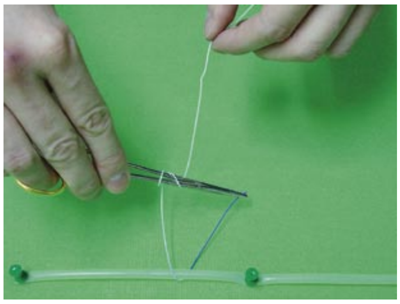
This is used when knots are to be tied in deep tissues, or in a deep cavity, or the thread is short (with this technique, thread can be saved) or in work with an atraumatic needle and thread. Such knots can be tied with a needle holder (this is used most frequently), with a hemostatic forceps (*Péan*), or with other grasping instruments.



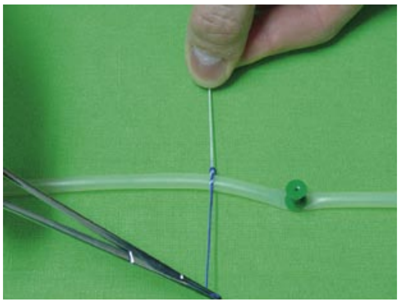
1. The instrument is placed on the long thread held in the left hand.



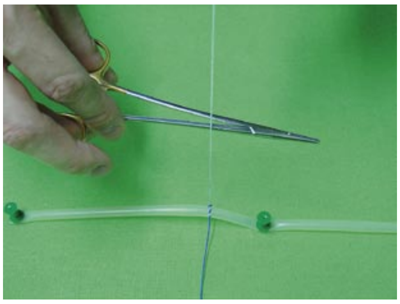
2. The thread is wrapped around the needle holder once when a reef knot is tied, or twice if a surgeon's knot is tied.



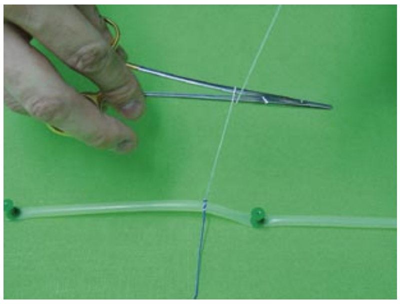
3. The short free end of the thread is grasped in the needle holder and pulled through the loop(s).



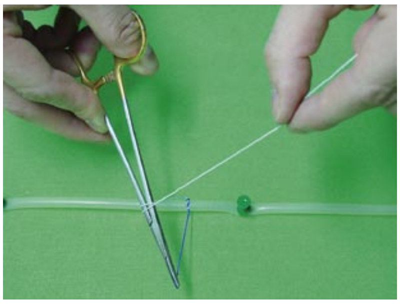
4. The base half-hitch is then tightened.



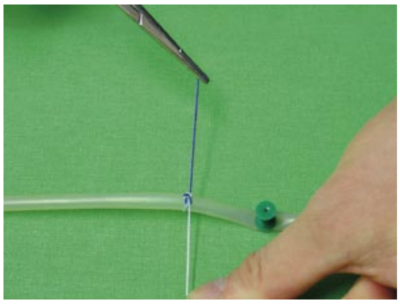
5. The instrument is placed under the long end of the thread.



6. The thread is wrapped around the needle holder once.



7. The short free end of the thread is grasped and pulled through the loop.

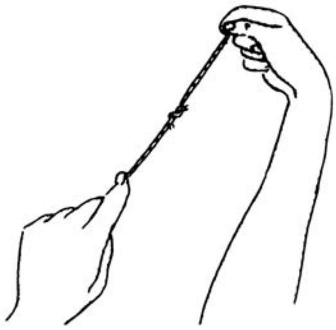


8. The second half-hitch is then tightened.

8.3. Knotting under special circumstances

8.3.1. Knotting close to the surface

The constriction of tissues should be avoided when sutures are tied. The degree of tightening should be just sufficient to oppose the tissues. The next half-hitch is tightened snugly onto the first one, and the third part of the triple throw knot is drawn tightly onto the second. As the knot is tightened, the direction of pull on the threads must be along a straight line which passes through the center of the knot.

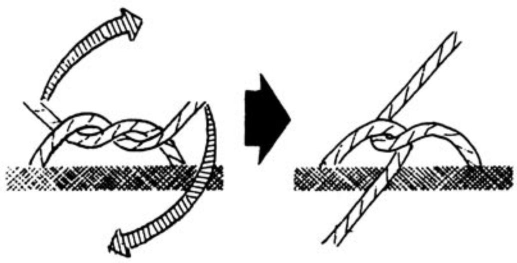


8.3.2. Tying under tension

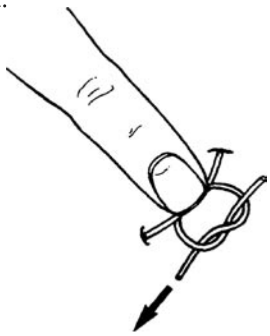
In general terms, tying knots under tension should be avoided. However, there are some circumstances when this can not be prevented. If knots have to be tied with threads which draw together two structures under tension, or around bulky elastic ducts that must be occluded, the slipping of the first half-hitch must be avoided while the second is being formed. This can be achieved by the following means:

1. After the first half-hitch has been tightened, a little tension is kept on the threads while the second half-hitch is formed and tightened.

2. After the first half-hitch has been tightened by pulling the threads in the correct line, they are sharply rotated to hold the first half-hitch, while the second hitch is formed.



3. The assistant's finger may be pressed on the tightened first half-hitch; the second hitch is formed and tightened onto it beneath the trapping finger, which is gently lifted.

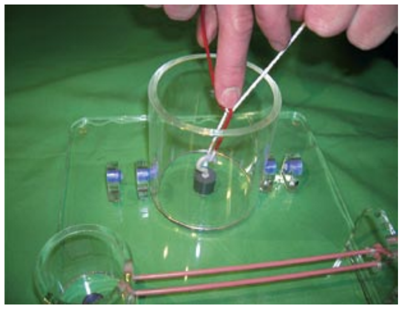


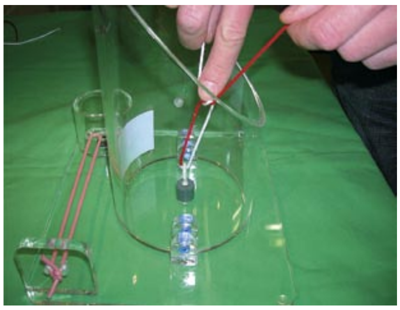
4. The extra friction produced by a second turn on the first hitch of a surgeon's knot may be sufficient to hold the tension while the second hitch is formed and tightened.

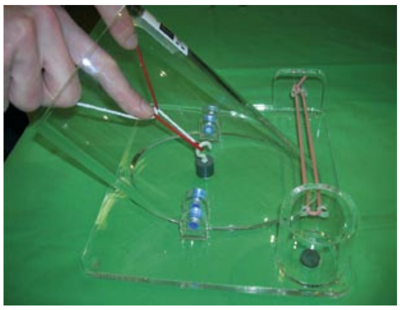
8.3.3. Tying knots in cavities

When a knot is tightened within a cavity, it is not always possible to pull the threads in opposite directions in the horizontal plane, yet they must be tightened by pulling with equal force in opposite directions. In some situations, it is easier to form the half-hitch in a large loop outside the mouth of the cavity and to tighten this, rather than to form a half-hitch in the depths of the cavity.

Tightening a knot in a cavity can be practised on practice boards with different shapes.



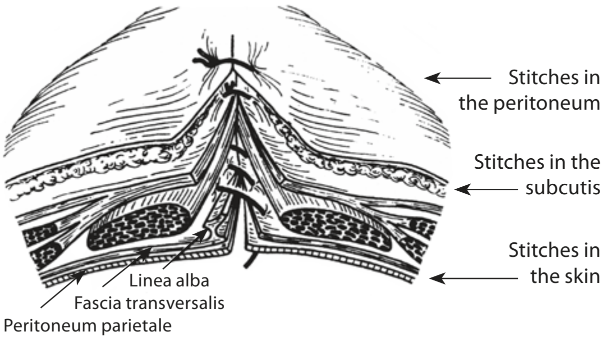




Practising of knot tightening in a cavity with a small aperture (left), in the abdomen (middle) or in the pelvis (right).

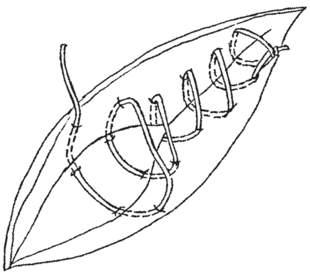
9. Wound closure in separate layers

Sutures involving multiple layers are demonstrated on a laparotomy site.



9.1. Approximation of tissues in the depths

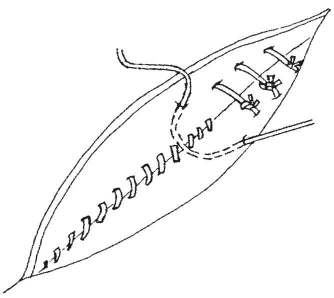
A lower incision of the abdominal wall is always closed with a continuous suture.



Continuous sutures should always be performed with the aid of an assistant. After the first knot has been finished, the short thread should be cut, but the remaining long one should be kept continuously under tension by the assistant. The tension on the long thread should be restored after each stitch.

9.2. Closure of the subcutis

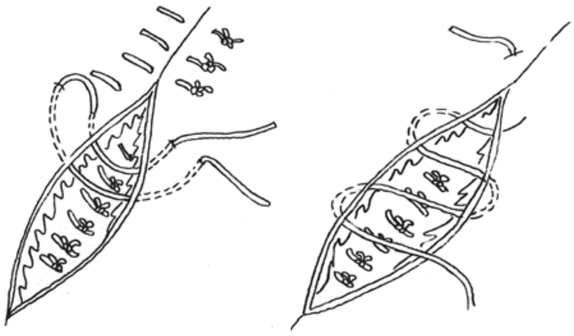
As the diagram shows, stitches in the subcutis should be placed appreciably deep, as far from the skin stitches as possible.



Although the subcutis seems to be smooth and vulnerable, stitches placed into it contribute significantly to the security of wound closure and help to prevent hernia formation in the abdomen. Stitches in the subcutis should not be placed closer to the skin, because this makes stitching of the skin difficult and leads to the formation of space (tunnel) close to the base of the wound. This may lead to the accumulation of body fluids.

The threads are cut only after of all the stitches have been completed. This clearly exposes the layer.

9.3. Skin stitches



Donati stitches and Intracutaneous stitches (see above)

10. Drainage

Drains are inserted to empty existing fluids and those that might collect later. Drains are used to channel pus, blood, body secretions or air in order to alleviate pain and inflammation. They prevent the build-up of tension and the formation of spaces which would keep tissue surfaces from coming into contact with each other and healing.

Main types of drains

A. Passive (without suction) drain types are strips, tubes or bands made from the fingers of surgical gloves. These drains are usually laid into the wound or on the base of a cavity and enter the surface through a distinct aperture.

B. Active drainage with suction.

10.1. Passive drainage

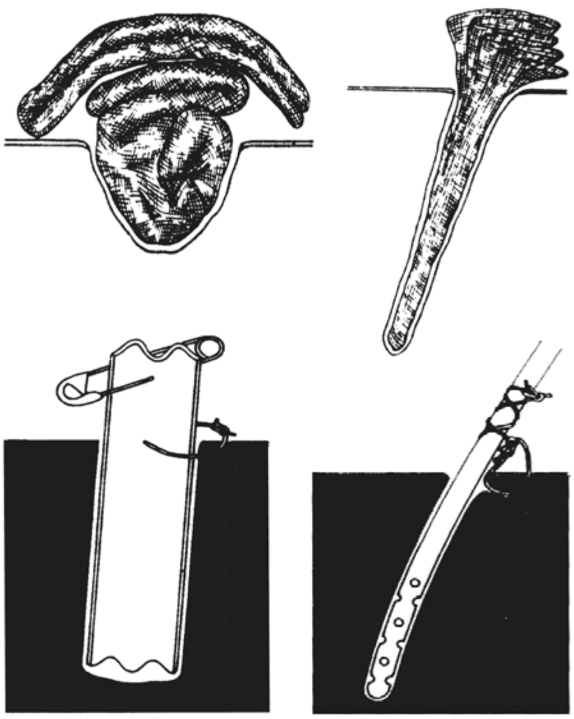
Historical methods

- Gauze pads were earlier used for the packing of wounds with folded sheets of cotton gauze to absorb the discharge from wounds or to treat infected wounds. Because of the deposition of fibrin their removal was painful and the suture area could be damaged. Soaking with fluid was therefore applied upon removal.

- When the source of drainage cannot be fully exposed or brought close to the surface, a wick can be passed down. This is the *Mikulicz* drain (after Jan Mikulicz-Radecki (1850–1905), a professor of surgery in Cracow, one of the discoverers of gastroscopy). It rapidly becomes wet, swells and often occludes the movement of fluid discharge.
- When the fluid reaches the surface, it should be soaked up by gauze packs sutured to the skin.

Modern methods

- The track can be kept open with corrugated sheet drains made of rubber or plastic. Tube drains are supplied with multiple holes, made of silicone, rubber or latex. These also should be secured in place by sutures.
- The *Penrose* drain (after Charles B. Penrose (1862–1925), an American gynecologist) is a tube drain.
- The *Delbet* drain (after Pierre Delbet (1861–1957), a French surgeon) is a corrugated sheet drain.



Passive drainage with gauze pads (tampons) (A), a gauze wick (B), a rubber wick (C) or a tube drain (D).

10.2. Active drainage (with negative pressure): open, open-closed and closed tube systems

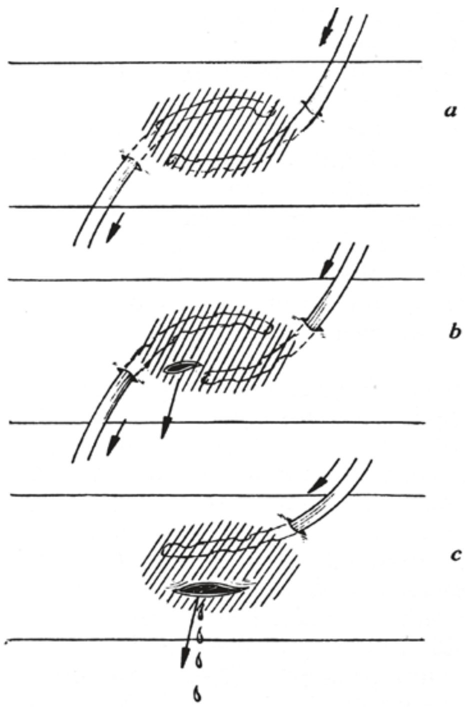
- In a partially closed system, a fenestrated tube leaves the body through a distinct aperture and is connected to a sterile reservoir (*Robinson* drainage).
- Low-pressure suction can be used with a compressible harmonica bottle (Polyvac).
- A closed system with strong active suction involves the use of a *Redon* drain (an ~ 50 cm-long plastic tubing visible under X-rays and with perforations).

Suction drainage (e.g. *Redon* drain)

A tube drain (made of silicone or plastic) supplied with multiple holes is used. It reaches the surface at an aperture separate from the wound. The tube is secured to the skin and connected to a sterile bottle in which subatmospheric pressure (“vacuum”) has previously been created. This bottle will suck out the discharge as long as the pressure is lower than that in the cavity.

Rinsing drainage (*Willinegger*)

Lactated *Ringer* solution with or without antibiotics is introduced into the wound via a closed system and the rinsing solution is continuously removed with a suction drain. This is particularly advantageous in cases of infected wounds (and improves wound healing).



Rinsing drainage with closed (a), partially closed (b) or (c) open systems.

10.3. Important localizations of drainage

Localization	Drains	Alternatives
Subcutis	Gauze or rubber wicks, tube drains	Open wound management
Subfascial, intramuscular	Less suitable	Leaving the fascia open
Extraperitoneal	A tube drain through a separate stab wound	Open wound management
Intraperitoneal	A tube drain through a separate stab wound. It often becomes obliterated.	
Pleural cavity	Mostly for the removal of air, introduced at the upper part of the 7^{th} and 8^{th} rib into the intercostal space. The drain is connected to a bottle containing vacuum and fluid.	
Abscess, cysts	Tampon, gauze or rubber wicks, tube drains	Open wound management
External fistulas	Drainage is usually not applied, but the spontaneously flowing discharge can be attached to collecting stoma bags or can be suctioned through a cannula.	Surgical management if possible

10.4. Drain removal

- A drain is a foreign body (!)
- Indications for removal: reduced fluid production and altered cell constitution (cell type or number).
- In the event of postoperative bleeding: within 1–2 days.
- In the event of bacterial infection: within 2–5 days.
- Closure of a cavity or dead space: within 3–14 days.

V. The operation

"With us ther was a doctour of phisik;
In al this world ne was the noon hym lik,
To speke of phisik and of surgerye."
The Canterbury Tales by Geoffrey Chaucer (? – 1400)

The word surgery originates from the Greek *cheirourgia*, meaning "*hand work*". Surgery is a branch of medicine concerned with the diagnosis and treatment of injuries, and the excision and repair of pathological conditions, by means of operative procedures. An operation is therefore a therapeutic or diagnostic procedure with instruments with the aims of recognizing or repairing damage or arresting disease in a living body. Most commonly, it is an act or series of acts performed to remedy a deformity or injury, cure or prevent diseases, or relieve pain or other symptoms. The parts of the operation are 1. opening (entry into the body by incision, puncture, etc.), 2. intervention, and 3. closure. Depending on the aim, curative (radical) and symptomatic (palliative) operations are distinguished.

1. Basic surgical interventions

- Closing an incision, wound or cavity (*suture*)
- Opening the skin or cavity *(-tomy, -puncture*)
- Moving organs or tissues (- *transplantation*)
- Removing tissue, an obstruction or a blockade (– *resection, amputation, - ectomy*)
- Connection within an organ, or between organs *(-stomy, anastomosis*)
- Separation or elimination of pathological connections (*extirpation*)
- Restoration or repair of normal anatomy (*-plasty*).

2. Preparations for an operation

- **Indications and contraindications**: These are involved in the decision-making as to whether or not to carry out a given operation, i.e. the decision before the intervention. There are different levels. The indications for surgery should be clearly known, as these will determine the urgency of the procedure.
- **Vital indications** (*indicatio vitalis*): These are involved in the case of life-saving procedures. The patient can be treated only with an operation (100% mortality without operation). The timing has narrow limits, and the possibility of evaluation and deliberation is very limited.
- **Absolute indications** (*indicatio absoluta*): These are involved in urgent procedures. The disease can be treated primarily with an operation. The time can be chosen (the operation can usually be delayed for 12–24 h to allow further evaluation). The surgeon makes a decision as to the type of operation which may be considered the most effective, and in agreement with the anesthesiologist determines the optimal time of the operation.
- **Relative indications** (*indicatio relativa*): These are factors in elective procedures, i.e. programmed operations, the aim of which is to cure the patient or to improve a condition (the disease can be treated with surgery or otherwise). The condition leaves time for a full evaluation and optimization before the operation.

3. Informed consent

1. After having been fully informed concerning the state of health that may be expected following the operation, together with the possible complications and consequences of such a regularly performed operation, patients acknowledge their approval of the intervention by their signature on a printed form.
2. If the patients are under the ages of legal consent, their legal representatives must be informed and their permission must be obtained in writing.
3. The physician makes an effort to clearly instruct a patient capable of learning. The physician who makes this effort and obtains consent has met both the legal and ethical obligations imposed upon him or her by society. The surgeon should be prepared for the possibility of a complication. In surgical cases, the rates of complication (as percentages of all operations) are as follows:

Infections:	14.3%
Wound infections:	5.1%
Pneumonia:	3.6%
Urinary infections:	3.5%
Sepsis:	2.1%
Intubation:	2.4%
Respiration > 1 day:	3.0%
Acute myocardial infarction:	0.7%

To obtain informed consent that meets ethical obligations and is acceptable to a court of law, the following information must be provided:

- The nature of the disease and the proposed treatment or surgery.
- The chances of success, based on medical knowledge.
- The known risks of the proposed treatment or procedure.
- The known adverse effects of the proposed treatment or procedure.
- Reasonable alternatives and their chances of success, risks and adverse effects.
- The consequences of deciding not to proceed with the recommended course of treatment.

4. Operative risk

- The most important general factors involved in the determination of the operative risk are as follows:
  - The operative risk comprises the summation of the surgical and anesthesiological risks, which have their own aspects.
  - The preoperative examination must answer the questions of both surgeon and anesthesiologist, allowing them to give their agreed opinion in writing.
  - In the event of a stable condition, 1-month-old findings could be acceptable. In urgent cases, an effort is made to minimize examinations.
- From the aspect of risk, operations can be divided into three main groups:

1. Low-risk surgery: Minor operations belong in this group (e.g. inguinal hernia repair or arthroscopy), where the expected blood loss is less than 200 mℓ.
2. Medium-risk surgery: Surgical interventions of medium severity can be classified here (the expected blood loss is less than 1000 mℓ), e.g. tonsillectomy, cholecystectomy, transurethral prostatectomy.
3. High-risk surgery: Extended abdominal, thoracic and intracranial operations fall into this category. The blood loss exceeds 1000 mℓ. The patient needs postoperative intensive care and treatment. The rates of postoperative morbidity and mortality are high (e.g. liver resection or pulmonary lobectomy).

- Additional classification is possible on the basis of the scheduled time of the intervention:
  A. Life-saving operations: The mortality would be 100% without intervention (e.g. bleeding).
  B. Urgent operations: The patient would suffer permanent organ lesions without surgery. The intervention can be delayed for a short time to improve the patient's condition. The postoperative morbidity and mortality are high (e.g. bone fractures).
  C. Elective operations: The intervention can be delayed in the interest of the improvement of the patient's state (e.g. hernia repair).

The classification of patients on the ASA (*American Society of Anesthesiologists*) grading system (the most commonly used grading system) accurately predicts the operative morbidity and mortality. Thus ~ 50% of patients undergoing elective operations belong in ASA grade I, for which the operative mortality is < 1:10.000.

