Introduction to Anaesthesiology

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1. Introduction

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Anaesthesiology is a specialty taught primarily in medical schools. However, some skills, such as resuscitation, securing of airways and using anaesthetic medical equipment are also taught in some technical universities.

This textbook is designated mainly for students of the Third Faculty of Medicine and contains basic information all medical students should by the end of their studies. Relevant anatomy and physiology is omitted from this text and pharmacology is limited to medications used during anaesthesia. For more detailed information on these displicines, consult the “Further Reading” section at the end of this book.

Basic and advanced life support are presented separately at the following web sites:
https://www.lf3.cuni.cz/3LFEN-232.html
https://www.lf3.cuni.cz/3LFEN-233.html

The authors have made a lot of effort to ensure that the information in this book reflects the current state of knowledge at the time of publication. Although this information has been carefully reviewed, it is not possible to guarantee its complete flawlessness with absolute certainty. For these reasons, the authors and publishers and all other people involved in creating this textbook do not assume any liability for direct or consequential damages resulting from the contents of this textbook

2. History of anaesthesia

J. Málek, J. Pokorný, B. Dvořáček

Although surgery has been performed since the prehistoric times, anaesthesia is a relatively young discipline. It appeared approximately 180 years ago and after a series of discoveries and inventions became an established part of modern medicine during the nineteen fifties. Healed trepanation holes in skulls provide evidence of the use of surgery in the prehistoric world. However, documented evidence of anaesthesia from this period does not exist. The Incas managed to drill holes in the heads of patients with relatively little pain by chewing coca leaves and spitting into the wounds. Alcohol was sometimes used as an anaesthetic, but more commonly, people had to make due with folk-anaesthetics like mulberry and lettuce. Neolithic humans as far back as 10,000 BC may have used alcohol to ease pain. Archaeological evidence indicates that the Sumerians (living in what is now Iraq) may have cultivated the opium poppy for anaesthetic and probably euphoric purposes as early as 3400 BC. Mandrake was used a part of some sedative and analgesic mixtures. A process for extracting its potency using wine was described by Pediacus Dioscorides, a Greek physician employed in Nero's Roman army, who advised its use to "cause the insensibility of those who are to be cut or cauterized." In later years, mandrake was applied to a sponge in combination with opium to augment its sedative powers. In the 13th century, the first prescription of the *spongia soporifica*, a sponge soaked in the juices of unripe mulberry, flax, mandrake leaves, ivy, lettuce seeds, lapathum, and hemlock with hyoscyamus was written. The sponge could be heated and the vapours inhaled with an anaesthetic effect. Discoveries that are more recent suppose that it could be applied as a solution directly to nasal mucosa with rapid absorption into the systemic circulation.

Various techniques to anesthetise limbs, such as using compression to cut off blood flow and dull sensation, or numbing it with ice have been document throughout history. Using ice is documented as late as during Soviet-Finish war in 1939. However, before the establishment of modern anaesthesia, the main method to decrease the suffering of patients was the speed of surgeon. The famous English surgeon Lister was known for being able to amputate a limb in less than in a minute.

The first scientific publication concerning anaesthesia is presumed to be the manuscript written by H. Hickman, who tried to decrease the suffering of surgical patients. He performed experiments in animals

with inhalation of carbon dioxide. He died before he was able to continue his experiments in humans, although the gas he was using did not have anaesthetic properties.

Further important progress continued with two substances: ether and nitrous oxide.