Grade	State of health of the patient	Mortality
I	Healthy	0.1%
II	Mild systemic disease	0.5%
III	Severe systemic disease	4%
IV	Decompensated life-threatening diseases	24%
V	Moribund state*	51%

* Not expected to survive 24 hours with or without surgery

4.1. Acute risk factors in surgery

- Hypovolemia or dehydration (most common).
- Inflammation (bronchial tract, urinary tract, gastrointestinal tract, etc. diffuse or localized conditions).
- Thromboembolism.
- An acute organ dysfunction.
- An acute endocrine imbalance (pancreas – diabetes, thyroid – hyperthyreoidism, adrenocortical insufficiency – Addison disease).

4.2. Chronic risk factors in surgery

- Hypovolemia (anemia).
- Age (over 65 years).
- Malnutrition or obesity.
- An immunological dysfunction (allergy or immunodeficiency).
- Cardiovascular, pulmonary or cerebrovascular disease
- A chronic renal insufficiency.
- A chronic endocrine insufficiency.
- Bleeding disorders.
- Malignancies.
- Chronic alcoholism.
- Drug abuse.

5. Preoperative management

The preoperative management of a patient with a surgical problem involves a *diagnostic work-up* to determine the cause and the extent of the patient's condition: a *preoperative evaluation* (a thorough, overall assessment of the patient's health to identify operative risks, the patient's chronic diseases, medical therapies, etc. that may influence the recovery period) and *preoperative preparation*.

Recommended investigations	Patient groups
Minimal (routine) laboratory	ASA I, ASA II
Routine hematological testing, total blood count	Males over 60 years, all adult females, cardiovascular and hematological diseases.
Chest X-ray	Cardiovascular and thoracic diseases, malignancies, upper abdominal and thoracic surgery.
Complete urine test	Age over 60 years, cardiovascular, renal and urological diseases, diabetes, steroid therapy, ACE inhibitors.
Quantitative hematological tests	Males over 60 years and all adult females.
ECG	Males over 40 years, females over 50 years, cardiovascular diseases, diabetes

5.1. Evaluation of preoperative investigations

Preoperative investigations are important and obligatory, but their value is not absolute.

- Preoperative investigations rarely (< 5%) reveal unsuspected disease conditions.
- They are inefficient as a means of screening for asymptomatic disease.
- Only 0.1% of these investigations ever change the patients' management.
- 70% of preoperative investigations could be omitted without any adverse effect.
  (Reference: *Barnard NA et al. Preoperative patient assessment: a review of the literature and recommendations. Ann Royal Coll Surg Eng, 1994*)

6. The preoperative preparation

Definition: A series of procedures that make the patient suitable for the planned intervention and ensure the optimal conditions for the operation. These procedures are implemented on the basis of the nature of the expected operation and the findings of the diagnostic work-up and the preoperative evaluation. This will allow specific measures to be taken so that the patient may be in the best possible condition for both anesthesia and surgery. The functions of the organs and organ systems should be controlled and restored if necessary:

- Cardiovascular system
- Respiratory system
- Metabolic status
- Renal function
- Liver function
- Endocrine balance
- Ion homeostasis
- Immunological status
- Energetics

7. Postoperative complication

A postoperative complication may be *defined* as any negative outcome appearing during or after the operation, as perceived either by the surgeon or by the patient, that can influence the healing of the patient. Principles of prevention:

- In the preoperative phase a proper investigation-preparation is needed.
- During the operation, careful anesthesiology procedures and fine surgical techniques should be used.
- Postoperatively, careful control, attention, checks on temperature, BP, HR, respiration, urine output, bowel movements, etc., early mobilization, and regular checks on drains, catheters and wounds are needed.

Classification of complications

Complications can be associated with:

- medical specialties, e.g. anesthesiology or surgery;
- the time of occurrence (before, during or after the operation);
- the site of operation (e.g. the thorax or abdomen);
- the primary disease (external conditions);
- the type of the operation (vital – elective).

7.1. Complications of anesthesia

The mortality rate for surgical patients is 1:200,000–250,000 narcose.

Nerve injuries (due to the positioning of the patient)

- Brachial plexus
- Ulnar nerve
- Radial nerve
- Common peroneal nerve

Tissue injuries

- Corneal abrasion (during the control of the cornea reflex)
- Fracture of teeth or crowns, etc. (during intubation)
- Diathermy burns
- Dislocations or fractures
- Pharyngeal or esophageal injuries

Narcosis

- Drug reactions
- Hypoxia
- Awareness
- Temperature changes (hypo- or hyperthermia)
- Aspiration

7.2. Complications depending on the time of occurrence

7.2.1. Intraoperative complications

- Bleeding (see later)
- Temperature changes (hypo- or hyperthermia)
- Organ lesions
- Circulatory, respiratory or renal disturbances, etc.

7.2.2. Postoperative complications

- Postoperative fever
- Wound healing complications
- Postoperative nausea and vomiting
- Respiratory disorders, cardiovascular complications, urinary excretion disorders, ion and water homeo-

stasis disorders, hemostasis disorders, gastrointestinal function disorders, neurological disorders, and metabolic disorders (subjects of anesthesiology and internal medicine).

7.2.2.1. Postoperative fever

- Postoperative subfebrility is common within 48–72 h. If prolonged, it can indicate an inflammatory process (phlebitis caused by an intravenous cannula, an infection caused by a urinary catheter etc.), but it can also be associated with the primary disease.
- Fever within 24 h is most frequently caused by atelectasis, and rarely by the Streptococcus and Clostridium infection of wounds.
- Fever appearing between 24 and 48 h is caused by long-lasting atelectasis, bacterial pneumonia, aspiration pneumonia or septic thrombophlebitis.
- Fever developing after 72 h is caused by a urinary tract infection (days 3–5), wound inflammation (days 4–7), the insufficiency of intestinal anastomosis, or an abscess in the abdominal cavity (approximately after the first week).

7.2.2.2. Complications of wound healing

Hematoma
Cause: Inefficient control of bleeding, a short drainage time or anticoagulation therapy. The risk of infection is high. *Signs:* Tenderness, swelling, fluctuation, pain and redness. *Treatment:* In the early phase, sterile puncture; later, surgical exploration is required.

Seroma
Cause: The collection of serous fluid under the suture line; the wound cavity is filled with serous fluid and lymph. *Signs:* Fluctuation, swelling, pain and subfebrility. *Treatment:* Sterile puncture, compression, if repeated, and a suction drain (drainage to alleviate pain and tension of the wound by using a large-bore needle and syringe); in cases of infection: antibiotics.

Wound infections
See sections I.4 and X.3.

Wound disruption
Etiology: Surgical error is the most common cause. Excessive tension on the wound and tight sutures strangulate the wound edges, causing necrosis and decreased strength (motto: “O*nly approximation; if strangulation, then evisceration*”). This is a complication of the tissues, not of the suture material (in the majority of cases, intact sutures are found). The use of electrocautery coagulation decreases the tensile strength of wounds by increasing inflammation in response to necrotic tissue.

Incisional (scar) hernias are typical consequences of a *chronic* wound disruption. An *acute* wound disruption involves the deeper layers first and finally the skin.

The major types are:
- Partial, superficial (dehiscence)
- Complete separation (disruption)
- An intestinal protrusion together with peritoneum disruption across the wound with eventeration and evisceration (sterile separation of the abdominal wall: “*Platzbauch*”).

  Risk factors of disruption are:

Metabolic causes
- Malnutrition
- Poorly controlled diabetes
- Corticosteroids
- An older age (> 65)
- Malignancies

Mechanical causes
- Obesity
- Increased intraabdominal pressure, and abdominal distension (including ascites)
- Wound infection
- Stretching and coughing

Symptoms:
This situation is generally manifested within 5–14 days following surgery (on average 8 days later); the warning sign is a pink oozing (secretion) from a seemingly intact wound.

Therapy:
- Immediate intervention is usually needed, always in the operating room under narcosis, and never in the emergency room or ward.
- The wound is covered by a povidone-iodine sheet or a wide abdominal kerchief is applied. If the intervention must be prolonged (i.e. because of a recent meal), broad-spectrum antibiotics and laboratory investigations are needed.
- During the operation, necrotic tissues, clotted blood and old sutures are eliminated. A sample is taken from the abdominal excretion for bacteriological examination, and then a plentiful wash with warm saline solution is applied. If the fascia is intact, the wound should be closed by *Smead-Jones* technique, which is similar to *Donati* suturing. In the event of a damaged fascia a retention suture is used (with #2.0 nylon or polypropylene thread).
- To relieve tension, a U-type *en masse* suture is used. This is removed after 21 days on the average.

7.2.2.3. Postoperative nausea and vomiting

- These are among the most common side-effects of narcosis associated with surgical procedures (the incidence is 5–30%); they delay recovery and discharge and increase the postoperative morbidity and the costs of medical care.
- Complications related to postoperative nausea and vomiting include possible wound disruption, esophageal tears, gastric herniation, muscular fatigue, dehydration and an electrolyte imbalance.
- The etiology involves vagotonia and dehydration (an extracellular fluid loss). Preoperative fasting for 8 h is equivalent to a loss of 1 ℓ volume/70 kg bw.
- The risk is increased in cases involving preoperative preparation of the gastrointestinal tract, in geriatrics and infants; other factors are obesity, ascites, burns, trauma, ileus, peritonitis, late operative programs, perspiration, narcotic gas without evaporation, blood loss, urine loss, or the loss of other body fluids (ascites and gastrointestinal content).

7.3. Complications associated with the operative field

Abdominal cavity

- Bleeding
- Hemoperitoneum
- Peritonitis
- Biliary leakage
- Foreign body
- Acute complications of drains
- Anastomosis insufficiency
- Ileus (small and large intestine)
- Gastric atonia
- Abscess
- External fistulas (enterocutaneous fistulas: gastric, duodenal, pancreatic, and small and large intestines)
- Internal fistulas (entero-enteral, entero-vesical, etc.)
- Postgastrectomy syndromes: dumping, afferent loop and reflux gastritis
- Gastrointestinal bleeding
- Postoperative pancreatitis or cholecystitis

(For other complications such as those of the thoracic cavity, skull, joints, etc.: see later or during the courses of the appropriate specialties.)

8. Minor surgery

By the end of the 19th century, general anesthesia had made surgery much safer (according to John Collins Warren: "G*entlemen, this is no humbug*"). The scope of surgery expanded; and methods of narcosis have subsequently progressed and become increasingly complex. Anesthesiology divorced practical surgery and became a separate subject during the second part of the 20th century. However, the overcoming of local pain (local anesthesia) is still the duty of the surgeon.

8.1. A short historical survey of local anesthesia

1860 Isolation of cocaine from *Erythroxylum coca.*

1884 Karl Koller (1857–1944): local cocaine (topical) anesthesia.

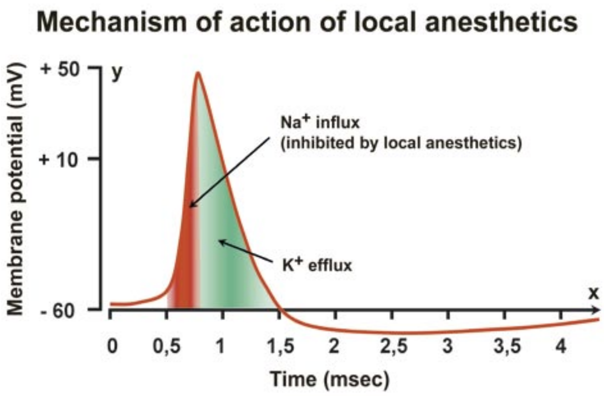
1885 William S. Halsted (1852–1922): peripheral nerve blockade.

1899 August Bier (1861–1949) tried spinal anesthesia on himself (because "*Ein Professor ist ein Herr, der anderer Ansicht ist*" – A professor is a gentleman with a different point of view).

1908 August Bier: intravenous regional anesthesia.

8.2. Local anesthetic drugs

Definition: Local anesthesia is the regional loss of sensation caused by a substance which reversibly inhibits nerve conduction when applied directly to tissues in nontoxic concentrations.



Mechanism of action of local anesthetics: By limiting Na^+ influx, local anesthetics inhibit the depolarization of the membrane, thereby interfering with propagation of the action potential. The action potential is not propagated because the threshold level is never attained.

8.2.1. Main classes, the "I" rule and the dangers of local anesthesia

Amide	Ester
Bupivacaine	Cocaine
Lidocaine	Chlorprocaine
Ropivacaine	Procaine
Etidocaine	Tetracaine

Amino esters are metabolized in the plasma via pseudocholinesterases, they are unstable in solution, and are likely to cause true allergic reactions. Amino amides are metabolized in the liver; they are very stable in solution; true allergic reactions are rare (patient reports of "allergy" are frequently due to previous intravascular injections, e.g. tonogen). Most reactions of esters such as hydrolysis (normal metabolism), lead to the formation of PABA–like compounds. Tissue toxicity is rare. It can occur if these compounds are administered in high enough concentrations (greater than those used clinically), which is usually related to the preservatives added to the solution. Systemic toxicity is rare. It is related to the blood level of drug secondary to absorption from the site of injection; the effects can range from tinnitus to seizures and central nervous system/cardiovascular collapse.

8.2.2. Dosage of local anesthetics and duration of anesthesia

Drug	Onset	Maximum dose (with epinephrine)	Duration (with epinephrine)
Lidocaine	Rapid	4.5 mg/kg	120 min
		(7 mg/kg)	(240 min)
Bupivacaine	Slow	2.5 mg/kg	4 h
		(3 mg/kg)	(8 h)
Procaine	Slow	8 mg/kg	45 min
		(10 mg/kg)	(90 min)
Chloro-procaine	Rapid	10 mg/kg	30 min
		(15 mg/kg)	(90 min)

8.3. Main types

Local – topical anesthesia
Definition: Application of a local anesthetic drug to the mucosa or cornea. *Indications:* Awake oral or nasal intubations, in cases of superficial surgical procedures. *Pros:* Technically easy; minimal equipment. *Cons:* Potential for large doses leading to toxicity.

Local – infiltration anesthesia
Definition: This is the injection of a local anesthetic agent into the tissues for the reversible inhibition of nerve conduction within the area of operation. *Indication:* Awake minor surgery (e.g. inguinal herniotomies). *Pros:* Complete loss of pain sensation. *Cons:* The noises, etc. of the operations are present.

Regional anesthesia
Definition: This renders a specific area of the body, e.g. a foot, arm or lower extremity insensate to the stimulus of surgery or other instrumentation. Peripheral nerve blocks are achieved by injecting anesthetic solution around a nerve root to produce anesthesia in the distribution of that nerve (e.g. a foot, hand or other extremity).

A. Peripheral nerve block
This involves the injection of a local anesthetic near the course of a named nerve. *Indications:* Surgical procedures in the distribution of the blocked nerve. *Pros:* A relatively small dose of local anesthetic to cover a large area; the onset is rapid. *Cons:* Technically more complex; neuropathy can evolve.

B. Spinal (intradural)
This is a central neuro-axial blockade with the injection of a local anesthetic solution into the cerebrospinal fluid. *Indications:* Deep anesthesia of the lower abdomen and extremities. *Pros*: Technically easy; rapid onset. *Cons:* "High spinal" – hypotension due to sympathetic blockade; headache (dura puncture).

C. Peridural (extradural)
This comprises central neuro-axial blockade with the injection of a local anesthetic solution into the epidural space at any level along the spinal column. *Indications:* Thorax, abdomen or lower extremity anesthesia/analgesia. *Pros:* Controlled onset of blockade; long duration when a catheter is placed; postoperative analgesia. *Cons*: Technically complex; toxicity.

VI. The perioperative period

"The likelihood of successfully initiating an intravenous line is inversely proportional to the necessity of having the line to resuscitate the patient"
(The Law of Intravenous Access Necessity)

The exploration of the physiological–pathophysiological processes in the perioperative period began at the end of the 19th century and such investigations are continuing today. The observations made have led to the much safer pre- and postoperative procedures of modern surgery, which are used before and after the operation to ensure the safe recovery of the patients. The surgical preoperative management now relates to all organs and systems.

1. General preoperative preparation

1.1. Rules, interventions

- Psychological support (to release fear and anxiety) through the provision of information.
- Removal of cosmetics, contact lenses, dentures, etc.
- Menstruation is not a contraindication; the operation need not be postponed.
- Toilette (bathing and shaving).
- Fasting (an "empty stomach" to prevent vomiting and aspiration).

The goals of fasting are to prevent aspiration by decreasing the gastric content, but avoiding thirst and dehydration. Aspiration is a serious, frequently lethal complication. In elective cases, the incidence is 1:10,000; and the death rate is 1:200,000 (*Warner MA et al. Anesthesiology, 1993*). The process originates from Lister, who stated that: "*there should be no solid matter in the stomach, but patients should drink clear liquid about 2 hours before surgery.* (*Lister J. On Anaesthetics. In: The Collected Papers of Joseph, Baron Lister, Volume 1, 1909*). A study in the 1970s demonstrated that a gastric content of 0.4 mℓ/kg (i.e. ~ 25 mℓ in adults) and a pH < 2.5 are associated with high risk of aspiration (*Roberts RB, Shirley MA. Anesthesia and Analgesia, 1974*). The present recommendation of "nothing by mouth after midnight" should apply only to solids for patients scheduled for surgery in the morning. Clear liquids should be allowed until 3 h before the scheduled time of surgery. For patients with gastroesophageal reflux, a histamine H_2-receptor blocker or proton pump inhibitor may be advisable to minimize gastric acid secretion.

ASA fasting guidelines

Ingested material	Minimum fast
Clear liquids	2 h
Breast milk	4 h
Non-human milk	6 h
A light meal	6 h

1.2. Medication

- Premedication for sedation, analgesia and inhibition of undesired reflexes.
- Antibiotic prophylaxis (if necessary, e.g. before a septic operation).

1.3. Instruments

- Injections, securing intravenous routes for fluid therapy, drug administration or transfusion (if necessary; see later).
- Emptying the intestines (enemas and laxatives).
- Nasogastric catheter (if necessary; see later).
- Permanent urinary catheters (if necessary; see later).
- Thrombosis prophylaxis.

2. Special preoperative preparation

2.1. Depending on the type of the operation

- Before strumectomy in cases of hyperthyroidism: β-blocker, sedatives, *Plummer* solution (iodine-containing solution), securing airways.
- Operation for mechanical icterus: Vitamins K and C, fresh frozen plasma and placing stents to secure bile drainage.
- Removal of stomach tumor: Gastric lavage, acid replacement, etc.
- Colon surgery: Laxatives, enemas, potassium replacement (hypokaliemia).

2.2. Preoperative preparation depending on the (organ) system

- Acid-base system.
- Respiratory system: Lung diseases predispose to respiratory complications. General preoperative investigations should be supplemented with chest X-ray examination, spirometry and arterial blood gas analysis.

- Airway infections increase the risk of postoperative chest complications; in this case, the elective operation should be postponed for 2–4 weeks. In smokers the risk of postoperative chest complications is doubled. The increased risk persists for 3–4 months after they give up smoking; smoking increases the blood carboxyhemoglobin level, the concentration remaining elevated for 12 h after the last cigarette.
- Endocrine system (e.g. diabetes mellitus): The pre- and perioperative management depends on the severity of the disease. 1. In diet-controlled diabetes there are no specific precautions; a check on the blood sugar and consideration of glucose-potassium-insulin (GKI) infusion if >12 mmol/ℓ (15 U of insulin + 10 mmol of KCl + 500 mℓ of 10% dextrose/100 mℓ/h) is enough. 2. In diabetes treated with oral antidiabetics: long-acting sulfonylureas are stopped 48 h prior to surgery; short-acting agents should be omitted in the morning of the operation; earlier treatment should be restarted when the patient is eating normally; a GKI infusion is given in major surgery. 3. Insulin-dependent diabetes: conversion of long-acting insulins to 8-hourly Actrapid; early placement on the operating list; GKI infusion until the patient is eating normally.
- Gastrointestinal system (see later).
- Circulatory system (see later).

3. The perioperative fluid balance

3.1. General rules

Careful planning and maintenance of the perioperative fluid balance is *mandatory*; a regular review of the fluid therapy is essential before and after surgery. Patients are more often underfilled than overloaded. Dehydration (which can be difficult to assess in the elderly) can precipitate renal failure, while excess fluids can cause pulmonary edema. Measurement of the central venous pressure (see later) should always be considered with large fluid shifts.

Perioperative fluid therapy requires a knowledge of the body water compartments. The total body water (TBW) varies with age, gender and body habitus. In males, the TBW is ~ 55% of the bodyweight (bw); it is 45% in females and 80% in infants. The TBW is less in the obese because fat contains less water. The approximate proportions of the body water compartments: the intracellular water is 2/3 of the TBW, extracellular water is 1/3 of the TBW, the extravascular water is 3/4 of the extracellular water, while intravascular water is 1/4 of the extracellular water.

The preoperative evaluation of the fluid status includes monitoring of:

- the oral intake and output,
- the BP in the supine *and* standing positions,
- the HR,
- the skin turgor,
- the urinary output,
- the serum electrolytes/osmolarity, and
- the mental status.

Checking for orthostatic hypotension may be very useful. In this case, the systolic BP decreases by more than 20 mmHg from the supine to the standing position, indicating a fluid deficit of 6–8% bw.

Note: The HR should increase as a compensatory measure. If there is no increase in HR, this may indicate an autonomic dysfunction or antihypertensive drug therapy.

3.2. Perioperative fluid requirements

These are determined by several components; to assess the needs, several points should be considered.

1. There is a basic or continuous fluid requirement. This loss occurs continually: in adults, it is ~ 1.5 mℓ/kg/h, in infants the "4-2-1 rule" is valid: 4 mℓ/kg/h for the first 10 kg of bw; 2 mℓ/kg/h for the second 10 kg bw; and 1 mℓ/kg/h for any subsequent kg bw. In addition, an extra fluid loss is calculated for fever, tracheotomy or denuded surfaces.
2. Colon preparation may result in a fluid loss of up to 1000 mℓ.
3. Other measurable fluid losses (e.g. on nasogastric suctioning, vomiting, diarrhea and colostomy) should be reckoned with.
4. Third space losses: These cover the isotonic transfer of extracellular fluids from *functional* body compartments to *non-functional* compartments. This depends on the location and duration of the surgical procedure, the amount of tissue trauma, the temperature and the room ventilation. Replacement of third space losses is as follows:
   - Superficial surgical trauma: 1–2 mℓ/kg/h
   - Minimal surgical trauma: 3–4 mℓ/kg/h (head and neck, hernia and knee surgery)
   - Moderate surgical trauma: 5–6 mℓ/kg/h (hysterectomy and chest surgery)
   - Severe surgical trauma: 8–10 mℓ/kg/h or more (aortic repair and nephrectomy)
5. In the event of blood loss, 1 mℓ of blood is replaced by 3–4 mℓ of crystalloid solution (crystalloid solutions leave the intravascular space; see later). When blood products or colloids are used, blood loss is replaced volume per volume (1:1).

4. Intravenous fluids

The choices are conventional crystalloids, colloids, hypertonic solutions, blood/blood products and blood substitutes.

4.1. Crystalloids

These are combinations of water and electrolytes. Isotonic crystalloids are balanced salt solutions: the electrolyte composition and osmolarity are similar to those of plasma:

- Saline (0.9%, normal salt) solution:
  Na^+ 154 meq/ℓ, Cl^- 154 meq/ℓ
- Lactated *Ringer's* (*Hartman* solution):
  Na^+ 130 meq/ℓ, Cl^- 109 meq/ℓ, K^+ 4 meq/ℓ, lactate$^-$ 28 meq/ℓ, Ca^{++} 3 meq/ℓ
- Normosol-R:
  Na^+ 140 meq/ℓ, Cl^- 90 meq/ℓ, K^+ 5 meq/ℓ, Mg^{++} 3 meq/ℓ
- Plasmalyte:
  Na^+ 140 meq/ℓ, Cl^- 98 meq/ℓ, K^+ 5 meq/ℓ, Mg^{++} 3 meq/ℓ
- Hypotonic salt solution: the electrolyte composition is lower than in the plasma; example: dextrose 5%.

Isotonic crystalloids remain in the extracellular space (the interstitial place is 3 times larger than the intravasal space), and absorb less water from the intracellular space because of their mildly increased tonicity. Following the infusion of 1 ℓ of crystalloid, there is an ~ 275 mℓ increase in plasma volume. The Na^+ content of normal saline (0.9%) is 154 meq/ℓ and that of lactated *Ringer*'s solution is 140 mEq/ℓ; thus, normal saline is advantageous for *hyponatremic* patients (but its pH is 5.5). Saline can cause hyperchloremic acidosis when infused in larger volumes. Lactated Ringer's solution has pH 6.5. The lactate component is converted to bicarbonate if the liver function is normal, but it causes metabolic alkalosis when given in larger amounts. With an abnormal liver function, lactate accumulates and metabolic acidosis evolves.

The electrolyte composition of hypotonic salt solution (e.g. 5% dextrose) is lower than that of the plasma. A 5% dextrose solution is equally distributed in the TBW, and thus an increase of 85 mℓ in plasma volume occurs after the infusion of 1 ℓ of dextrose. Its indication is *hypernatremia* or the treatment of an increased plasma osmolarity, rather than volume replacement.

4.2. Colloids

These solutions contain macromolecules which remain in the intravasal space in much higher volume than do crystalloids. Thus, their volume-expanding effect is more significant (there is no capillary membrane transport because of the size of the molecules, and such solutions will remain in the space into which they are infused). There are variations depending on the properties and effects within the same colloid group. Examples of natural colloids (protein-containing) are 5% albumin and 25% albumin, while artificial colloids (non-protein containing) include gelatin, hydroxyethyl starch and dextran.

- ***Albumin***
  This is a natural (protein-containing) colloid, commercially available in 5% and 20% forms. The volume-active effect lasts for ~ 4–6 h; it increases the plasma colloid osmotic pressure and the intravasal volume by retaining water. If the capillary permeability is enhanced, a significant proportion effuses into the interstitial space, thereby increasing edema formation. Recent meta-analyses have led to conflicting conclusions, but albumin administration could be beneficial in hypo-albuminemic patients. Albumin administration combined with diuretic drugs results in an improved fluid balance, oxygenization and more stable hemodynamics in hypoproteinemic patients. Severe septic patients also respond well to albumin treatment.
- ***Gelatin***
  Gelatin originates from bovine (bone, sinew and skin) sources; it is on the average a 35,000 D polypeptide. It contains many lower molecular weight components, which move freely into the extravascular space, so that its intravascular volume-increasing effect is short, lasting for 1–2 h. It has relatively few side-effects (in higher doses it inhibits the thrombocyte function and worsens the quality of clot formation), but this is counterbalanced by an increased risk of allergic reactions or a theoretical chance of BSE. Its use in Europe is declining.
- ***Dextran***
  Dextrans are simple-chain carbohydrates of bacterial origin, with a high water-binding capacity, which are distributed with an average molecular weight 70,000 D or 40,000 D. They have an appropriate initial volume-expansion effect, which can be sustained for 3–6 h. They have severe side-effects: in doses of > 1.5 g/kg/day, they disturb blood coagulation, cause kidney failure, and increase the tone of the pregnant uterus. In spite of haptene prophylaxis dextrans

cause anaphylactic reactions most frequently among the artificial colloids. Their use as first-line volume expanders has declined, and overall, dextrans are not indicated for routine volume expansion. In special cases, their favorable effects on thrombocyte and leukocyte adhesions and inhibition of the inflammatory cascade system could be utilized therapeutically. The maximal dose is 20 mℓ/kg/day. They are currently being used less frequently; in 2004 they were administered to 8% of septic shock patients in Hungary.

- ***Hydroxyethyl starch (HES)***
  HES is a corn-derived modified amylopectine polymer, made resistant to the enzymatic effects of alfa-amylase in the plasma. The average molecular weight, substitution rate and C2/C6 hydroxyethylation rate account for the pharmacokinetics and side-effects. Today, two types of HES solutions are used with volume therapy goals in Hungary: a second-generation HES 200/0.5 infusion with 6% (isooncotic) or 10% (hyperoncotic) contents and a third line HES 130/0.4 6% product. These products eliminate the side-effects of the earlier HES solutions as concerns blood coagulation and the kidney function. HES is accumulated and broken down slowly in the reticuloendothelial system and does not activate the mononuclear-phagocyte system. Its intravascular volume-expansion effect lasts for 4–6 h. Anaphylactic reactions are rare, as compared with other colloids. The long-term use of HES may result in itching.

5. Perioperative fluid therapy in practice

There is no widely accepted routine recommendation for perioperative fluid therapy. The most important point is that preoperative dehydration (induced by starving, colon preparation, different diseases, etc.) must be corrected prior to the operation. Surgical specialties prefer liberal fluid therapy to the traditional one (5–15 mℓ/kg/h), because the stable hemodynamic state ameliorates the perfusion and oxygen supply of the tissues and therefore reduces postoperative complications, enhances restarting of the intestinal function, decreases nausea and vomiting, and shortens the duration of hospitalization. On the other hand, if there are major accompanying diseases, the administration of crystalloids in higher doses may result in significant side-effects (myocardial ischemia, a pulmonary function failure, a decreased oxygen supply of the tissues, and disorders in wound healing because of interstitial edema, prolonged paralytic ileus and metabolic acidosis). A controlled study of patients in the ASA I or II stages undergoing laparoscopic cholecystectomy demonstrated a better postoperative recovery when liberal (40 mℓ/kg/h) fluid therapy: was applied: the postoperative pulmonary function, exercise capacity and subjective recovery measures all improved (nausea, general well-being, thirst, dizziness, drowsiness and fatigue). Lung surgery seems to be the main indication of restriction of the perioperative fluid intake.

In surgical patients the effects of different solutions on hemostasis must be considered. Several studies have proved that crystalloids (independently of their type) increase the coagulability and decrease the serum level of antithrombin III. As regards postoperative bleeding, it is a benefit, but it may be harmful by worsening the perfusion of the tissues and increasing the likelihood of thrombosis. In colloids, albumin and gelatin do not influence the tendency to bleed; however, dextran and starch with a higher substitution level and with a higher molecular weight increase this tendency.

6. Clinical evaluation of the effectiveness of fluid replacement

The urine output is at least 1.0 mℓ/kg/h, while the BP and HR are in the normal ranges; on physical assessment, the skin and mucous membranes are not dry. The awake patient is not thirsty. Measurement of the central venous pressure or pulmonary wedge pressure and laboratory tests (periodical monitoring of the hemoglobin and hematocrit levels) are necessary.

When is transfusion necessary?
The "transfusion trigger" is the level of hemoglobin (Hgb) at which transfusion should be given. The tolerance of acute anemia depends on the type of the surgical procedure, the maintenance of the intravascular volume, the ability to increase the CO and HR, increases in 2,3-diphosphoglycerate to deliver more of the carried oxygen to the tissues, the Hgb and oxygen delivery (DO_2).

- DO_2 is the oxygen that is delivered to the tissues = CO x oxygen content (CaO_2). The Hgb is the main determinant of CaO_2.
- CO = HR x stroke volume (SV)
- DO_2 = HR x SV × CaO_2

The consequence of the last equation is that, if HR or SV are unable to compensate, Hgb is the major factor determining DO_2. Healthy patients have good compensatory mechanisms and can therefore tolerate Hgb levels of 7 g/dl. Patients with a compromised perfusion may require Hgb levels > 10 g/dl.

7. Tools of volume correction: injections, cannulas, tubes

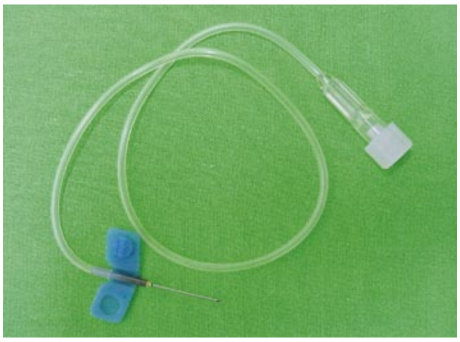
The parenteral routes of drug delivery are utilized when
1. drug delivery through the gastrointestinal tract is impossible,
2. the drug is altered by ingestion (broken-down in the intestine),
3. the patient requires faster or prolonged action.

Giving an injection may lead to infection, and therefore strict adherence to asepsis to ensure sterility is mandatory. The basic requirements for injection are syringes and needles.

Syringes
Syringes, devices for injecting or withdrawing fluids, are made of glass or plastic. Their parts are a glass or plastic barrel, a tight-fitting plunger at one end and a small opening at the other end, which accommodates the head of a needle. Syringe tips may be of two main types: Record and *Luer*, but today *Luer* syringes are used exclusively. *Luer* syringes are made of plastic, are sterile, and are single-use. The syringe volume ranges from 1 (tuberculin with 0.01-mℓ gradations) to 2, 5, 10 20, 50 or 60 mℓ. Insulin syringes have unit gradations rather than volume gradations.

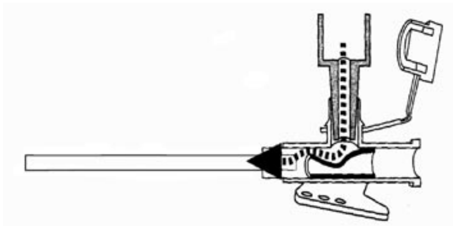
Hypodermic needles
Hypodermic needles are stainless steel devices that penetrate the skin for the purpose of administering a parenteral product.

Single-use ***Luer*** needles: They are metal + plastic, sterile, and can be connected to *Luer* syringes. The needle size is classified according to a color-coded scale (G = gauge). The needle gauge refers to the outside diameter of the needle shaft; the larger the number, the smaller the diameter. The needle lengths range from 1/4 to 6 inches. The choice of needle length depends on the desired penetration. The end of the needles is beveled to facilitate injection through tissues or rubber vial closures.
"Butterfly" needles: These have plastic wings which can be attached to the skin.
Braunule: This is the most often used needle + catheter combination. The commercial names include: Abbocath, Introcan, Jelco, Mecath, Surflo®, Vasofix-Braunüle, Venflon, etc. Parts: A plastic catheter (its end is smoothly beveled so that it dilates the opening made by the needle), a metal needle which is a little longer than the catheter (to pierce the skin), an injection port (with a valve which allows the infusion of medication, but the blood cannot flow out; after use, the valve closes automatically), and plastic wings.

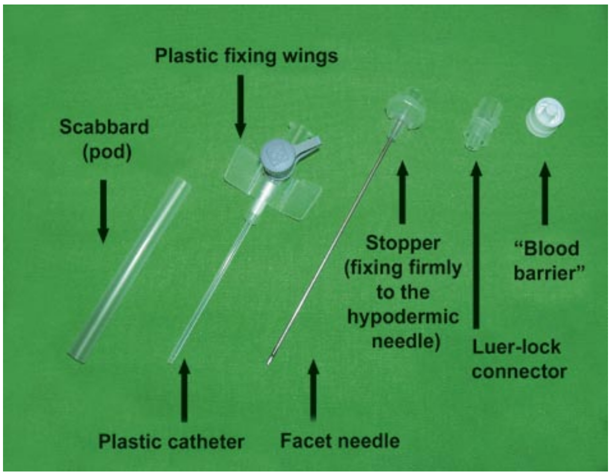


"Butterfly" needle with cannula

Braunule



Valve mechanism of injection port



Parts of a braunule

Selecting the adequate iv. cannula
There are different iv. cannulas with various lengths and diameters to meet the various requirements. The table below gives information on B.Braun (Melsungen, Germany) cannulas (ISO=International Organization for Standardization).

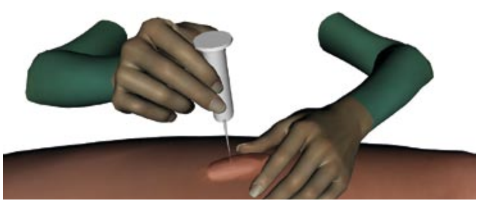
Color code (ISO standard)	Outer diameter	Flow	Examples for practice
Yellow	0.7 mm	13 mℓ/min	Infants (neonates)
Blue	0.9 mm	36 mℓ/min	Infants
Pink	1.1 mm	61 mℓ/min	Thin veins; children
Green	1.3 mm	96 mℓ/min	Adults
White	1.5 mm	128 mℓ/min	
Gray	1.8 mm	196 mℓ/min	Quick volume replacement
Orange	2.2 mm	343 mℓ/min	Transfusion

8. Types of injection techniques

- Ampoules are made entirely of glass; for single use only. After an ampoule is opened, the drug must be utilized in a short time (sterility and degradation). Traditional opening: The ampoule is wrapped in thick gauze, and a file cut is made on the neck. The end of the ampoule is broken off by applying pressure on the side opposite the file score. Today, such a procedure is no longer needed as the thinned neck can easily be broken. The drug is sucked out so that the needle does not touch the outside of the ampoule.
- Vials: These are glass or plastic containers closed with a rubber stopper and sealed with an aluminum shield. They may be liquid vials or powder vials with diluents (mostly distilled water or physiological salt solution). The diluent is first added to the vial, the vial is then shaken, an air volume equal to the volume of the solution is expelled, and the solution is then sucked into the syringe.
- Air removal: Giving an injection may lead to air embolism. Before drug administration, therefore, air is removed from the syringe: the plunger is pushed into the syringe to remove air from the liquid.

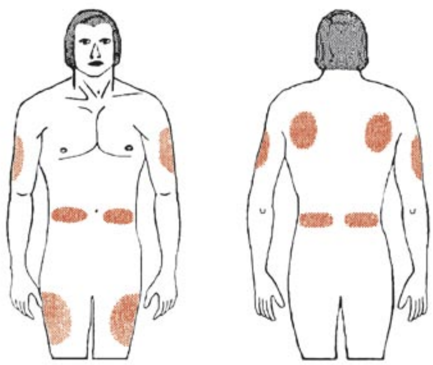
8.1. Intracutaneous (ic.) injection

This is administered to layers of the skin, it is used mainly for diagnostic purposes (allergy testing, tuberculosis screening and local anesthetics). A tuberculin type syringe (1 mℓ) and a thin needle (25–27G) are used to administer a small volume (max. 0.5 mℓ) of medication. Sites: Inner forearm, posterior of upper arm. The needle should be inserted at an angle of 10 to 20°, bevel up, and the medication is administered just under the epidermis.



8.2. Subcutaneous (sc.) injection

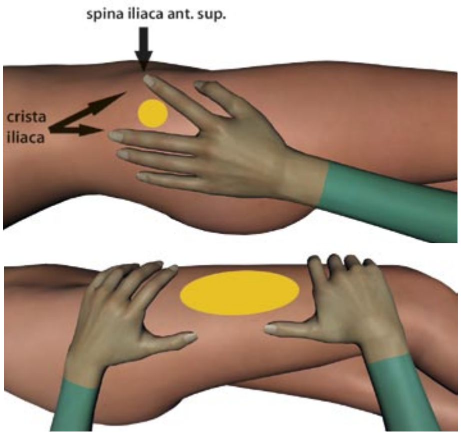
This is administered into the fat and connective tissue underlying the skin with a thin (25–27G) needle. Sites: External-upper third of the upper arm, external-medial area of the thigh, or abdomen (insulin and heparin). The skin should be gently pinched into a fold to elevate the sc. tissue, which lifts the adipose tissue away from the underlying muscle. The injection should be given at an angle of 45° into the raised skin fold. The injection can be started only when no blood can be drawn back into the syringe. The absorption of drugs in shock states is uncertain.



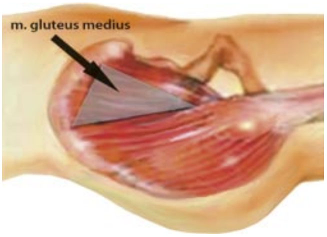
The sites of sc. and ic. injections

8.3. Intramuscular (im.) injection

This is used for the injection of a larger volume (max. 5 mℓ) of medication into the muscular tissue. Sites: The gluteal muscle (m. gluteus maximus) with the ventrogluteal *Hochstetter* technique (*sec.* Ferdinand von Hochstetter, 1829–1884); in infants the lateral side of the femoral muscle. When an im. injection is to be given, the skin over the site should be stretched to reduce the sensitivity of the nerve endings, and the needle (20–25G) should be inserted at an angle of 90°. The skin should be stretched by using the Z track technique. If this does not happen, the fluid injected will come back out of the hole made. The Z track technique can be performed by stretching the skin gently between the thumb and index finger. It is contraindicated for patients treated with anticoagulants.



The sites of im. injections in adults (top) and infants (bottom)

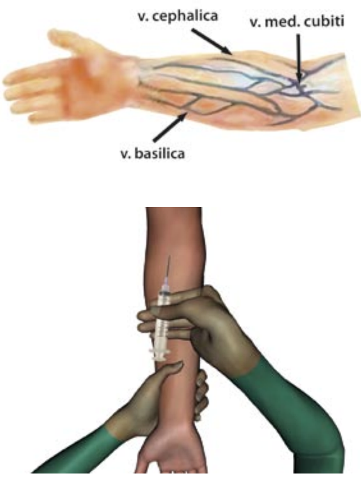


The site of *im.* injection

8.4. Intravenous (iv.) injection

During an iv. injection, the needle is inserted through the skin into a vein, and the contents of the syringe are injected through the needle into the bloodstream.

Sites for iv. injections are the v. mediana cubiti, the v. cephalica, and the dorsal veins of the hand and foot. It is necessary to use a *tourniquet* centrally to the vein to make the vein bulge. 18–23G, "butterfly" or braunule needles are used, and the vein must be punctured with the bevel up at an angle of 30 to 45° in the direction of the vessel. Once the needle is in place, it is helpful to draw blood, thereby verifying the real position of the needle; the tourniquet is then released before the injection is slowly given. A sterile sponge is pressed on the site of the injection, the needle is pulled out and the patient's elbow should be kept in a flexed position.



The sites of iv. injection (top) and implementation (bottom)

9. Complications of injections

- The skin should be intact; injections should never be made into injured or infected skin. Nonsterile devices (needle, syringe or solution) can cause skin infections.
- Drugs injected into the tissue via an incorrect injection technique can damage the tissue or cause a nerve injury. An improperly given intragluteal injection can injure the ischiadic nerve.
- Hematoma (blood enters the surrounding tissue from the vein through the sting channel); paravenous injection ("para" – the needle slips out from the vein and drug solution passes into the tissue, causing pain and tissue necrosis). This can be decreased by means of a Novocaine infiltration or an aqueous fomentation.
- In allergic patients, a toxic reaction, edema and fever can occur. Administration of the drug must be stopped immediately.
- Sterile venous inflammation (after hyperosmolar compounds).
- Hematoma
- Intraarterial injection.

10. About veins in details

Indications for securing peripheral venous access: 1. Fluid therapy, 2. solutions with pH from 7.2 to 7.6; 3. if the osmolarity of the solution does not exceed 1100 mosm/ℓ; 4. the planned duration of therapy is less than 3 days; 5. iv. administration of drugs or taking blood samples.

Contraindications: Thrombophlebitis; local inflammation; lower limbs in adults.

For the puncture of veins, we should look for a site in the periphery (the dorsum of the hand) in order not to disturb the flow toward the heart if further interventions are necessary. Preferable features are a large lumen, branches of veins, introduction at the branching, the dorsum of the hand (here the veins can be strained better), and the dominant side (in a right-handed patient, the right hand).

Points to be avoided

- An infected skin area; inflamed veins.
- Punctures are never made in the medial-upper sector of the crook of the arm, due to the proximity of the artery.
- Thrombosis of veins (without flow).
- Paralytic arm (after a stroke), since the lack of muscle pump means that the blood flow could be inhibited.
- Blockage of lymph flow (e.g. following a breast operation).
- Joint regions (danger of inflection).
- Vein valves.
- Veins are usually vulnerable and small on the anterior side of the forearm.