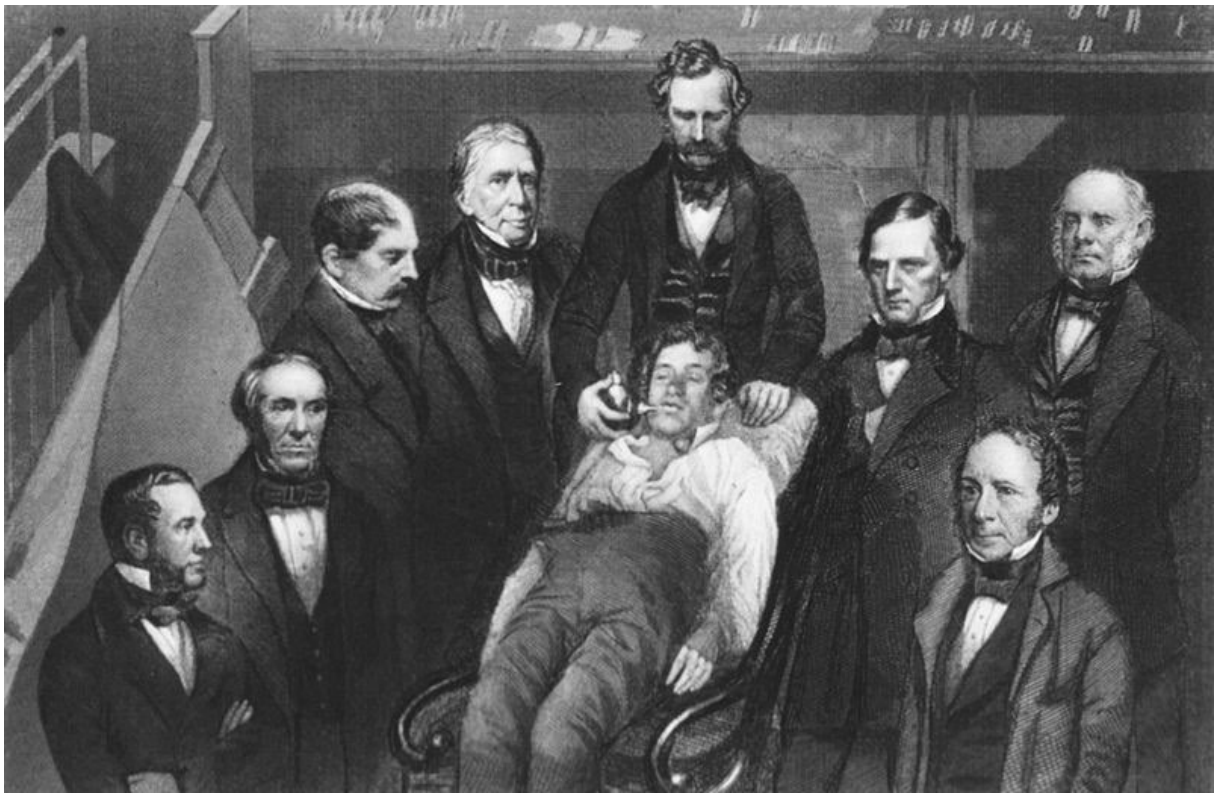
2.1. Horace Wells and nitrous oxide

Horace Wells was an established dentist in the American city Hartford. Wells first witnessed the effects of nitrous oxide on December 10, 1844, when he and his wife Elizabeth attended a demonstration by Gardner Quincy Colton reported in the local newspaper the Hartford Courant as *"A Grand Exhibition of the Effects Produced by Inhaling Nitrous Oxide, Exhilarating, or Laughing Gas"*. The demonstration took place at Union Hall, Hartford. During the demonstration, a local apothecary shop clerk Samuel A. Cooley became intoxicated by nitrous oxide. While under the influence, Cooley did not react when he struck his legs against a wooden bench while jumping around. After the demonstration, Cooley was unable to recall his actions while under the influence, but found abrasions and bruises on his knees. From this demonstration, Wells realized the potential for the analgesic properties of nitrous oxide and met with Colton about conducting trials. The following day Wells conducted a trial on himself by inhaling nitrous oxide and having John Riggs extract a tooth. Upon a successful trial where he did not feel any pain Wells went on to use nitrous oxide on at least 12 other patients in his office. In 1844, Hartford did not have a hospital so Wells sought to demonstrate his new findings in either Boston or New York. He gave a demonstration to medical students at the Massachusetts General Hospital in Boston on January 20, 1845. However, the gas was improperly administered and the patient cried out in pain. The patient later admitted that although he cried out in pain, he remembered no pain and did not know when the tooth was extracted. The audience of students in the surgical theatre jeered "humbug". After the embarrassment from his failed demonstration, Wells immediately returned home to Hartford the next day. Shortly after, he became ill and his dental practice became sporadic.