Visualization of veins

- Hang the arm down.
- Ask the patient to clench his fists several times (muscle pump).
- Massage the veins with your finger.
- Apply 10 min of hypothermia (with warm water).
- Sprinkle/spray alcoholic solution on the skin above the vein.

Fixing of veins

- Stretch the skin above the vein so that it does not move before an iv. catheter is introduced.
- There are three possibilities to ensure a successful puncture: stretch the skin in the opposite direction to the puncture (dorsal hand); push the skin in the direction of the puncture (forearm); strain the skin on the side with a "C" maneuver, grasping the arm underhand.

10.1. Technique of blood sampling

Materials that should be available: Compression cuff; disinfection solution (alcoholic spray), sponges, sampling tubes, needle with syringe with closed cap, Braunule, adhesive tape/sticking plaster, container for used needles, sponges and gloves.

Position of patient

The patient is lying, supported by the elbows and with arms extended.

Localization of vein

Palpate with the fingers to identify a vein with large a lumen (see above).

Vein compression / tourniquet

Compress the cuff centrally to the vein so that the arterial pulsation is palpable. Ask the patient to clench his/her fists and wait several seconds. The tourniquet pressure can be precisely controlled following BP measurement, using the inflated cuff. The optimal counterpressure is normally 60–80 mmHg, under the level of the diastolic BP. Arterial pulsing should always be palpable, to avoid intraarterial puncture.

Disinfection

An alcoholic spray or a sponge with alcohol is used for disinfection and the skin area of the puncture is scrubbed. It is necessary to wait for 15–30 s for the effect of disinfection to be reached. It is always reasonable to disinfect the area of the puncture, because it decreases the risk of contamination even if the duration of exposure is not sufficient for the inactivation of all causative agents.

A hygienic environment is an important aspect

- Hands should be washed or disinfected.
- A new braunule is used for each attempt.
- The cap of the injection port is closed.
- The braunule should be changed every 2–3 days.
- If blood or lipid-containing solutions are administered, a more frequent change is required.

Fixing the vein

The skin above the vein is strained to block the movement of the vessel (see above).

Injection technique with a needle or braunule

- If a needle is used, it is introduced with face turned upward into the skin, at an angle of 30° to the skin surface, parallel to the axis of the vein.
- When an iv. catheter or braunule is applied, the injection port is grasped with the index and middle fingers while the stopper is held with the thumb, and the fourth and fifth fingers are placed on the patient's skin. The catheter is pushed slowly into the vein at an angle of 30–45° until some blood appears in the blood chamber. It is then advanced about 1 cm at a decreased angle of puncture to ensure that the needle and catheter are in the lumen of the vein.
- When an iv. catheter or braunule is introduced, two resistances will be encountered: 1. the needle penetrates the skin; 2. the plastic catheter reaches the site of the puncture. (Penetration of the wall of the vein is often not be felt to be a discrete resistance.)
- When the above procedure is performed, the skin, the sc. connective tissue and the wall of the vessel should be penetrated in one continuous movement. As the first step, the skin will be penetrated; in the second phase, the catheter is introduced into the vein.
- With thinner (blue or pink) catheters, it is advisable to wait until the blood appears in the blood chamber as otherwise the posterior wall of the vein may be penetrated.

- The vein is pressed down with the ring finger above the end of the catheter while the needle is drawn back about 1 cm, until the appearance of blood in the plastic catheter. This means that the catheter is positioned in the vessel lumen. The catheter is pushed forward into the vein lumen. The drawing-back of the needle stabilizes the iv. catheter during the introduction (preventing its inclination), without damaging the wall of the vein.
- A sponge is placed under the end of the braunule. The catheter tip is touched by the right hand finger under the skin and pressed gently. The catheter is held with the thumb and index finger while the needle is removed with the other hand, and connected to a closing cap or infusion set.
- The tourniquet is released.
- Blood retraction: The needle is held with the left hand while the right hand draws back the plunger of the syringe. For blood sampling, the needle is fixed with one hand, while the blood sampling tubes are changed with the other hand.

Removing the needle or braunule

- An alcoholic sponge is first pressed onto the site of the puncture and the sponge is then pushed while the needle or braunule is removed. Next, the alcoholic sponge is pressed on the puncture site again until the bleeding has stopped (at least 1 min). The arm of the patient remains extended.

Blood sampling tubes

The sample is shaken gently to avoid damage to the blood cells, and it is mixed with anticoagulant. The coagulation (green), sedimentation (purple) and hematocrit (red) tubes should be filled exactly to achieve the correct dilution.

The sequence of sampling: a sample is first taken in the serum (white) tube, since the serum K^+ level may be elevated within 30 min as a consequence of stress. The second tube is green and serves for determination of coagulation factors. Coagulation occurs in the tube. (For this purpose, a blood sample must not be taken in the first tube because it might contain air or the concentrations of coagulation factors can be changed in the needle.) Other tubes should be filled thereafter. Blood sedimentation is usually evaluated at the department, and the sample should therefore not be sent to the laboratory for this.

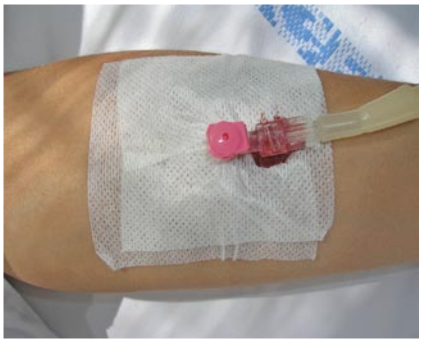
Fixation of braunule

Adhesive tape is placed on the site of the puncture. The iv. catheter is fixed with the prepared adhesive tapes. The infusion tube is relaxed at the adhesive tape, the joint is fixed with a splint if necessary and apply gauze bandage is applied.

- It is important for the cannula to be fixed so as not to be pulled out or broken when the patient moves the arm. Mechanical irritation of the vein must be avoided.
- If the cannula remains in the vein for a longer period, a piece of gauze should be placed under the braunule in order to prevent pressure-induced injuries.
- A piece of adhesive tape fixed to the injection port provides protection against contamination. Furthermore, customary kits for fixation are available.

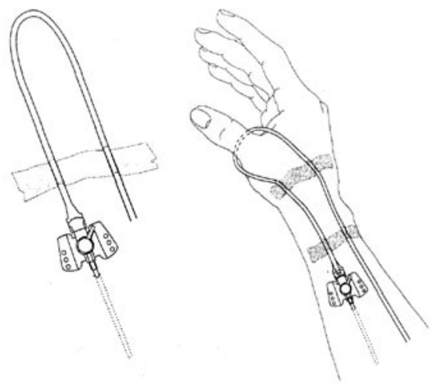
Final fixing

A loop of infusion tube is made and fixed with another adhesive tape. This will prevent the cannula being pulled out unintentionally. If the cannule is close to a joint, fixing of the joint with a splint may be helpful. In anxious patients, the limb should be covered with a bandage or fixed with a splint (e.g. children).



Checking

The tap of the connected infusion is opened for a few seconds. If the flow of the fluid is uninterrupted and no swelling can be seen at the site of the puncture, the cannule is very probably in the right position. This check can be performed prior to fixing too.



10.2. Infusions

In the event of a serious loss of fluid, or electrolyte and fluid imbalances, fluid substitution is the first thing to do. If this is not possible orally, fluid must be administered parenterally, most often as an iv. infusion. Infusion therapy provides a possibility for the administration of a major volume of fluid, electrolytes and drug into the circulatory system. The rate and duration of fluid administration can be regulated. If the concentration of a drug exceeds the physiological range, it can be administered in an infusion. Thus, a longer period of administration and a constant concentration in the blood can be achieved.

Infusion therapy is proposed before admission in the following cases:

- acute myocardial infarction, left heart failure,
- pulmonary embolism,
- stroke, hypertensive crisis,
- status asthmaticus,
- acute bleeding,
- shock, allergic reaction, burns,
- an unconscious state,
- acute artery blockade in the extremities,
- acute metabolic comas (hyperglycemia),
- Addison, or a hyper- or hypothyroid crisis.

Infusions are usually delivered into superficial veins (in the forearm, or the dorsum of the hand/foot); most often, it is delivered into the cubital vein. If a vein cannot be reached by punctures, it must be exposed surgically. In a long-term continuous infusion, etc, a catheter may be inserted into the superior vena cava after the exposure and dissection of the jugular veins. This catheter can also be used to measure the central venous pressure. The iv. infusion therapy involves many risks, and should be performed strictly in accordance with the rules of asepsis.

Infusions

Devices for iv. infusion

A sterile plastic infusion bag (infusion glass bottle), a sterile iv. administration set, hypodermic needles ("butterfly" and braunule), disinfecting solution, gauze, tapes, an infusion stand, and sterile disposable gloves.

The infusion set

The sterile set is wrapped in a double package (plastic and paper). The package should be opened only just before use. Sets of damaged packages must not be used (sterility!).

Parts of the iv. administration set

A spike, a drip chamber (flexible), and long tubing with the flow regulator (a plastic roller clamp for control of the flow rate):

The protective covering is removed from the port of the infusion bag and from the spike of the set, and the spike is inserted into the bag. The bag is hung on the stand; the lower part of the drip chamber is squeezed to set the fluid level, until the drip chamber is approximately one-third full. If the level of the fluid is too low, the chamber is squeezed to remove air to the bag. If the chamber is overfilled, the bag is lowered to below the level of the drip chamber and some fluid is squeezed back into the bag. The flow regulator is opened and the fluid is allowed to flow into the tubing (removing air). The end of the tubing is connected to the iv. catheter in the patient's vein, and the flow rate is adjusted as desired. After a loop has been made in the tubing, the catheter is secured to the skin with strips of tape. During infusion, the patient, the administration set and the flow of fluid must be controlled continuously.

Dosage of infusion

- There are two types of drip chambers: microdrip (60 drops/mℓ; for the administration of medication or fluid delivery in pediatrics), and macrodrip (10–15 drops/mℓ; for routine/rapid fluid delivery or keeping the vein open).
- The volume of infusion fluid/drugs should be calculated. A formula to calculate drops: volume of infusion fluid (mℓ) × drop factor (drops/mℓ) / time to infuse (min) = drops/min. As an example, an infusion of 1000 mℓ of saline during 12 h with a microdrip chamber should be delivered at a rate of $1000 \times 60/720 = 83$ drops/min.
- The amount of the infusion depends on different factors (the body surface area, the physical condition, the age and the osmolarity of the infusion fluid).
- At the end of the infusion, the tubing is clamped, the tapes are removed, followed by the needle or braunule catheter, and sterile gauze is placed on the site of the puncture.

Other iv. administration sets

1. Set with hydrophobic bacteria filter

2. Dual drip infusion iv. set (with a micro- and a macrodrip chamber)

Risks and complications of iv. infusion therapy

- In peripheral iv. therapy, the position of the vein puncture should be changed after 48 or 72 h, and the catheters must be changed after 24 h.
- Hematoma: during the vein puncture, the wall of the vessel may be damaged (therapy: compression).
- Inflammation-thrombosis (during long-term infusions or the administration of acidic or alkaline solutions, or infusions of high osmolarity).
- The endothelium of the vessel wall may be damaged by the tip of the needle (compress).
- Air embolism (remove air!).
- Fever (rules of asepsis!).
- Circulatory insufficiency (in heart or renal failure during infusion at too high a rate!).

Variations of iv. infusion

Infusion of two different solutions. Two infusion sets are used. The tubes are connected with a Y tubing below the drip chambers.

Medication administration with an iv. infusion. This is delivered slowly together with the infusion fluid to attain a constant drug level in the blood.

10.3. Infusion pumps (IP)

IPs are used for the accurate, continuous, long-term and slow delivery of infusions and medication, medical fluids, enteral feeding products and blood to reach a constant blood level during therapy or in clinicopathological investigations. They are designed to allow precise control of the flow rate and the total amount of fluids for both clinician and patient use.

Types of IPs

- **Volumetric IP:** This allows the accurate, reliable, continuous, long-term and non-pulsatile iv. or ia. delivery of medical fluids (infusions, blood or enteral feeding products) to patients.

An electric or battery-operated peristaltic mechanism drives the fluid. The flow rate and volume infused can be preset. The pump is equipped with different optical and sound alarms, including air detection, empty container sensing, and occlusion alarm pressure setting (automatic shut-off). A volumetric IP can also be used to keep the vein open (a slow iv. infusion at 1 mℓ/h).

- **Syringe IP:** This facilitates the long-term, continuous iv. or ia. delivery of small volume of infusion or medication with different sizes of syringes.

The flow rate (e.g., depending on the type of syringe, from 0.1 to 1200 mℓ/h) and volume infused can be preset. Automatic shut-off is possible at the end of the infusion or at occlusion. These IPs are electric or battery-operated. They can be placed one on another, like a tower (also on an infusion stand). In this way, the simultaneous administration of several drugs can easily be checked.

- **Patient-controlled analgesia (PCA) pump** for pain management. This is a battery-operated, portable IP for patient use at home. It is easy for the patient to

wear it in a sack on the shoulder or fixed to a belt, and it does not disturb his/her movement. The PCA pump allows the patient to administer the pain-killing drug whenever he/she needs it.

10.4. Central venous catheterization, venasection, venous cut-down

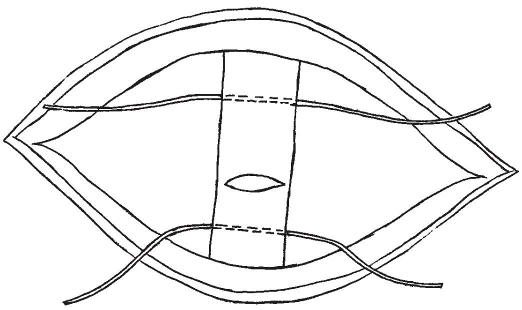
The surgical catheterization of a peripheral vein was one of the first unaided interventions performed by a young surgeon. It improves practical skills, and provides possibilities for practising incision of the skin, the sharp and blunt dissection of tissues, and closure of the wound.

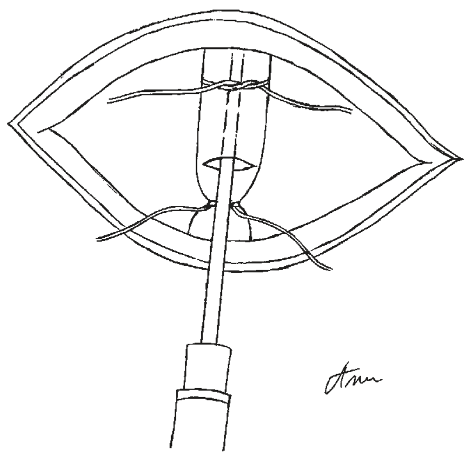
The veins of choice are the cubital veins (medial cubital vein, cephalic vein, and basilic vein), the external jugular vein in the collar region, and possibly the superficial veins of the leg (though thrombosis may develop in these veins). Major saphenal veins too can be chosen in the absence of other possibilities. During skills courses, preparation and catheterization of femoral and jugular veins can be demonstrated *in vivo*.

Technique of venous cut-down (venasection)

- A local anesthetic drug, a wide-bladed scalpel, *Mayo* scissors, *Péan* forceps (mosquito), thread, needles and needle-holder are required. Special attention must be paid to asepsis. The operating site should be disinfected and draped as usual.
- In clinical practice, a transversal incision should be applied in the cubital and collar region, but during *in vivo* training practicals an incision parallel to the vein can also be chosen. In this case, the vessel will be easier to access and there are more possibilities to practise different techniques of preparation. The scalpel should be used at right angles to the skin. The incision line is straight and the wound is the same in depth throughout its whole length. The scalpel is moved toward the operator with one decisive movement. Before the incision, the skin should be stretched with the thumb and index finger. Gross bleeding is rare. If the bleeding originates from capillaries, the bleeding area is pressed with a sponge for 1–3 min. Bleeding from major vessels is stopped by ligation.
- Subcutaneous tissues are easy to dissect. They should be cut bluntly and sharply with *Mayo* scissors. The tissue is lifted up with two forceps and a small incision is made with the scissors. The closed scissors are inserted into this gap and the tissue is dissected by opening them. The dissected layer can be cut, and thus the sc. area can be elongated to the ends of the wound. The deeper layers should also be dissected according to this method. The preparation should be made parallel to the vessel.
- The vessels appear; the artery is pink and pulsating. The veins have thinner walls and their color is blue. Closed scissors are placed next to the vessels, and veins should be dissected free by careful blunt preparation. When a 2–3-cm portion of the vein is free, a double thread is introduced under the vessel with mosquito forceps.
- The vein should be ligated peripherally. In animals, collateral vessels can replace the function of closed vessels better than in human (ligation of end-arteries and main arteries supplying organs leads to necrosis). However, after the ligation of major veins (femoral, subclavian and jugular veins) in animals, only transient signs of stagnation are to be found. A loose half-hitch is made on the proximal thread under the vein. A V-shaped incision should be made in the vein with vessel-scissors, close to the distal thread (5 mm from the knot). The incision involves 1/3 of the diameter of the vessel.
- The lumen should be opened with dental forceps. A catheter filled with saline is inserted, and the forceps are then removed. The catheter should be introduced carefully through the loose proximal loop and further, to reach a central position. Arrival at a lateral branch must be avoided. If an obstacle is found, the catheter is retracted slightly and moved to the side in order to find the way to the main branch. Before the proximal thread is tightened, saline is injected into the lumen and blood is aspirated into the syringe in order to check the function. The proximal half-hitch is tightened and a second knot is made. Care must be taken not to close the lumen!
- The catheter should be fixed with the distal thread too. Before the wound is closed, bleeding (if any) is stopped and clotted blood is removed. The wound is closed with subcutaneous sutures and vertical mattress sutures (*Donati*). The catheter is fixed to the skin with another simple suture.

Remark: At present the central venous catheterization is most often performed by percutaneous puncture of the jugular or subclavian veins.





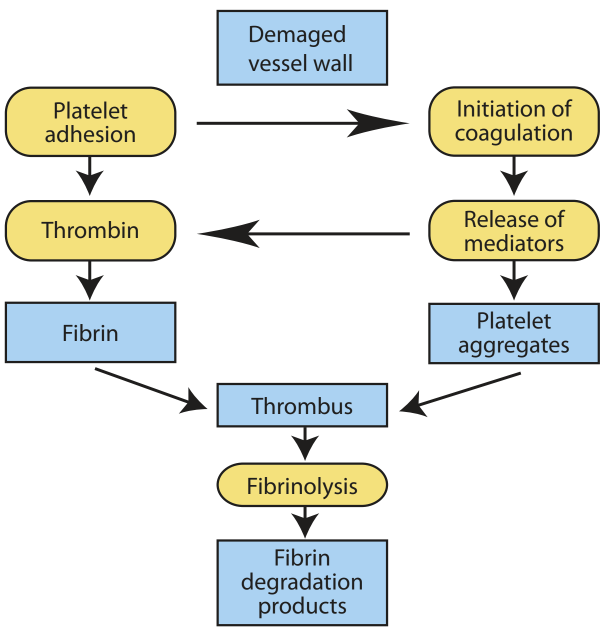
VII. Bleeding and hemostasis in surgery

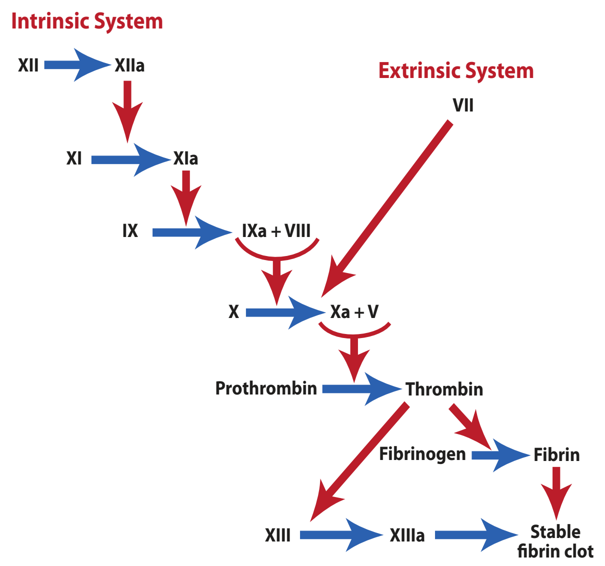
"The only weapon with which the unconscious patient can immediately retaliate upon the incompetent surgeon is haemorrhage"
(William S. Halsted: Bulletin of the John Hopkins Hospital, 1912)

1. Hemostasis

Definition: This is a natural, life-saving defense mechanism which has three main factors: 1. a vascular mechanism (vasoconstriction), 2. a thrombocyte mechanism, and 3. clotting. All of these inhibit or decrease bleeding from the vessels.

During injury (incision), the endothelial damage (e.g. surgical incision) exposes matrix proteins and collagen, and the platelets clump and adhere to connective tissue at the cut end (*adhesion*). The platelets then release adenosine diphosphate (ADP), epinephrine, thromboxane A_2, serotonin (*release*), binding sites for fibrinogen appear on the platelet membrane, fibrinogen is involved in platelet-platelet adhesion (*aggregation*), and ADP + thrombin cause further platelet activation = primary thrombus. Platelet adhesion and aggregation form a plug that is reinforced by fibrin for long-term stability:





2. Main types of hemorrhage

Losses of circulating volume and oxygen-carrying capacity are generally termed hemorrhage.

This can be acute or chronic; primary or secondary. Secondary hemorrhage can be the aftermath of infected wounds, inadequate primary wound care, inadequate or traumatic dressings, or necrosis of the vessel wall (compression, drains, etc.).

Gross bleeding from cut or penetrated vessels
Arterial bleeding is bright-red and pulsating with the cardiac function. The volume loss depends on the size of the artery. Venous bleeding is often a continuous flow of dark-red blood with lower intensity (large veins: danger of air embolism!).

Oozing from denuded or cut surfaces
The continuous loss of blood from oozing can become serious if it remains uncontrolled. Capillary bleeding: a tamponade with dry or wet (warm saline) towels (only press) is used to stop oozing. Parenchymal bleeding: absorbable sutures or gelatin are used (see later). Minor bleeding during skin incision can be controlled by compression of the skin edges with towels.

3. Clinical classification

Hemorrhage can be classified according to the volume of blood lost. To assess hemorrhage, the patient's mean blood volume must be known (males have ≈ 70 mℓ/kg (6% of the body weight), while females have ≈ 65 mℓ/kg).

	Class I	Class II	Class III	Class IV
Blood loss (mℓ)	Up to 750	750–1500	1500–2000	>2000
HR	<100	>100	>120	>140
BP	Normal	Normal	Decreased	Decreased
RR	14–20	20–30	30–35	>35
Capillary refill	Normal	Slight delay	>2 seconds	No filling
Skin	Pink and cool	Pale and cold	Pale, cold, moist	Mottled
Urine	>30 mℓ/h	20–30 mℓ/h	5–15 mℓ/h	<5 mℓ/h
Behavior	Slight anxiety	Mild anxiety	Anxious, confused	Lethargic, confused
Fluid therapy	Crystalloid	Crystalloid	Crystalloid, blood	Crystalloid, blood

4. Direction of hemorrhage

Clinically, bleeding can be external (e.g. trauma, or a surgical incision resulting in visible hemorrhage) or internal (e.g. urinary tract: hematuria, pulmonary: hemoptoa; see urology and internal medicine). The latter can be directed toward body cavities (intracranial, hemothorax, hemascos, hemopericardium or hemarthros), or among tissues (hematoma and suffusion).

4.1. Gastrointestinal hemorrhage

The dividing point between upper and lower gastrointestinal bleeding is the ligament of *Treitz* at the junction of the duodenum and jejunum.

- Hematemesis: The vomiting of blood or altered blood ("coffee-grounds") indicating bleeding proximal to the ligament of *Treitz*.
- Melena: Altered blood (black and tarry) from the rectum. Approximately 100 mℓ or more blood is required for one melenic stool. Melena indicates bleeding proximal to the ligament of *Treitz*, but it can be as far distal as the ascending colon. Iron, licorice, beets, blueberries and charcoal cause black stools.
- Hematochezia: Bright-red or maroon rectal bleeding. The bleeding is usually beyond the ligament of *Treitz,* but it can be due to rapid (> 1000 mℓ of blood) upper gastrointestinal bleeding.
- Occult: Unapparent bleeding. A common site is the intestines.

4.2. Causes of gastrointestinal hemorrhage

Before operation

- Mouth and pharynx: Malignant tumors or hemangiomas.
- Esophagus: An aortic aneurysm eroding the esophagus, esophagitis, hiatal hernia, tumors, peptic ulcers or varices.
- Stomach: Tumors, carcinoma, diverticulum, gastritis with erosion, peptic ulcers or varices.
- Liver: Cirrhosis.
- Duodenum: Peptic ulcer, diverticulum, tumor or duodenitis.
- Jejunum and ileum: Intussusception, tumors, peptic ulcers, enteritis, Meckel's diverticulum or tuberculosis.
- Pancreas: Eroding carcinoma or pancreatitis.
- Colon and rectum: Malignant tumors, diverticulitis and diverticulosis, a fissure, a foreign body, hemorrhoids, polyps or ulcerative colitis.

After operation

- Inadequate primary care.
- An unligated vessel or an unrecognized injury.
- Sutures or clips.
- A necrotic vessel wall; drain erosion; abscess wall erosion.
- Anticoagulant therapy or a long-term heparin effect.

5. Preoperative – intraoperative – postoperative hemorrhage

Bleeding can be classified according to the time of surgical interventions: it can be preoperative, intraoperative or postoperative.

Preoperative hemorrhage
Bleeding outside the hospital (see traumatology and anesthesiology). Prehospital care for hemorrhagic injuries includes maintenance of the airways and ventilation, the control of an accessible hemorrhage with bandages, direct pressure and tourniquets (these methods have not changed greatly in 2000 years), and the treatment of shock with iv. fluids (see later).

Intraoperative hemorrhage
This can be anatomical and diffuse. Risk factors include drugs used in clotting disorders to reduce clotting (anticoagulants, antiplatelet drugs and thrombolytics), cirrhosis, a liver dysfunction (clotting factors), uremia, hereditary coagulation syndromes/disorders and sepsis. The main factors influencing perioperative blood loss:

- The attitude of the surgeon: the training, experience and care of the surgeon (probably the most crucial factor).
- Careful planning and the optimal technique (minimally invasive/atraumatic surgical technique).
- The optimal size of the surgical team.
- Meticulous attention to bleeding points – use of diathermy (ligation, laser, argon coagulation, etc.).

- Posture – the level of the operative site should be a little above the level of the heart (e.g. the *Trendelenburg* position for lower limb, pelvic and abdominal procedures; and the head-up posture for head and neck surgery).
- The size of the bleeding vessels.
- The pressure in the vessels.
- Hemostasis: the diameter of bleeding vessels decreases spontaneously due to vasoconstriction (more pronounced in arterioles than in venules).
- Handling bleeding from arterioles is easier ("surgical") than that from diffuse venous vessels.
- Anesthesia (!): Intraoperative bleeding depends much more on the BP rather than on the CO; the BP can be maintained at an optimally low level by the anesthesiologist. Various anesthetic techniques are applied to minimize perioperative blood loss:
- If adequate levels of anesthesia and analgesia are ensured, avoiding hypertension and tachycardia due to sympathetic overactivity can be avoided.
- Controlled anesthesia (increase of the intrathoracal pressure increases CVP, while an increased pCO_2 increases MAP).
- Regional anesthesia (epidural or spinal), where appropriate (a 45% reduction in blood loss!); sympathicolysis leads to a lower MAP, and spontaneous breathing to a lower CVP).
- Controlled hypotension.
- Adequate medication of hypertonic patients.

6. Surgical hemostasis

6.1. Historical background

Ambroise Paré (1510–1590) used a hemostatic clamp and ligatures to stop bleeding at the siege of Damvillier in 1552.

Ambroise Paré

In surgery, bleeding is usually caused by ineffective local hemostasis. Bleeding is a dangerous complication as it impedes the surgical procedures, hides the tissues or organs being operated, and prevents wound healing. Surgical bleedings should therefore be controlled as rapidly as possible. The aim of local hemostasis (handling bleeding) is to prevent the flow of blood from the incised or transected vessels. Methods are 1. mechanical, 2. thermal, or 3. chemical.

6.2. Mechanical methods – temporary and final interventions

Digital pressure

- The first approach for hemorrhage control.
- When possible, direct pressure is combined with elevation of the bleeding site above the level of the heart.
- Applied over a proximal arterial pressure point.
- Intraoperative maneuvers (e.g. the *Pringle (Báron)* maneuver; compression of the abdominal aorta).

Tourniquet

- There is no completely safe tourniquet duration.
- In most cases, a tourniquet can be left in place for 2 h without causing permanent nerve or muscle damage.
- A tourniquet is commonly used in hand surgery to produce a bloodless operative field.

Ligation

- Hemostat (artery forceps: *Péan, Kocher*, mosquito, etc.): this is the most commonly used method of hemostasis in surgery.
- The source of the bleeding should be grasped by a hemostat with minimal inclusion of the neighboring tissues. This intervention (requiring the harmonized movements of the operator and the assistant) consists of three phases: soaking, clamping and ligation (see page 95).
- The assistant soaks up blood with sponge (only with a press, avoiding vasoconstriction). The surgeon clamps the vessel with the tip of a *Péan* without clipping the surrounding tissues. The point of the *Péan* should be upward and toward the surgeon. The surgeon passes the thread (nonabsorbable, thin suture material) around the vessel, and ties off the vessel with a knot.
- After the first knot (half-hitch) has been tied, the assistant removes the artery forceps. The surgeon ties the second knot, and cuts the threads with *Mayo* scissors just above the knot (leaving as little thread, as possible – foreign material!). Ligatures must not be used directly under the skin, because they hinder wound healing.

Suturing transverse, transfixing, "8": *sutura circumvoluta*): in cases of large-caliber vessels or diffuse bleeding. Nonabsorbable: silk, polyethylene or wire; absorbable: catgut, polyglycolic acid (Dexon) or polyglactic (Vicryl) can be used. A double stitch (suture twice) is applied under the bleeding tissue to form an "8"shaped loop and the knot is then tied.

Preventive hemostasis: with ligatures. In the operating field, a vessel should be clamped with two *Péans*, the vessel between them is cut, and the two ends of the vessels should be tied separately.

Ligating clips (Ligaclip®): metal or plastic.

Bone wax (Horsley and Squire in 1885–1892): This is a sterile mixture of beeswax, almond oil and salicylic acid. It adheres readily to the bloody bone surfaces, thereby achieving local hemostasis of the bone. The wax mechanically occludes and seals the open ends of bleeding vessels.

Expedients: suction, drainage (Hemovac, Jackson-Pratt, etc.) to remove body fluids and air. This

- facilitates the emptying of dead spaces,
- improves tissue regeneration, and
- blocks the development of edema and hematoma.

Other devices or mechanical methods for handling bleeding

- Rubber bands for digits.
- The *Esmarch* (1873) bandage (sec. Johann von Esmarch 1823–1908).
- The *Penrose* drain to remove fluid or blood.
- Vessel loops.
- Pneumatic tourniquets (single or double-cuffed).
- Pressure dressings, packing (compression) and tamponades.

6.3. Thermal methods

Low temperature – hypothermia

- Hypothermia (a hypothermia blanket, ice, cold solutions for stomach bleeding),
- cryosurgery: -20 to -180 °C cryogenic head
  - dehydration and denaturation of fatty tissue
  - decreases the cellular metabolism/O_2 demand
  - leads to vasoconstriction.

Heat (high temperature)

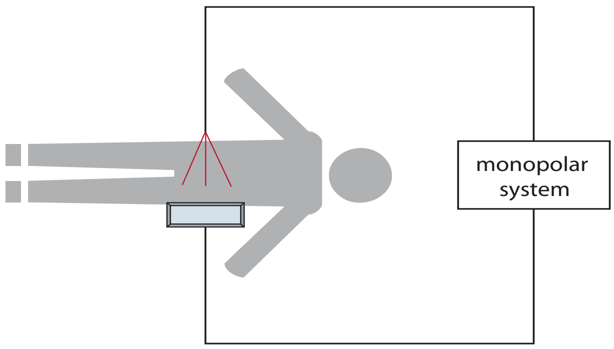
Based on protein denaturation (sec. *Galen*).

Electrosurgery

- In *Paquelin* electrocauterization (which stops bleeding by "burning" the bleeding vessels), the tissue is not part of the circuit. In diathermy, the patient is in the circuit. By 1910, the suitable frequencies had been determined, and a firm basis of knowledge on the effects of electrical heating of tissues and the concepts of fulguration, coagulation, desiccation/dehydration, and cutting current was established. Hemostatic scalpels appeared in 1928. Electrical current incises/excises or destroys tissues; the area is automatically sterilized and burned: bleeding is controlled with an aseptic technique. It can be used instead of scalpels or curettes.
- The principles involved are those of the handling of bleeding and an aseptic technique.
- When activated, the blade transfers thermal energy to the tissues as it cuts. It can be used to incise soft tissue and muscle.
- The effect depends on the current intensity and wave-form used. Coagulation is produced by interrupted (damped) pulses of current (50–100/s) and a square wave-form. Cutting is produced by continuous (undamped) current and a sinus wave-form.

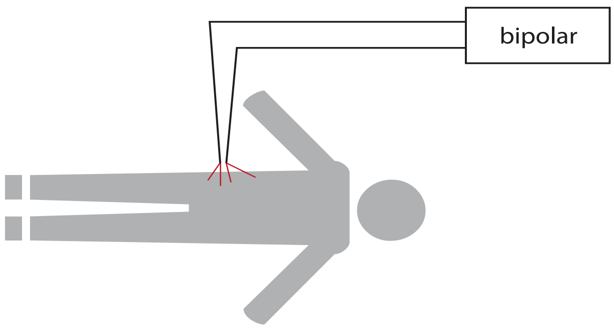
Monopolar diathermy

An electrical plate placed on the patient acts as an indifferent electrode. Current passes between the instrument and indifferent electrode (large surface). As the surface area of the instrument is an order of magnitude less than that of the plate, localized heating is produced at the tip of the instrument, and a minimal heating effect is produced at the indifferent electrode.



Bipolar diathermy

In bipolar diathermy, two electrodes are combined in the instrument (e.g. forceps), and the current passes between the tips and not through the patient.



Local effects of electrosurgery

Electrocoagulation
Characteristics: A needle or disc touches the tissue directly, and burns the tissue (a grayish discharge). The tissues are expelled after 5–15 days. *Usage:* Bleeding coagulation.

Electrofulguration
Lighting or spark: The needle does not touch the tissue directly (it is 1–2 mm away). *Usage:* "Spray" function – control of diffuse bleeding.

Electrodesiccation
The current concentration is reduced, less heat is generated and no cutting action occurs (the cells dry out). The needle is inserted into the tissues. *Usage*: To destroy warts and polyps.

Electrosection
With a knife, blade or electrode. *Usage:* Excision or incision. In general, diathermy should not be used to cut skin, but only deeper layers (burn injuries). Recently, the generators operate with blended modes, i.e. they allow the operator to control the levels of cut and coagulation in combination. With high voltage, a coagulative effect is achieved, while a lower voltage produces a cutting effect.

Laser surgery
Laser surgery is based on the emission of radiation by light amplification through a tube at a microscopic level. *Usage:* Coagulation and vaporization (carbon or steam) in delicate and fine tissues (eyes – retina detachment repair, brain, spinal cord, or gastrointestinal tract). The operator must wear safety goggles. Suction of steam (CO_2) is necessary.

6.4. Chemical-biological methods

There are sterile hemostatic devices which aid the patient's coagulation system in the rapid development of an occlusive clot, and there are agents which cause vasoconstriction. *Characteristics:* Easy handling, quick absorption, non-toxic, and local effects without systemic consequences. Expected consequences: Vasoconstriction, coagulation and a hygroscopic effect.

Main types

- **Aethoxysclerol (polydocanol)**
  This is not used for active coagulation. *Main indications*: Small superficial skin varices (injection into the veins) and esophagus varix sclerotization (given to the proximity of the varix).

- **Absorbable gelatin:** (Gelfoam, Lyostypt or Spongostan) powder or compressed-pad form, made from purified gelatin solution. This can absorb 45 times its own weight in blood. Absorption takes place in 20-40 days.

- **Absorbable collagen** (Collastat®): This is in the form of a hemostatic sponge, applied dry to the oozing or bleeding site. Its use is contraindicated when there is infection or in areas where blood has pooled.

- **Microfibrillar collagen** (Avitene®): This is powder-like, absorbable material from a bovine source; it is applied dry. It stimulates the adhesion of platelets and the deposition of fibrin. It functions as a hemostatic agent only when applied directly to source of bleeding. It is applied to oozing surfaces, including bone and areas of bleeding difficult to reach.

- **Oxidized cellulose** (Oxycel®, Surgicel®): This is available as an absorbable, pad form. It is sutured to, wrapped around, or held firmly against a bleeding site, or laid on an oozing surface. It reacts with blood and quickly forms a clot. It increases in size to form a gel, and stops bleeding where other methods of control have failed; only a small amount is needed. It is absorbed in 7–30 days.

- **Oxytocin**: This is a hormone produced by the pituitary gland, but is prepared synthetically. It is used to induce labor (it causes contraction of the uterus after delivery of the placenta). It is a systemic agent used to control hemorrhage from the uterus, rather than a true hemostatic agent.

- **Epinephrine**: This hormone secreted by the adrenal gland, is also prepared synthetically. It is a vasoconstrictor used to prolong the action of a local anesthetic agent and to decrease bleeding. It is rapidly dispersed and has a short duration of action.

- **Thrombin:** This enzyme, extracted from bovine blood, accelerates the coagulation of blood and controls capillary bleeding. It combines rapidly with fibrinogen to form a clot. It is in liquid form, as a spray, mixed with saline. It must not be allowed to enter large vessels. It is for topical use only and is never injected.

- **Novel hemostatic agents** (recommended by the US Tactical Combat Casualty Care Committee and FDA approved). *Indications:* External bleeding, recombinant activated factor VII and conventional pressure dressings fail.
  1. HemCon: It is available as a chitosan-based product, made from shrimp shell polysaccharide + vinegar. This is a firm 7 × 7 cm dressing that is sterile

and individually packaged. It adheres to a bleeding wound, and exerts vasoconstrictive properties.

2. QuikClot: This granular zeolite absorbs fluid, acts as a selective sponge for water, dehydrates blood, has handling properties similar to those of sand, and can generate significant heat during the absorption process.

7. Intraoperative diffuse bleeding

7.1. Main causes

- A platelet deficiency after massive transfusion
- Hypothermia-induced coagulopathy
- DIC
- Elevated levels of circulating anticoagulants

7.2. Management of intraoperative diffuse bleeding

Locally

- Fibrin glue (fibrinogen + thrombin + XIII factor), a biological tissue adhesive, initiates the final stages of coagulation, when a solution of human fibrinogen is activated by thrombin. It is prepared during surgery by combining equal volumes of cryoprecipitate (usually one or two bags) and thrombin solution containing $CaCl_2$ (and sometimes antifibrinolytic agents). Commercial preparations: Tisseel VH, etc.
- *Indications:* Potential leaks in the dura mater, large traumatized bleeding surfaces in life-threatening conditions, leaking vascular suture lines, middle ear or microsurgical procedures, and plastic surgery.

Medication

- A thrombocyte suspension
- Aprotinine (a serine protease inhibitor)
- Synthetic lysine analogues: epsilon-aminocaproic acid (Amicar), and tranexamic acid: competitive antagonists of plasmin-fibrin binding
- Fresh frozen plasma, fresh whole blood.

8. Replacement of blood in surgery (for details, see transfusiology)

8.1. Historical background

1665 Dog-to-dog experiments were conducted by Richard Lower (1631–1691), an Oxford physician, who proceeded to animal-to-human over the next 2 years.

1818 James Blundell (1791–1878), a British obstetrician, performed the first successful transfusion of human blood to a patient for the treatment of postpartum hemorrhage.

End of 19th century: Anesthesia and asepsis and antisepsis made surgery a viable branch of medicine, though control of blood loss was still a problem.

1901 Karl Landsteiner (1868–1945) documented the first three human blood groups – blood types were discovered.

1916 Plasma was used first during World War I.

1932 The first facility functioning as a blood bank was established in a Leningrad hospital.

1936 The first blood bank in the USA was established (Cook County Hospital, Chicago).

8.2. Auto(logous) transfusion

Advantages: This reduces the risk of postoperative complications (e.g. infection, HIV, hepatitis B or C and CMV), there are no incompatibility or alloimmunization problems, no immunosuppressant is present, and the need for allogeneic blood transfusion is reduced.

8.2.1. Preoperative autologous donation = predeposit transfusion

Indications: This is performed in surgical procedures involving a large blood loss, and in delayed interventions, if the patient is suitable for blood transfusion or the blood is adequate for retransfusion. *Contraindications:* Anemia (Hgb < 11 g/ℓ), infections, circulatory insufficiency, cerebral or coronary sclerosis, a cachectic patient, or organizational difficulties.

- **Autotransfusion – whole blood transfusion**
  Blood is collected 3–5 weeks preoperatively, once a week. 1 unit of blood (400 mℓ) provides 1 unit each of concentrated red blood cells + fresh frozen plasma.

- **Autotransfusion – plasmapheresis**
  Plasma is separated from blood by centrifugation or filtration, and then frozen. The concentrated red blood cells are immediately returned to the patient to prevent O_2 transport disorders. During blood removal, crystalloid and colloid solutions are infused simultaneously.

- **Acute normovolemic hemodilution**
  Technique: Blood (1 to 3 units) is collected at the start of the operative procedure, and simultaneously replaced with crystalloid solution in a ratio of 1:3 or with plasma volume expander in a ratio of 1:1. During surgery, the diluted blood removed must be replaced at the end of the procedure. Advantages: The microcirculation is improved by the maintenance of normovolemia, and autologous blood replacement occurs. *Disadvantages:* O_2 transport is decreased, and clotting factors are diluted. *Contraindications:* Coronary and cerebral vascular diseases, a decompensated circulatory insufficiency, serious respiratory diseases, anemia, or hypovolemia.

8.2.2. Blood salvage

Technique: Blood (with anticoagulant!) is collected in a sterile container and returned to the patient through a microfilter. *Contraindications:* The blood is mixed with harmful agents (intestinal content, pancreatic fluid, cancer tissue or contaminated fluids). *Dangers:* The Hgb concentration is increased in salvaged blood, and it contains large amounts of clotting factors, fibrinolytic enzymes, damaged platelets and anticoagulants. It is necessary to control hemostasis because of hemophilia or a serious blood loss. *Advantages:* Simple and cheap.

8.2.3. Autotransfusion – adjuvant therapy

Erythropoietin (EPO) therapy
Technique: EPO-induced erythropoiesis is not related to the patient's age and gender, but depends on the patient's iron stores. Iron must first be added iv.; the number of red blood cells starts to increase after 3 days of treatment. During treatment, 1 unit of blood/week is produced; in 28 days, 5 units can be removed from the patient. *Indication:* The method can be used if the patient is not anemic, but a large blood loss is expected. *Disadvantage:* It is expensive.

8.3. Artificial blood

This can not be used in clinical practice (from 2006 on). Research pathways involve cell-free, chemically modified Hgb, synthetic perfluorocarbon solutions, or liposome-encapsulated Hgb. *Expectations*: A good O_2-binding capacity and delivery in sufficient time in the circulation; it must be similar to blood in some characteristics (viscosity, oncotic, osmotic pressure and rheology), can be stored and sterilized, does not have toxic and antigenous features and can be produced in large amount and at low cost.