2.2. Morton's success

William Thomas Green Morton, an American dental surgeon and former colleague of H. Wells, gave the first successful public demonstration of ether anaesthesia for a surgical operation on October 16, 1846, a date now referred to as *"Ether day"*. Morton used ether to anesthetise the patient Edward Gilbert Abbott, allowing the surgeon John Collins Warren to painlessly remove part of a neck tumour. After successful removal of the tumour, Warren announced triumphantly "Gentlemen, this is no humbug!". In reference to this historic milestone, surgical theratre in Massachusetts General Hospital in which the event took place is now known as *"The Ether Dome"*.

News of Morton's ether demonstration travelled quickly from Boston to Dr. Francis Boott in Great Britain and then onto Dr. James Robinson (1813-1862), who extracted a tooth on December 19, 1846, under ether anaesthesia. Dr. William Scott performed a leg amputation under ether anaesthesia in Dumfries, Scotland also on December 19, 1846 and two days later so did Dr. Robert Liston in London.



Picture 1: The first successful demonstration of ether anaesthesia by William Thomas Green Morton (1819–1868) on October 16, 1846 at the Massachusetts General Hospital in Boston. Source: Twitter.

2.3. Further developments

In 1847 Prof. James Y. Simpson (1811-1870), a Scottish obstetrician, began administering chloroform to women for pain during childbirth. Chloroform quickly became a popular anaesthetic for surgery and dental procedures, but had an unfortunate side effect of causing potentially lethal arrhythmias. The first fulltime anaesthetist since 1847, Dr. Snow, popularized obstetric anaesthesia by administering chloroform to Queen Victoria for the birth of Prince Leopold (1853) and Princess Beatrice (1857).

In 1853, Doctor Charles Pravaz in Paris and Doctor Alexander Wood in Scotland independently invented the hollow hypodermic needle, which was attached to an earlier invention, the syringe, which had been popularized in 1845 by Ireland's Francis Rynd.

In 1871, Trendelenburg performed the first tracheal intubation through a tracheostomy and in 1878, William Mac Ewen performed the first orotracheal intubation using two fingers for the treatment of diphtheria and later on for chloroform anaesthesia.

Direct laryngoscopy was introduced in 1895 by Alfred Kirstein in Berlin. Chevalier Jackson performed the first bronchoscopy in 1899 and in 1907 he published a book describing direct laryngoscopy. His original laryngoscope was modified by Magill and is still used today. Magill and Rowbotham introduced direct laryngoscopy into routine anaesthetic practice.

In 1934, Lundy used thiopental for the first time, in 1942 Griffith and Johnson in Montreal used curare for the world's first successful anaesthetic use of the muscle relaxant. Other milestones are suxamethonium (1951), halothane (1956), enflurane (1966), isoflurane (1971), sevoflurane (1981) and desflurane (1988). Propofol was approved with a new formula in 1986 and ketamine in 1964.

2.4. Regional anaesthesia

The discovery of local anaesthesia is attributed to two men who were born in lands now known as the Czech Republic: Sigmund Freud and Karl Koller. Several discoveries and inventions were necessary for this to happen: the invention of the syringe and injection needles and isolation of cocaine from coca leaves.

Freud wanted to know more about the analeptic effect of cocaine, which, he hoped, because of reports from the United States, might be useful in curing one of his great friends of addiction to morphine. Freud shared cocaine with Koller, who was able to help him investigate its effects on the nervous system. Koller was a junior intern in the Ophthalmological Clinic at the University of Vienna. After discovering the numbing effect of cocaine, Koller preformed several experiments to anaesthetise the conjunctiva. After these experiments, he performed an operation for glaucoma using topical cocaine anaesthesia on September 11, 1884, just four days before the congress of Ophthalmology was due to take place in Heidelberg. Koller immediately wrote a paper for the congress, but, being an impecunious intern, he could not afford the train fare to Heidelberg, so he gave the paper to a visiting ophthalmologist from Trieste, Dr. Brettauer, who had stopped in Vienna on his way to the congress. This report is considered to be the invention of local anaesthesia.