9. Postoperative bleeding

Causes: Ineffective local hemostasis, a complication of blood transfusion, a previously undetected hemostatic defect, consumptive coagulopathy, or fibrinolysis (a prostate, pancreas or liver operation). Causes of postoperative bleeding starting immediately after the operation:

- an unligated bleeding vessel;
- a hematologic problem arising as a result of the operation.

Therapy

- If the circulation is unstable, immediate reoperation is essential!
  Action to be taken if the circulation is stable:
  - reassessment of the history and medication given;
  - the transfusion should be stopped, and a sample should be sent to the blood bank;
  - the body temperature should be checked; if it is low, the patient should be warmed;
  - laboratory coagulation tests and a platelet function test should be performed.

10. Local signs and symptoms of incomplete hemostasis

Visible (skin) signs: Hematoma formation, suffusion and ecchymosis. Compression, suffocation and dyspnea (thorax and neck). Myocardial insufficiency (pericardium), intracranial pressure (head), compartment syndromes (muscle), dysfunction and hyperperistalsis in the intestines.

11. General symptoms of incomplete hemostasis

Shock symptoms: A cold skin, pale mucous membranes, sweating, cyanosis, hypotension, tachycardia, dyspnea, hypothermia, mental status, hemodynamics and laboratory alterations (see the chapter on shock).

VIII. Hemorrhagic shock

"Igitur corde percusso sanguis multus fertur, venae elanguescunt, color pallidissimus, sudores frigidi malique odoris tamquam inrorato corpore oriuntur, extremisque partibus frigidis matura mors sequitur."
Aulus Cornelius Celsus: De Medica (1478) Liber V. 28.8.

1. General remarks

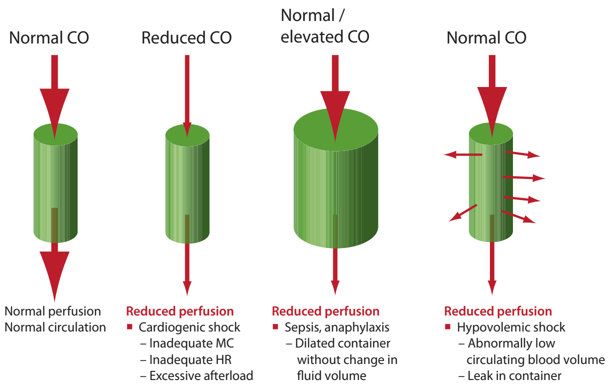
- Hemorrhagic shock was well characterized by Celsus (1st century Roman savant): "*When the heart is injured, much blood is lost, the pulse becomes feeble, the skin becomes extremely pale, the body is covered with a malodorous sweat, the extremities are frigid, and death occurs speedily*".
- Shock is a condition leading to death - according to John C. Warren (1895): "*a momentary pause in the act of death*". The treatment depends on the early recognition. Shock may be presumed suspected from the anamnesis and the risk factors.
- Shock is not equal to hypotension (shock is not always accompanied by hypotension due to the compensation mechanisms in the circulation). Not every hypotensive state indicates a shock circulation, and not every shock state is accompanied by low BP.
- The main types of shock, depending on the cause of the syndrome: hypovolemic, cardiogenic, distributive, and others, such as obstructive. There are many other shock states; the clinical shock types are not strict categories.
- Independently of the category, the key factor of shock is inadequate tissue perfusion (CO may be low or high), i.e. independently of the main cause (trigger), the main pathogenetic factor is an imbalance between the O_2 delivery and demand, resulting in a disordered cell function.

2. Types of shock

Hypovolemic	Distributive	Cardiogenic	Others
Dehydration, starvation	Anaphylactic	Congenital cardio-myopathy	Heat
Gastro-enteritis	Neurogenic	Ischemic	Pulmonary emboli
Burns	Drugs (toxicity)	Anoxic	Pancreatitis
Hemorrhage	Septic	Tamponade	Obstructive

Shock may be comprised of components of different subtypes (e.g. distributive and cardiogenic): the types are not obligate!

3. The essential patterns of circulatory shock



4. Anamnesis of shock

Signs upon physical examination:

- depressed central nervous system activity,
- an abnormal mucosal color,
- a decreased urine output (a sign of systemic tissue hypoperfusion),
- tachypnea, tachycardia,
- decreased capillary refill.

Biochemical changes:

- arterial blood gases: acidosis with a base deficit (a sign of tissue hypoperfusion),
- venous blood gases: decreased venous O_2 saturation,
- an electrolyte imbalance.

5. Compensatory mechanisms after blood loss

5.1. Baroreceptor reflex

This responds to small changes in vascular tone/pressure. It leads to a decreased vagal tone, which increases the HR, and decreases the coronary resistance (improves the myocardial O_2 supply). The sympathetic tone is increased, which causes venoconstriction, constriction of blood reservoirs (increasing circulating blood volume), and decreased perfusion in the skin and skeletal muscle.

5.2. Chemoreceptors

These are sensitive to O_2 and CO_2 and sense hypoxia (due to inadequate blood flow in the peripheral tissues and a MAP of ~ 60 mmHg). Important chemoreceptors are the carotid and aortic bodies. Reflexes that regulate BP are integrated in the medulla. The results are further vasoconstriction and an improved venous return (to the pump).

5.3. Endogenous vasoconstrictors

The adrenal medullary hormones norepinephrine and epinephrine cause vasoconstriction and an increased CO. Vasopressin (anti diuretic hormone - ADH) released from the posterior pituitary causes intense vasoconstriction in cases of extremely low MAP. Renin (from a decreased renal perfusion) leads to angiotensinogen and angiotensin II production. The endothelium-derived factors endothelin-1 and prostaglandin-derived growth factor are both potent vasoconstrictors.

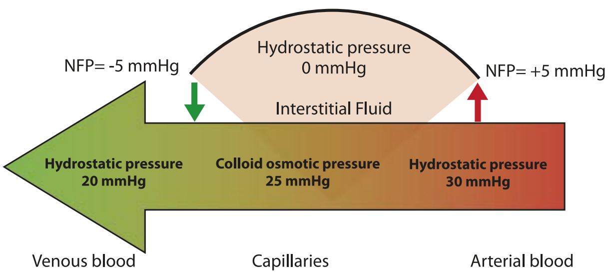
5.4. Brain ischemia

Low MAP (60 mmHg) causes a decreased cerebral perfusion pressure and an increased sympathoadrenal activity (which is higher than that induced by baroreceptors), involving the increased release of catecholamines from the adrenal glands and sympathetic nerves (leading to vagus nerve stimulation, which has opposite effects).

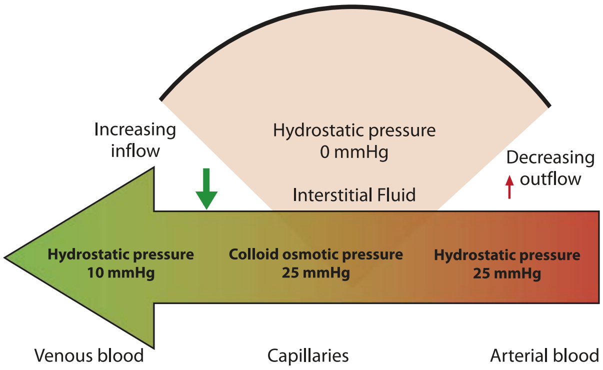
5.5. Changes in renal water metabolism

The aldosterone release stimulated by vasopressin results in Na^+ reabsorption in the distal tubules of the kidneys; water follows the Na^+.

5.6. Reabsorption of tissue fluids (*"fluid shift"*)



At the arterial end, the hydrostatic pressure dominates, and fluid moves out of the circulation with +5 mmHg. At the venous end, the oncotic pressure predominates and fluid moves into the bloodstream with an NFP of -5 mmHg.



Decreased MAP and arteriolar constriction lead to a decreased hydrostatic pressure and a decreased venous pressure. The oncotic pressure is constant, so the fluid exchange from the capillaries to the extracellular space decreases, and the fluid return from the extracellular space to the capillaries increases. This "fluid shift system" increases the blood volume, which increases MAP and helps compensate for shock (the fluid shift in adults is 1 ℓ/h). Two remarks:

1. *"One great consequence of blood loss is the intense vasoconstriction, the shrinkage of the capacity of the vascular bed to accommodate the decreased blood volume...adjustments for blood loss take place...the entry of fluid into the blood vessels in a compensatory attempt. The greatest extravascular store of readily available fluid in the body is... in the extracellular space." (Beecher et al. Recent Advances in Surgery I. The internal state of the severely wounded man on entry to the most forward hospital. Surgery, 1947).*

2. Caveat: *"Possibly, too much attention has been given to the fact that on many occasions [patients in shock may have a normal blood pressure]. ...this has led to a tendency to dismiss the blood pressure as a helpful sign even when it is low - a fatal error, on some occasions. More helpful than the level of the blood pressure is the direction of its swing - a falling blood pressure, a rising pulse rate, are in most cases an urgent indication of the need for blood." (Beecher, LTC and Henry K: Annals of Surgery, 1945).*

6. Decompensatory mechanisms after blood loss

6.1. Cardiac failure

This has many potential etiologies (i.e. the actual etiology is controversial). The myocardial strength may decrease from ischemia secondary to a reduction of circulating red blood cells, lower oxygen saturation, or decreased coronary perfusion secondary to hypotension (especially diastolic hypotension).

6.2. Acidosis

Hypoperfusion leads to an anaerobic metabolism and lactic acidosis. As a depressant of the myocardial function, there is a decreased response to catecholamines in both the myocardium and the peripheral vasculature.

Caveat: *"Although this is a time-honored concept, recent data do not find evidence of this phenomenon. Metabolic acidosis is a sign of underlying lack of adequate oxygen delivery or consumption and should be treated with more aggressive resuscitation, not exogenous bicarbonate"* (John P. Pryor: Hemorrhagic Shock, 2004).

6.3. Central nervous system depression

This is due to opioid release (enkephalins and beta-endorphin). Naloxone has been used as treatment in shock, with some success.

6.4. Disseminated intravascular coagulation (DIC)

Abnormalities of the clotting system develop as a result of attempts to control hemorrhage, but also dilution/loss of clotting factors. Gastrointestinal hemorrhage is seen as a complication of acute hemorrhage, hours after the initial event.

6.5. Reticuloendothelial system dysfunction

Loss of the antibacterial function can lead to endotoxin release from native bacteria, aggravating an already compromised situation.

7. Stages of hemorrhagic shock

7.1. Compensated shock

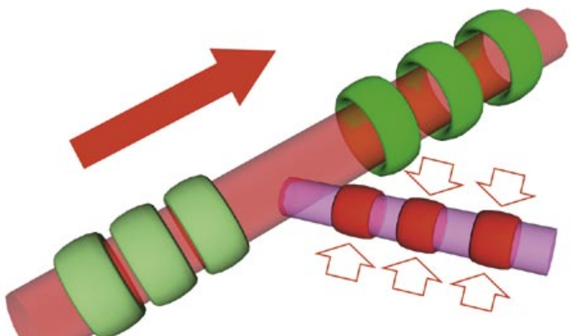
This entails some decrease in tissue perfusion, but the body's compensatory responses are sufficient to overcome the decrease in available fluid.

7.2. Decompensated shock

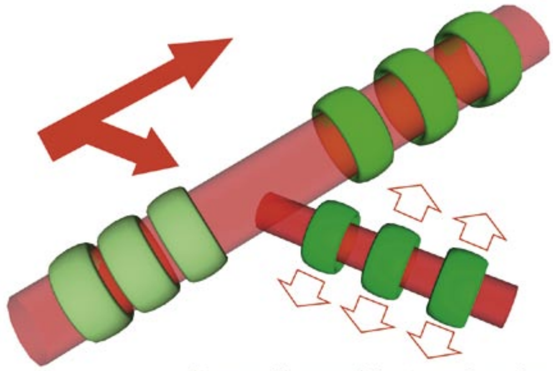
Blood moves to more vital organs. The decreased venous return results in a fall in CO. Viscera (lung, liver, kidneys and gastrointestinal mucosa): These are congested due to the stagnant blood flow. Respiratory system: Attempts are made to compensate for the acidosis by increasing respiratory rate and producing a partially compensated metabolic acidosis. Activation of clotting mechanisms leads to hypercoagulability (DIC).

7.2.1. Main microcirculatory phases during decompensation:

a. The precapillary sphincters relax due to shock-related stimuli.



Precapillary sphincter constriction



Precapillary sphincter relaxation

b. The postcapillary sphincters resist local effects and remain closed => pooling/capillary stasis, capillary engorgement.

c. Increasing hypoxemia and acidosis lead to the opening of additional capillaries, and the vascular space expands greatly.

- The degree of change is so great that even the normal blood volume can not fill the available space.
- The circulatory blood volume can not fill the vena cava.
- Decompensated shock progresses to irreversible shock if fluid resuscitation is inadequate or delayed.

7.3. Irreversible shock

The body is no longer able to maintain the systolic BP, and both the systolic and diastolic BP begin to drop. The pulse pressure may be narrowed to such an extent that it is not detectable with a BP cuff. The loss of arterial BP causes damage from which ultimate recovery is not possible despite temporary restoration of the MAP. Multiple organ system failure and organ damage (MOF and MOD) occur, and even with treatment death is the result.

8. Signs of progressing shock

- Bradycardia
- Serious arrhythmias
- Serious hypotension
- MOF
- A pale, cold and clammy skin
- Prolonged capillary filling/stagnation
- Cardiopulmonary failure.

9. Ischemia-reperfusion injury

A complex cascade mechanism occurs in two steps, an inflammatory (a local and then a systemic) reaction, leading to MOD and MOF. The target organs of ischemia-reperfusion injury are the heart, lung, skeletal muscle and gastrointestinal tract. During ischemia, an anaerobic metabolism and cellular function disorders are initiated. Injury and cell death (necrosis and apoptosis) are caused by reductive stress. During reperfusion, the production of reactive free radicals (oxygen and nitrogen) is started with the activation of leukocyte-endothelial cell interactions and enzymes, etc. Injury/cell death (apoptosis and necrosis) are caused by oxidative stress.

10. Intestinal mucosa injury

- Splanchnic redistribution is one of the compensatory mechanisms.
- There are serious consequences if shock processes are prolonged (the mucosa is sensitive to hypoxia and ischemia-reperfusion).
- Injury to the intestinal epithelium leads to bacterial translocation (intestinal flora, toxins, etc. are translocated into the circulation); the consequences are systemic inflammatory response syndrome, MOD and MOF.

11. Shock diagnosis

The first thing to note is that this is a clinical diagnosis! In most cases, the diagnostic tools are only available after initiation the therapy.

- Decreasing Hbg, hematocrit (responds only later due to the *fluid shift*).
- Decreasing CVP (1–9 cmH_2O).
- Decreasing pulmonary capillary wedge pressure: 5–12 mmHg.
- Decreasing CO (4–6 ℓ/min).
- Decreasing mixed (venous) O_2 saturation (the normal value is ~ 75%).
- Increasing total peripheral vascular resistance (the normal values are ~ 800–1400 dyne s/cm^5).

12. Relationship between mortality and time elapsed from injury to therapy

	Interval [h]	Mortality [%]
World War I	12–18	8.5
World War II	6–12	5.8
Korean War	2–4	2.4
Vietnam War	1–4	1.7

Approximately 53% the cases of traumatic death occur onsite, 7.5% in the emergency room, and39.5% in hospitals. In the hospital 50% of the deaths are caused by central nervous system-related problems, **31%** by hemorrhage and 18% by sepsis (Trunkey DD, Holcroft JW. *Trauma: general survey and synopsis of management of specific injuries.* In: Hardy's Textbook of Surgery, 1988).

13. Treatment of hemorrhagic shock

1. Evaluation: Internal or external hemorrhage? Are there underlying cardiac problems? Amount of blood lost? Duration of bleeding? **And** stop the bleeding!

2. Level of consciousness (motto: "*Report and record*"):
   - alert,
   - verbal response to stimuli,
   - pain response to stimuli,
   - no response to stimuli.

3. Determination of aims (to determine and increase tissue perfusion and oxygenation, and to eliminate and treat the triggering cause. The cause, and not the shock, is what must be treated!).

4. The first steps involve positioning, the ABC approach, keeping the patient at normal temperature to prevent hypothermia. Ongoing assessment (every 10–15 min) is mandatory.

A = Airways
- Depends on etiology: from minimal to complex therapy (intubation, and mechanical ventilation).
- If the patient can say his/her name: the airways are free (!)

B = Positive-pressure ventilation
- Breathing: Patients need respiratory support (intubation or other respiratory support) and monitoring. In general, respiratory support and monitoring are needed even in the case of adequate O_2 saturation to help compensation for metabolic acidosis.

C = Circulation

- What is to be given? "Volume" (!)
- How to give it? The flow in the catheter is inversely proportional to the length of the tube and directly proportional to the cross-section: a short, wide and peripheral iv. infusion set must be used!
- Where to give it? Into peripheral (antecubital) visible/palpable veins. Intraosseal colloid therapy is probable in children, if an iv. route cannot be secured quickly. A central vein can be used only after a routine has been attained!
- What type of fluid? Isotonic (in the ideal case iso-oncotic) fluid should be given. Physiological salt solution is available everywhere; first, 2 ℓ of salt solution or lactated Ringer, but in most cases much more (20 mℓ/kg!) is given. 3 units of crystalloid is ℓ unit of intravascular fluid (!), colloid solutions supplement the volume in a 1:1 ratio (see above).
- 2 U of red blood cells are given if the circulation is unstable after the administration of 2000 mℓ of crystalloid. More blood may be needed during active bleeding (warming, taking a blood sample before transfusion, cross-reaction!).
- Fresh frozen plasma and a thrombocyte suspension are indicated for the treatment of the symptoms of coagulopathy (usually after giving 6-8 U of blood).

D = Definitive therapy / Drugs:

- The goals are to 1. increase the preload, 2. to increase the contractility, and 3. to decrease the afterload.
- Correction of acidosis
  - Background: A pH < than 7.25 will interfere with the effects of catecholamines and inotropic resistant hypotension evolves.
  - Method (see above): Na-bicarbonate is given if the deficit > 6 meq/ℓ.
    A useful formula: 0.3 × kg bw × base deficit = meq $NaHCO_3$ will compensate for half of the loss. It should be given slowly in a 1–2 meq/kg bolus; 10–20 meq/kg could be needed, which means a large Na^+ load and hyperosmolarity.

Treatment with pressors
- β effects: Increase inotropy and chronotropy - increasing CO (beta-1), and also some pulmonary and peripheral vasodilation (beta-2).
- α effects: Increase the systemic vascular resistance - maintaining the BP
- Vasodilators: Decrease the systemic vascular resistance, and decrease the afterload, potentially improving the cardiac function, but also dramatically reducing the MAP in hypovolemic patients.

	Alpha Peripheral	Beta 1 Cardiac	Beta 2 Peripheral
Norepinephrine *alpha and beta, more alpha*	++++	++++	0
Epinephrine *beta and alpha, stronger beta*	++++	++++	++
Dopamine	++++	++++	++
Isoproterenol	0	++++	++++
Dobutamine *beta-1 alone*	+/0	++++	+

(Source: NEJM, 300:18, 1979)

5. Further important interventions – correction of electrolyte abnormalities.

The Na^+ level can be markedly abnormal as a result of the underlying disease (hypo/hypernatremic dehydration); it can become elevated during the process of correcting a base deficit. The goal should be to normalize the Na^+ level- slowly! Hyperchloremia may aggravate acidosis.

The K^+ level can be elevated to the point of cardiac dysrhythmias. As the correction of acidosis occurs, K^+ can be driven back into the cells, severe hypokalemia developing in some cases.

Ca^{++} can be chelated in the treatment of a base deficit and dramatically decrease, leading to problems from seizures, hypotension and a myocardial dysfunction.

Glucose: As part of the response to compensatory mechanisms (epinephrine and corticosteroids), hyperglycemia is a common occurrence in stressed children. This can cause problems from osmotic diuresis and glucose intolerance. Care should be made not to overload the glucose management system in the body (i.e. no dextrose in flush solutions).

6. Blood gases: It is important to maintain good DO_2 so as to minimize the anaerobic metabolism and acidosis. Venous blood gases are also of benefit since mixed venous O_2 saturation is a measure of tissue perfusion and CO.

7. Hemodynamics: MAP and ECG: A decreasing MAP may be a sign of decompensation. Monitoring the CVP may be indicative of tissue hydration and the preload (see above).

8. Coagulation status: DIC is a common complication even early in shock.

9. Urinary output: This is representative of the organ perfusion. An improving urinary output can be a sign of an improving volume status, while a worsening output suggests the need for more aggressive therapy.

10. Neurologic status: Indicative of brain perfusion.

14. Signs of cardiovascular stabilization

- MAP is stable.
- HR is decreasing.
- Consciousness, and decreased anxiety.
- Increasing capillary refilling, improved color of mucous membranes.
- The urinary output exceeds 30 mℓ/h.

15. Medical – legal pitfalls

- Unrecognized occult bleeding.
- Hypotension after head trauma (hypotension and other causes!).
- Omission of rectal finger examination.
- Undiagnosed bleeding source.
- Inadequate resuscitation (*immediate, correct, sustained therapy*)

16. Variations in physiological responses to hemorrhagic shock

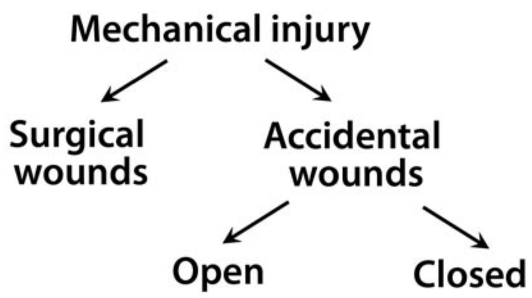
It is important that there are significant differences in relation to the following parameters:

- Age and relative health
- General physical condition
- Preexisting diseases
- Ability to activate compensatory mechanisms
- Older adults are less able to compensate (they develop hypotension early)
- Children compensate longer and deteriorate faster
- Medication may interfere with compensatory mechanisms.

IX. Wounds

"Notae vero inflammationis sunt quattuor: rubor et tumor cum calore et dolore".
Aulus Cornelius Celsus (BC 25-50 – 45-50 AD)
De Medica (1478) Liber III. 10.

The etymology of the word wound is the Old English "wund" and the Old Norse "und". A wound is a disruption of the continuity of tissues produced by an external mechanical force, a cut or break in the continuity of any tissue, caused by an injury or operation. As a consequence, the circulating blood volume is lost, while the breakdown of the defense mechanisms of the skin leads to the entrance of pathogens and foreign materials into the body. The exposure of body cavities and internal organs means a further risk. Surgical wounds are usually made under sterile circumstances and are closed layer by layer upon completion of the surgical intervention. Accidental wounds, however, are caused by mechanical trauma and can be either open or closed. Wounds can result from mechanical, thermal or chemical forces and irradiation, but the focus here will be on the characteristics and management of wounds caused by mechanical injury. The term injury is used synonymously with wound, but can have a wider meaning; wound (in surgery) = mechanical injury.



1. Classification of accidental wounds

1.1. Morphology / classification depending on the penetration route

A puncture wound *(vulnus punctum)* is caused by a sharp pointed tool, wood splinters, pins, nails, glass, scissors or knives and usually, misleadingly, seems to be negligible. Some punctures are merely on the surface, whereas others can be very deep, depending on the source and cause.

Treatment: Such wounds usually close quickly on their own. Treatment may be necessary to prevent infection, as the object that caused the wound may carry bacteria or tetanus spores into the skin and tissue.

An incised wound *(vulnus scissum)* is caused by sharp objects; it involves a linear cut in the skin, which is usually superficial, but may involve deep structures (surgical incisions). This type of wound exhibits the best healing. The extent of opening of the wound depends on the tissue flexibility and the directions of the Langer lines. These wounds are accompanied by considerable bleeding.

A cut wound (*vulnus caesum*) is similar to an incision, but with an additional direct, perpendicular force. The impact bursts the tissues open (e.g. an axe injury).

A crush wound *(vulnus contusum)* is caused by a blunt force and can be either open or closed. Heavy objects split the skin and shatter or tear the underlying structures. Fingers and toes are commonly involved. This is a painful injury with much swelling. The wound edges are usually uneven and torn. The bleeding is negligible, but the pain is proportionately greater than would be expected from the size of the injury (termed wound stupor).

A torn wound *(vulnus lacerum)* is caused by great tearing or pulling forces and can result in the incomplete amputation of certain body parts.

A shot wound *(vulnus sclopetarium)* consists of an aperture, a slot tunnel and an output. A shot from close range is usually accompanied by some degree of burn injury at the aperture. Other characteristic features are the incorporated foreign materials: textile fibers, bullets and the various types of tissues penetrated.

A bite wound *(vulnus morsum)* is a ragged wound with crushed tissue characterized by the shape of the biting teeth and the force of the bite. It is also accompanied by the features of torn wounds. There is a high risk of infection (transmission of malaria, rabies, etc.; human bites carry a considerable risk of infection through the transmission of HIV or hepatitis B). Such wounds should not be sutured.

1.2. Classification according to "cleanliness" – bacterial contamination

Clean wounds (operation or sterile conditions; only the normally present skin bacteria are detectable) with no signs of inflammation.

Clean-contaminated wounds (the contamination of clean wounds is endogenous or comes from the environment, the surgical team, or the patient's skin surrounding the wound). They include opening of the digestive, respiratory or urogenital tract.

Contaminated wounds (large contaminates infect the wound) arise when an incision is performed in a purulent area or in cases of a leakage from the gastrointestinal tract.

Dirty wounds (the contamination comes from the established infection), in which there are residual nonviable tissues and chronic traumatic wounds.

1.3. Classification depending on the time since the trauma

Acute wounds (mechanical and other injuries):
- Fresh wound: treatment within 8 h.
- Old wound: ≥8 h after trauma/discontinuity of the skin.

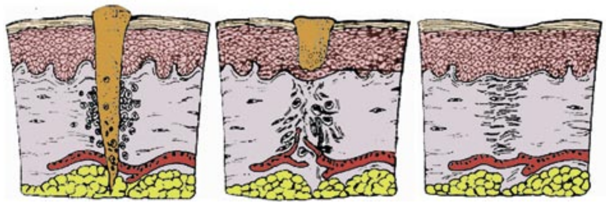
Chronic wounds (venous, arterial, diabetic and other ulcers, and skin or soft tissue defects):
- They do not heal within 4 weeks after the beginning of wound management.
- They do not heal within 8 weeks.

With chronic wounds, the normal process of healing is disrupted at one or more points (in most cases, the healing process is 'stuck' in the inflammatory or proliferative phase; see later).

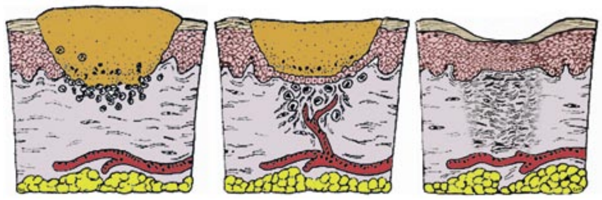
1.4. Classification depending on the number of skin layers involved

- **Grade 1:** Non-blanchable erythema of intact skin. Discoloration of the skin, warmth, edema, induration or hardness may also be used as indicators in people with dark skin.
- **Grade 2:** Partial-thickness skin loss involving the epidermis, dermis or both. The ulcer is superficial and presents clinically as an abrasion or blister.
- **Grade 3:** Full-thickness skin loss involving damage to or necrosis of subcutaneous tissue, which may extend down to, but not through the underlying fascia.
- **Grade 4:** Deep wounds or complex wounds (e.g. lacerations, or vessel or nerve injuries), or wounds of the bone or supporting structures, the opening of body cavities, or penetrating injuries of organs.

1.5. Classification depending on the factors affecting wound healing



The scheme of *sanatio per primam intentionem* ("p.p. healing"). According to Galen (Galenus, BC 129-199): "the major aim" of a doctor is the gap-free healing of wounds. Wounds are closed surgically by reconstruction of the skin continuity (a) by simple suturing, (b) by the movement (relocation) of skin fragments from the surrounding area (flaps), or (c) by the transplantation of free skin elements (grafts) of different thicknesses (e.g. split- or full-thickness grafts). Primary healing is usually the case in all wounds in which the anatomical location and the size allow the skin continuity to be restored (no significant degree of tissue loss); healing takes place from the internal layers outward.



The scheme of *sanatio per secundam intentionem*. Secondary healing is the mode of healing of abrasions or split-thickness graft donor sites. The tissue loss is compensated by a granulation tissue "according to the second potential goal of the doctor". (Due to the abacterial or purulent inflammation, the wound is filled with connective tissue which transforms into scar tissue. If there is significant tissue loss in the formation of the wound, healing will begin by the production of the granulation tissue wound base and walls. After wound *debridement* and preparation, the wound is left open to achieve sufficient granulation for spontaneous closure (re-epithelialization from the remaining dermal elements or from the wound borders).

Tertiary (delayed primary) healing occurs in primary contaminated wounds or mixed tissue trauma wounds (e.g. after the reconstruction of hard tissue).

Factors influencing wound repair
- Drugs: Glycocorticoids inhibit fibroblast activity, protein synthesis and immune responses. Some antibiotics inhibit collagen biosynthesis. Cytostatic agents slow down metabolic processes. Anti-inflammatory agents reduce hyperemia and the blood supply to the wound (they may slow down the healing process if they are taken after the first several days of healing, following which anti-inflammatory drugs should not have an effect on the healing process).

- General condition, nutrition, protein level, vitamins B, C and K, and trace elements (Zn and Mg) (malnutrition slows down the healing process).
- Diabetes mellitus: There is a risk of infection, dysfunction of the micro- and macrocirculation, and hyperglycemia = chronic wounds.
- Icterus and anemia.
- Bacterial/other infections: Bacterial contamination slows down the healing process.
- Age: The older the patient, the slower the wound heals.
- The location of the wound: Poorly vascularized areas or areas under tension heal more slowly than areas that are highly vascularized.

1.6. Classification depending on wound closure

Primary wound management was pioneered by Paul Leopold Friedrich (1898).

Primary suture: Immediate surgical wound closure can be performed within 12 h after the injury if no signs of inflammation or contamination can be detected (see below).

Delayed primary wound closure: After 3–8 days of open wound management, surgical wound closure is performed (see below).

Early secondary surgical wound closure: After 2 weeks of open wound management, surgical wound closure is performed (see below).

Late secondary surgical wound closure: After 4–6 weeks of open wound management, surgical wound closure is performed (see below).

2. Surgical wounds

2.1. Determinants of healing of surgical wounds

- Preparation of the operating site, hygiene, shaving, disinfection and isolation.
- The incision should be parallel to the *Langer* lines. The skin is stretched, the scalpel is held in a vertical position and the incision is performed until the sc. layer is reached.
- It is important to be aware of the anatomical aspects of the involved area. The muscle is separated along its fascia, the handling of bleeding is of importance, etc.

2.2. Skin incision

- A skin incision is made on a prepared (cleansed, draped) operative field.
- During the incision, the surgeon and the assistant stretch the skin with sterile towels on both sides of the operative field.
- Usually a scalpel (e.g. #20 blade, #4 handle) is used. The type of the scalpel depends on the site of the incision.
- The manner of holding the scalpel varies according to the use.
  - For the delicate, curved incision of fine structures, the scalpel is held like a pen.

  - For a long straight incision, the scalpel is held like a fiddle bow.

2.3. The requirements of skin incision

- The length of the incision should be appropriate for safe surgery.
- Vessels and nerves should not be damaged.
- The skin edges should be smooth.
- The incision is made perpendicularly to the skin with a single definite cut (failed attempts result in ragged edges and prevent wound healing).

- The direction of the incision depends on the location of the organ being operated on.
- The skin is incised parallel to the *Langer* lines (better wound healing and less scar formation), usually toward the operator, and from left to right.
- The depth of the incision must be the same throughout the whole length. At the beginning, the tip of the scalpel is inserted perpendicularly into the skin, the cut is made an angle of 45° with the blade of the scalpel (not with the tip!), and the incision is completed with the scalpel held perpendicularly.
- The skin scalpel is discarded into the container after the skin incision. In the deeper layers, another scalpel is used.

2.4. Main types of skin incisions

(See details later, on page 93)

- *Kocher*'s transverse incision at the base of the neck (thyroid gland), sternotomy, thoracotomy.
- Subcostal (gallbladder or spleen), median/paramedian laparotomy (this may be upper or lower relative to the umbilicus).
- Transrectal/pararectal/transversal laparotomies.
- *Pfannenstiel* suprapubic incision (bladder, uterus or ovaries).
- *McBurney* incision (appendectomy).
- Inguinal incisions (hernia).

2.5. Closure of surgical wounds

- Fascia and subcutaneous layer: Interrupted stitches. The fat must not be sutured (fat necrosis).
- Skin: Tissue-sparing technique, with accurate approximation of the skin edges. Tension and ischemia of the skin edges are to be avoided. A simple interrupted stitch is the most fundamental type in cutaneous surgery (other possibilities: *Donati* vertical mattress suture, *Allgöwer*, continuous intracutaneous, etc.; *Steri-Strips*, clamps and tissue glues may be applied).
- Dressing: Sterile, moist, antibiotic and non-adhesive dressings. Gauze placed directly on the wound makes dressing removal difficult and painful: tearing of the closure is possible.
- Holding the dressing: Stretchable adhesive tape, such as Hypafix.
- The dressing is removed on the 2nd postoperative day, and daily in cases of infection.
- Sutures are usually removed after 4–6 days. In areas of good blood supply, such as the face, it is after 5–7 days, and in the trunk and extremities after 10–14 days.

3. Early complications of wound closure

(See also sections I.4 and V.7.2.2.2)

- Hematoma
- Seroma
- Wound infection (see also SSI). Therapy in general:
  - The type of surgery (clean, clean/contaminated, contaminated or dirty) will determine the level of the risk of infection and the likely spectrum of pathogens. Empirical antibiotic therapy should be primarily directed against Staphylococcus aureus.
  - Swabs are commonly sent for culture; pus (if available) is a better sample. Other fluids or tissue biopsy samples may also be cultured. Blood culturing is recommended in febrile patients.
  - If wounds are not grossly infected, they may respond to local measures such as the removal of sutures. Frequent saline bathing should be undertaken and the wound requires a drain to allow healing. Deep-seated infection may require broad-spectrum antibiotics and possible surgical intervention.

Superficial SSI

1. Diffuse and superficial (e.g. erysipelas). Streptococcus haemolyticus-induced lymphangitis, linear, diffuse subcutaneous inflammation. *Treatment:* Rest, antibiotics and dermatology consultation.
2. Localized (e.g. abscess, stitch abscess, *filum suppuratio*). This can occur anywhere: under the skin, between the muscles, subfascially, in the chest, brain or liver. *Therapy:* Radical surgery and drainage. In the presence of dead tissue, the most critical aspect of treatment is the surgical removal of pus (Motto: "cut out the rubbish"). Antibiotics have a supportive role.
3. Foreign material *(corpus alienum)* could be present even years later (importance of X-ray examination!).

Deep SSI

1. Diffuse (e.g. anaerobic necrosis).
2. Localized (e.g. empyema) in body cavities (chest and joints). *Therapy:* Surgical exploration and drainage (Staphylococcus aureus!)

Mixed SSI

1. Gangrene: Necrotic tissues with putrid and anaerobic infection; this is a highly lethal, severe state. The terms gas gangrene and clostridial myonecrosis are used interchangeably and refer to the infection of muscle tissue by toxin-producing clostridia. *Therapy:* A combination of aggressive surgical debridement and effective antibiotic therapy is the determining factor.
2. Generalized reaction: Bacteremia, pyemia and sepsis.

4. Late complications of wound closure

- Scar formation at the penetration site
- Hypertrophic scar
- Keloid
- Necrosis and inflammatory infiltration
- Abscess containing foreign materials.

5. Prevention of wound infection

- Basic general surgical education
- Thorough examination and preparation before surgery
- Compliance with asepsis
- "Fast" decisions and optimal exposure
- Atraumatic techniques
- Correct handling of bleeding.

6. Signs of wound infections

Inflammatory signs are classical (*functio laesa* by Virchow (1858) and *rubor et tumor cum calore et dolore*). *General therapy*: Rest and steam bandage if necessary. In the event of aggravation of the symptoms, wound exploration is performed under local anesthesia, with surgical removal of pus, necrotic tissues or foreign material, daily rinsing with 3% H_2O_2 solution (or with antiseptics, povidone-iodine: Betadine, Braunol), open wound management and daily wound toilette.

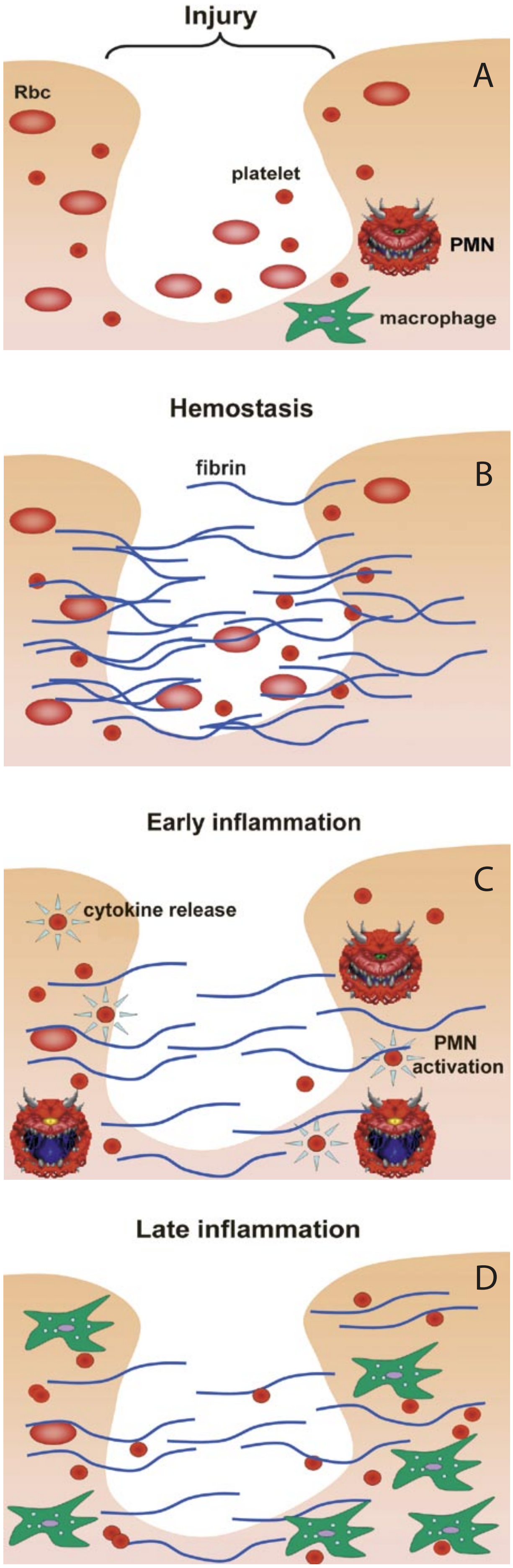
7. Phases of wound healing

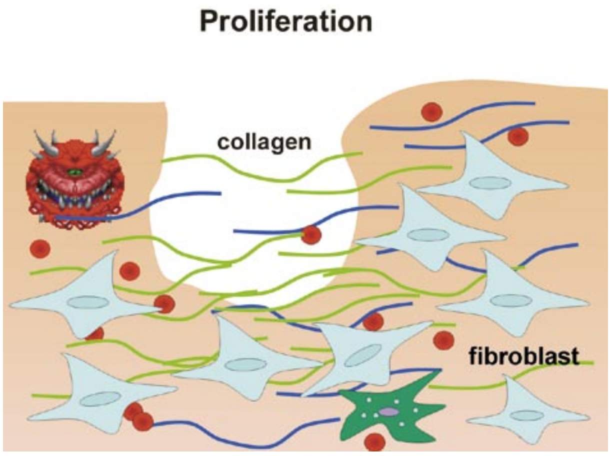
Hemostasis–inflammation (days 0-2)

Signs of inflammation (heat, pain, redness, and swelling) are present. The wound fills with blood clot and thrombocyte aggregates, and fibrin production develops. The blood flow is increased, and macrophage and leukocyte mediators are released. A chemical gradient develops, with the removal of nonvital cellular material and bacterial components (see Figs A–D).

Granulation–proliferation (days 3-7)

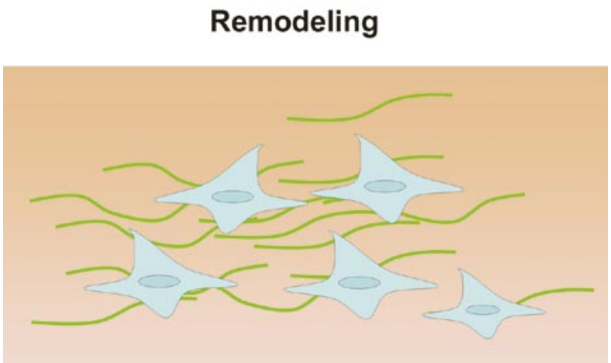
Characterized by the formation of granulation tissue: Fibroblasts, inflammatory cells, new capillaries embedded in a loose extracellular matrix (ECM) (angiogenesis) of collagen, fibronectin (modeling the ECM) and hyaluronic acid, providing a good basis for re-epithelialization. The healthy sprout is red and does not bleed.





Remodeling (lasting for months from day 8)

(A) Maturation = ECM remodeling, and continuous collagen deposition. The scar is characterized by intensive strand formation; the vascularity is reduced and becomes brighter. The ECM is loose and relatively weak (20% of the final strength after 3 weeks).
(B) The fibers contract and become smaller and stronger. This contraction can cause reduced of joint functions. This is pronounced for a year, but remodeling continues for an indefinite time.
(C) The final strength of the wound is around 70-80% of that of uninjured tissue.



8. Wound healing disorders

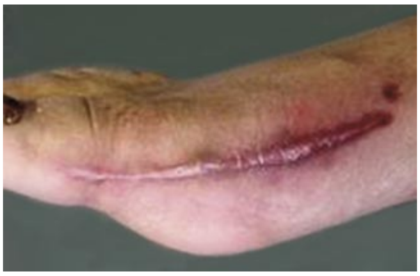
Keloids

- These are of unknown etiology; they resemble benign tumors, and affect mostly African and Asian populations.
- They have well-defined edges, with pinkish-brown, emerging, tough structures, which result from the sc. proliferation.
- They particularly affect scars on the pre-sternal and deltoid areas and ears.
- They do not cause any pain, but constantly develops.
- Treatment: Intralesional corticosteroid injections, cryosurgery, excision, radiation therapy, laser therapy and interferon therapy. Prevention with an atraumatic technique.

Hypertrophic scars

- These develop in areas of thick chorium.
- They are composed of non-hyalinic collagen fibers and fibroblasts.
- They are confined to the incision line.
- Treatment: They regress spontaneously, starting 12–18 months after surgery, and fall back to the level of the skin in 1–2 years.

Keloid



Hypertrophic scar

9. Wound management of accidental wounds

- All accidental (not surgical) wounds should be regarded as infected. Accordingly the causative agents and the devitalized tissues should be removed.
- An accidental wound should be transformed into a surgical wound.

PHASES	MANAGEMENT
Inspection	Under sterile circumstances (cap, mask and gloves)
Anamnesis	▪ Elucidation of the circumstances of the injury. When did it occur? The earlier the wound is managed, the lower the possibility of infection. Is the patient suffering from diseases associated with a poorer tendency to heal (diabetes)? Clarification of the circumstances of the injury helps the assessment of the danger of infection. ▪ The validity of tetanus vaccination should be clarified. In the presence of spoiled wounds, at least vaccination with anti-tetanus immunoglobulin is recommended. Vaccination and its registration are performed at the corresponding traumatology department. ▪ Prophylaxis of rabies in the event of bitten wounds: Vaccination with Rabipur on days 0, 3, 7, 14, 30 and 90)
Diagnostic procedures	▪ Exclusion of accompanying injury ▪ Examinations of circulatory, sensitivity and motor functions ▪ Exclusion of bone fractures by X-ray examination
Wound management	▪ Surgical wounds should be handled by the procedures described in the chapter focusing on suture types. ▪ Accidental wounds should be managed on the basis of the depth of the injury and the danger of infection, with primary or delayed wound closure (see Table below).

Types of wound management

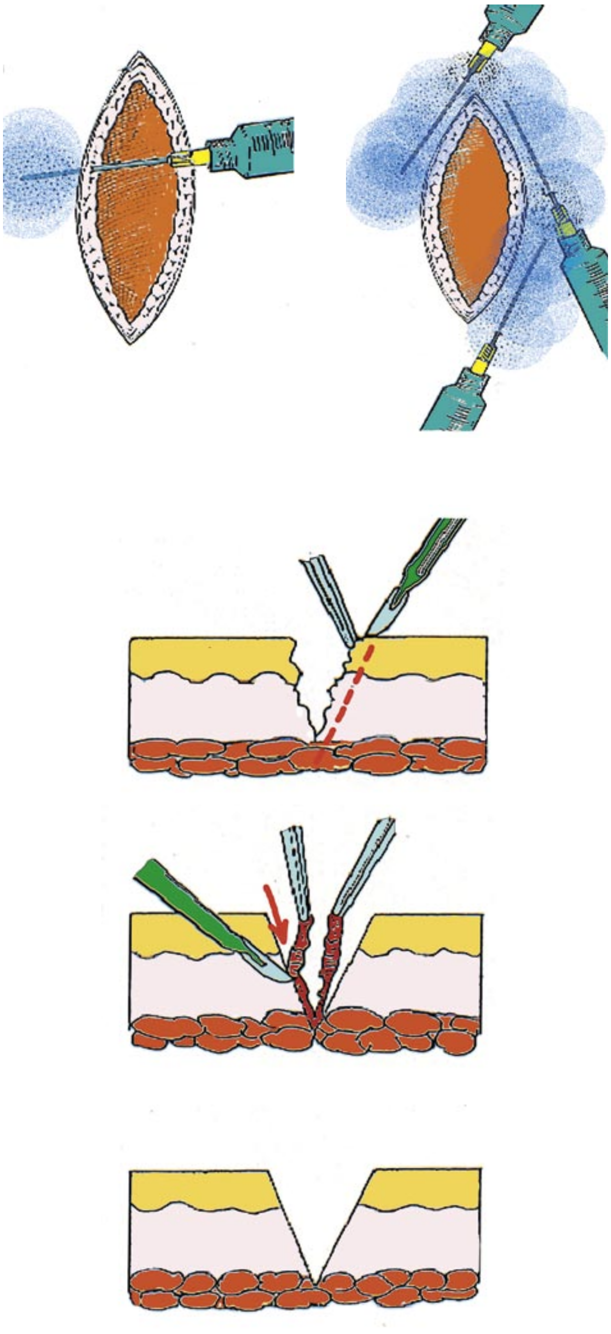
Temporary wound management (first aid)	Aim: Prevention of secondary infection	▪ Cleansing ▪ Handling of bleeding ▪ Covering
Definite primary wound management	Surgical wound closure is performed if the injury is less than 12 h old.	▪ Cleansing ▪ Anesthesia ▪ Excision (< 6–8 h, except face and hands) ▪ Sutures (puncture, bite, shot and bruised wounds: situating sutures* + drain)
Primary wound closure is always performed	Penetrating injuries of ▪ the abdomen ▪ the chest ▪ the dura mater	
Primary wound management is contraindicated:	In the cases below, after wound cleansing, the wound is covered with saline and a surgical covering, held in rest, and delayed sutures are placed after 4-6 days in the presence of: ▪ infectious signs ▪ severe contamination ▪ an incompletely removed foreign body ▪ pouched, greatly bruised wounds ▪ special injuries in certain professions: surgeons, butchers, veterinarians, pathologists and bacteriologists ▪ bite, shot or deep incised wounds	▪ Cleansing ▪ Covering ▪ Primary delayed suturing (3–8 days)
Never perform primary wound closure (except in cases of skull, chest and abdominal penetrating injuries)	War casualties ▪ Hostility wounds should always be regarded as infected with aerobic or aerobic bacteria ▪ The reaction time of the wounded person is prolonged ▪ The circumstances of wound management are poor	Alternatives: ▪ Primary delayed suturing (3–8 days) ▪ Approximation of wound edges with tapes, and later sutures ▪ Situating suturing * + drain ▪ Early secondary wound closure (> 14 days) ▪ Late secondary wound closure (4-6 weeks) ▪ Plastic surgery solutions later.
Primary delayed suture	If no signs of infection occur within 4–6 days, suturing (or also situating suturing*) is performed after excision of the wound edges, those are sutured	3–8 days later: ▪ Anesthesia ▪ Excision (refreshment of the wound edges) ▪ Suturing
Early secondary wound closure	In the event of wound inflammation and necrosis, but healing proceeded with proliferation, the wound edges should be refreshed and closed by suturing.	2 weeks after the injury: ▪ Anesthesia ▪ Excision (refreshment of the wound edges) ▪ Suturing ▪ Draining
Late secondary wound closure	The proliferating former wound parts and scars were first excised. With greater defects, plastic surgery solutions should also be considered.	4–6 weeks after the injury: ▪ Anesthesia ▪ Excision (of the secondarily healing scar) ▪ Suturing ▪ Draining

**Situating suturing* is performed at the time of the primary management, but the distance between the stitches is ~ 2–3 times that in primary surgical wound closure.

Management of accidental wound types

Severity/ depth of injury	Conservative/ surgical management	Cleansing, disinfection	Wound management, covering, bandaging
Bruised, not pyodermic superficial injury) (“excoriation”)	Needs conservative management	Cleansing with Betadine solution, removal of foreign bodies	Treatment with mercurochrome solution. After drying, sterile bandaging (mull-sheet, then mull strip or elastic net). Open wound management can also be considered
Bruised, pyogenic injury (“excoriation”)	Conservative management is followed by surgical wound closure	Cleansing with H_2O_2 solution, rinsing with saline	Disinfection with Betadine solution, sterile bandage. Open wound management and later secondary surgical closure
Deeper penetrating mechanical injury (vulnus scissum and vulnus caesum)	Requires surgical wound closure	Cleansing with Betadine solution	Handling of bleeding, cleansing, excision of bruised edges, open wound management, sterile bandaging. The wound is later closed secondarily
Deeper blunt mechanical injury (vulnus contusum)	Requires surgical wound closure	Cleansing with Betadine solution	Cleansing, excision of bruised tissues, open wound management, sterile bandaging. The wound is later closed secondarily. Transplantation may be necessary
Bite wound (vulnus morsum)	Requires surgical wound closure, but primary wound closure is forbidden (except the face)!	Cleansing with Betadine solution	Cleansing, excision of bruised edges, open wound management, sterile bandaging. The wound is later closed secondarily. Rabies prophylaxis!
Puncture and shot wounds (vulnus punctum et sclopetarium)	Require surgical wound closure	Cleansing with Betadine solution, probing of the penetrating route, removal of foreign bodies.	Cleansing, open wound management, sterile bandaging. The wound is later closed secondarily. Antibiotic prophylaxis in special cases!
Inflamed wounds (war injuries, wounds contaminated with soil, foreign bodies, if wound edges are irregular, poor immunological status)	Combined conservative and surgical management for days, then surgical wound closure	Steam bandage, keeping in rest. If inflammatory signs accelerate: ▪ Surgical exposure under anesthesia ▪ The wound is opened and the excretion, necrotic tissue and foreign bodies are removed ▪ Cleansing with H_2O_2 solution, rinsing with saline (or with antiseptic, Betadine, Braunol solutions, possibly diluted with saline, and intermittent flushing/ suctioning of the wound) (or disinfection with Octenisept, which does not irritate) (or soaking with Neomagnol on the limbs) ▪ Open wound management with daily cleansing ▪ Bacteriological sampling from the wound	▪ Open wound management until completion of the inflammatory process, daily wound cleansing, sterile bandaging ▪ Tranquillization of the inflamed skin (Burow ointment, ice, zinc-aluminum-containing pharmacy products) ▪ For epithelization: Mercurochrome treatment, Sol. Merbromi, Mikulitz ointment, Dermasin ointment, Bepanten, Neogranormon, Actovegin 20% creams ▪ Deodoration (alginate and carbon-containing bandages e.g. Kaltostat, Melgisorb, etc.) ▪ Purification (fibrinolysis with Fibrolan, Iruxol mono, Mesalt, etc.) ▪ Incision instead of antibiotics or Friedrich wound excision, drainage if necessary, complying with asepsis criteria.

The schemes of excision



Solutions, ointments

H_2O_2	A 3% solution which removes necrotic tissues. Bubbling can be observed on the surface when necrotic parts are present. It is allowed to act on the wound for some minutes, and then rinsed thoroughly with saline.
Betadine, Braunol solutions	Iodine-containing disinfecting solutions which (in contrast with iodine tincture) can come into direct contact with the wound.
Octenisept solution	A non-irritating disinfecting solution.
Mercurochrome tincture	A pharmacy product comprising excellent treatment for superficial wounds. Accelerates epithelization.
Vaseline ointment	Prevents adhesion formation between the wound and the bandage.
Betadine ointment	Prevents infection and also adhesion formation between the wound and the bandage.
Neogranormon ointment	Accelerates epithelization; particularly applicable in superficial erosions and sloughs.
Burow ointment	Applicable under steam bandages; facilitates the exhaustion of purulent material.
Fibrolan, Iruxol mono, Mesalt ointment	Fibrinolytic enzyme-containing substances which facilitate epithelization. Applicable to areas near ulcers, stomas and fistulas.

10. Dressing – bandaging

Definition: Bandages are stringy materials which protect injured body parts. An ideal wound dressing:

- maintains a moist environment at the wound interface,
- removes excess exudate without allowing 'strike-through' to the surface,
- provides thermal insulation and mechanical protection,
- acts as a barrier to micro-organisms,
- allows gaseous exchange,
- is not adherent and is easily removed without trauma,
- leaves no foreign particles in the wound,
- is nontoxic, nonallergenic and nonsensitizing.
- However, there is no single dressing that is appropriate for all wound types and all stages of healing.

10.1. Types of bandages

- Foils and film bandages (e.g. Tegaderm and Op-site)
- Polymer bandages
- Foam sponges and foam bandages
- Hydrocolloids (pectin, gelatin and carboxy-methylcellulose, e.g. Urgotul)
- Hydrogels (starch and polyacrylamide (94% water)
- Alginates (from marine algae)
- Island bandages
- Absorbent wound pillows
- Impregnated gauze sheets
- Mullsheets and mullbandages
- Flexible, tube-net bandages
- Wound approximators (strips)
- Fixing bandages
- Cotton

10.2. Layers of bandages

- The layer in direct contact with the wound (sterile, hypoallergenic, and not irritating); it is a simple sheet (e.g. mull sheet: a good fluid absorbent, but easily sticks to the wound).
- An impregnated sheet (Vaseline, paraffin, e.g. "Jelonet", but there are also sheets impregnated with antiseptic materials). It does not stick to the wound and protects it from drying-out. There are also sheets impregnated with saline which melt when they come into contact with body fluids and help cleaning of the wound, e.g. Mesalt.
- An absorbent layer (to absorb and store blood and excretions).
- A fixing layer to secure the bandage (adherent tapes, e.g. Centerplast, Leukoplast, Mefix or Mepore, the latter two for larger surfaces).

10.3. Types of bandages

Adherent/taped bandages
These are used to fix covering bandages or for the approximation of the edges of small wounds. Conditions of application: they should stick well to the skin surface and be hypoallergenic. There are self-adherent types with a surface in the middle ready to contact the wound. They should be permeable to air and good fluid absorbents.

Covering bandages
These are used to protect the wound and absorb secretion. They should be non-sticking, good fluid absorbents and well permeable to air. The bandage protects the wound from secondary infection and mechanical forces. Absorption of the secretion is very important, because this protects the skin from the irritation caused by soaking in body fluids, which also predisposes to infections. When a great amount of secretion is dried in the bandage, it compresses the neighboring skin, causing further injury.

The frequency of bandage changing depends on the fluid produced in the wound. During these procedures, the healing process is also checked. Swollen, painful, red skin indicates infection.

The bandage can be produced from natural fibers (cotton or silk), or from semi-synthetic, synthetic or synthetic materials. The advantage of natural fibers is the good fluid absorbent capacity, but they easily stick into the wound. Synthetic materials have the opposite features.

Primarily closed wounds are protected with sterile covering bandages for 2–3 days. If there is a sign of secondary bleeding or infection, earlier changing is necessary. Unnecessarily frequent changing facilitates infection. After the 5th postoperative day, a problem-free operative field can be left uncovered.

For larger traumatic areas or burn injuries, multi-layered poly-urethane sheets are applicable (e.g. Epigard). These are good fluid absorbents that are well permeable to air and provide ideal circumstances for skin transplantation.

Pressing bandages
These are for the temporary handling of capillary and venous bleeding under 40–60 mmHg.

Wedging bandages
These are used for temporary handling of capillary arterial and venous bleeding in order to prevent great blood loss before the final surgical intervention. The wound is covered by a sheet, and a gauze sponge ball is then placed on the source of the bleeding and fixed with a relatively tight bandage. The compression force must not exceed the arterial BP. The tourniquet can cause an inadequate blood supply, and it should therefore be relieved every 2 h.

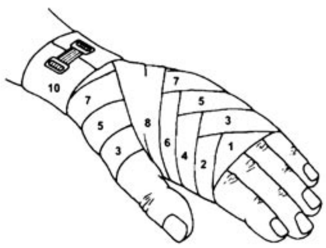
Compressing bandages
These are used to prevent postoperative bleeding in the limbs, for the prophylaxis of thrombosis and for the reduction of chronic lymphedema.
They can consist of different materials:

- mull strip, which has the disadvantage of crease formation, as it is not elastic,
- elastic strip,
- synthetic, self-adherent strip,
- elastic socks.

Window or crease formation should be prevented, because these can cause circulatory disorders. The upper limbs are more endangered, because the tissues are finer, and the vessels and nerves are more superficial. Nerve injuries caused by compression (neuropraxy) and circulatory disorders (*Volkmann* contracture and *Sudeck* dystrophy) can develop. The compressing bandage should always be started distally so as to prevent venous stasis. Circumferential application is forbidden because of the danger of strangulation!

Special compressing bandages

Ear bandages
Special bandaging of the extremities. They have the advantages of stability and non-creasing. They are applied from distal to proximal (see Figure).



Ear bandage

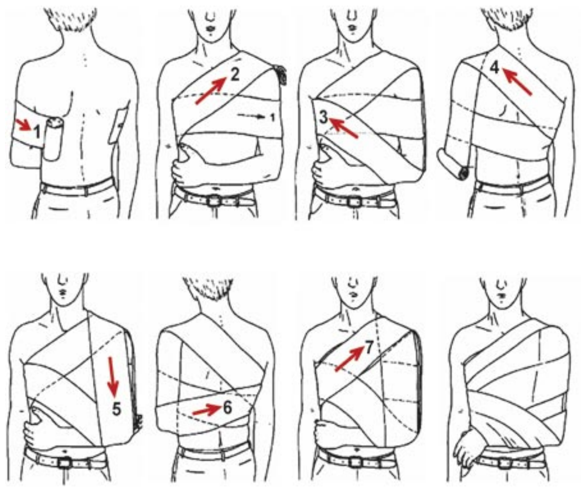
Esmarch tourniqet
Maximal compression is elicited by using a 10-cm rubber band to stop arterial bleeding from the limbs. The duration of application should not be longer than 2 h.

Fixing/retention bandages
These are used to immobilize the injured body part or to fix the reposition. The material used should be light and be worn with minimal strain. They can be made of elastic strip, cast, plastic or metal rails, or pneumatic rails, or cotton-embedded tubes (rucksack bandage or *Charnley* loop).

Special fixing/retention bandages
(see traumatology for details)

Schanz collar
This is used to immobilize the vertebras. Its material is special: an 8-15-cm-wide, 1.5-cm-thick, 50-cm-long padded strip. It can also be made of a cotton-embedded elastic band. It should be placed loosely so as to prevent movement of the jugular vertebras.

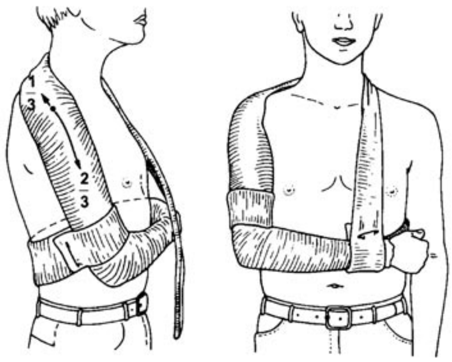
Desault bandage
This is used to immobilize the shoulder and elbow. It can be made of a cotton-embedded elastic band or a textile net. The skin should first be talc-powdered to



Desault bandage

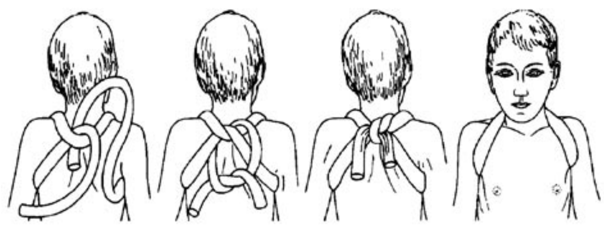
protect from perspiration. The injured arm (with the elbow flexed) is fixed to the trunk with circumferentially positioned bands. The bandage assumes an “8” shape around the chest, connecting the shoulder to the injured arm.

Gilchrist bandage
This is used to immobilize the shoulder and elbow. Hanging the arm over the neck toward the back prevents movements of the shoulder and elbow (see Figure).



Gilchrist-bandage

Rucksack bandage
This serves for repositioning and immobilization of the clavicle. It can be made of a cotton-embedded elastic band. The route is the same as that of the straps of a rucksack. The radial pulse and the venous perfusion should be frequently checked. This bandage should be checked and adjusted on a daily basis.



Rucksack bandage

Charnley loop
This is used to fix the elbow in cases of infant supracondylar humerus fractures. After repositioning, the elbow junction should be fixed at a sharp angle elicited by support of the arm around the neck. The radial pulse should be checked.

Charnley loop

Triangular scarf bandage
This is used to fix the areas of the shoulder and arm upon injury. The arm is placed into a triangular scarf and the corners are tightened behind the neck.

Sling bandage
This is applied to stop bleeding of the nose. A compressing bandage made of a gauze sponge is placed on the nose and tightened behind the head by using a mull band.

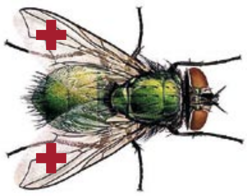
Cast bandages (see traumatology manuals for details).

11. Innovations in wound treatment

11.1. *Lucilia sericata, Phaenicia sericata* (greenbottles)

These 2-mm sterile fly larvae are available in a „biobag". The larvae ingest bacteria which are destroyed in their gut (e.g. methicillin-resistant *Staphylococcus aureus*). *Advantages:* they can be applied to a wide range of infected wounds to remove slough and malodor. *Associated problems:* Potentially infected larvae, allergic reactions, tickling sensation, and ethical and aesthetic issues.

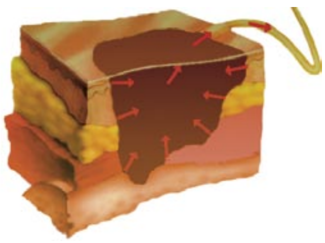
"Scat. orig."



Larva Lucilii

11.2. *Vacuum-assisted closure* therapy

This involves negative-pressure suction drainage. It is not a brand-new idea as drainage methods were earlier employed for decades; the fundamental difference is the application of topical negative sub-atmospheric pressure across the surface of the wound. *Advantages:* It provides a moist environment, prevents bacterial activity, evacuates excess exudate, kills anaerobic bacteria in the wound bed, and controls odor. *Contraindications:* Fistulas of unknown origin, opening into a body cavity, vulnerable body organs, malignancy, necrotic tissue with scar, and untreated osteomyelitis.



11.3. Biological dressings

11.3.1. Human skin

- Autologous (epidermal sheets, semi- and full-thickness skin)
- Allogenous (living donor, cadaver skin, amnion membrane)

11.3.2. Xenogenous skin

- Porcine skin (full-thickness skin, semi-thickness skin, subcuticular sheets)

11.3.3. Skin supplements

- Synthetic bilaminates (membranes, gels, foams and spray products)
- Collagen-based composites
- Collagen-based dermo-analogs
- Natural tissues (de-epithelized allografts)
- Dermal sheets (human, allogenous)
- Cryopreserved human and allogenic cadaver skin

11.3.4. Biosynthetic materials (cultured tissues)

- Keratinocyte suspensions and sheets (autologous and allogenic)
- Fibroblast-containing dermo-analogs
- Skin replacement composites and allograft keratinocytes
- Skin composites, autologs, and fibroblast-GAG-keratinocytes
- Artificial skin

11.4. "Wet wound healing"

- This protects the wound from drying-out
- Increased effects of local growth factors, cytokines, etc.
- Increased proteolysis
- Increased angiogenesis
- Decreased pH
- Decreased bacterial proliferation
- Increased phagocyte and neutrophil activity
- Increased fibroblast and endothelial proliferation
- Increased keratinocyte migration and proliferation