After this publication, the idea of injecting cocaine directly into tissues to render them insensible occurred simultaneously to several American surgeons. William C. Burke injected 5 minims (drops) of 2% solution close to a metacarpal branch of the ulnar nerve and painlessly extracted a 22-caliber bullet from the base of his patient's little finger (*29*). However, it was William Stewart Halsted (1852–1922) and Richard John Hall (1856–1897) and their associates who most clearly saw the great possibilities of conduction block. Infiltration anaesthesia with cocaine used for the first time used by C. L. Schleich in Germany in 1892 and the first spinal (subarachnoid) anaesthesia was used by August Bier in Kiel in Germany in 1898.

R. Jedlička was the first medical doctor in Prague to use spinal anaesthesia, which he did in the year 1900. Epidural anaesthesia was first used in 1920 and rediscovered in the 1930s.

The main problem of cocaine was its toxicity and the risk of addiction; many pioneers of regional anaesthesia performing experiments on themselves quickly became addicted. The first safe local anaesthetic, procaine, was synthetized in 1904, which was followed by lidocaine much later in 1943.

2.5. Anaesthesia in Czechoslovakia

In the 19th century, the part of Europe, which is today known as Czech and Slovak Republics, was part of the Austro-Hungarian Empire. Prague not only boasted one of the oldest universities in the Europe, but also took an active part in establishing the fame of the surgical school of Vienna. The Brother of Mercy Celestyn Opitz gave the first ether anaesthesia in Prague on 7th February 1847, less than four months after its demonstration by Morton in Boston. Two days earlier the first ether anaesthesia administered in Brno was given, but nonetheless Opitz is still recognised as the father of Czech anaesthesia.

Picture 2: Brother of Mercy Celestyn Opitz. Source: Wikipedia

Modern anaesthesiology in Czechoslovakia really began only after World War II. After specializing in anaesthesiology in the United Kingdom during the war, Dr. Lev Spinadel returned to Prague in 1948 where he founded the first independent anaesthesia department in Czechoslovakia. Two years later, he published the first Czech textbook on anaesthesia and in 1952, the first 10 specialists in anaesthesiology became certified. A prominent Czech surgeon, professor Arnold Jirásek, sent his assistant J. Pastorová MD to study anaesthesia in Oxford under professor Macintosh. After her return, an anaesthetic section in the surgical society was established in 1952. J. Pastorová was the first chairman, followed by Doctor Josef Hoder in 1959.

Important for further development was the one-year study stay in Copenhagen of Dr. Bořivoj Dvořáček from the University Hospital Kralovske Vinohrady in Prague. He was a leading member of the anaesthetic section who was responsible for founding the independent anaesthetic society and including resuscitation as an integral part of the speciality of anaesthesiology. The independent Society of anaesthesiology was established in Karlovy Vary in 1961 and the first congress was held in Olomouc in 1962. The society changed its name to the Society of anaesthesiology and resuscitation of the Czech medical society of Jan Evangelista Purkynje.

The first civilian anaesthetic departments were introduced in Vinohrady Hospital in 1960 and in Hospital Na Bulovce in 1963. The first specialised departments for intensive medicine and critical care was founded in Kladno by Vladimir Lemon in 1967.

After soviet occupation in 1968 many anaesthetists including B. Dvoracek emigrated but nonetheless kept contact with their colleagues in Czechoslovakia and sent journals and books to their motherland to guarantee a high professional level of anaesthesia. The anaesthetist Dimitrij Miloschwsky founded the first pain clinic in 1976 in Hospital Na Bulovce. In 1974, the speciality of anaesthesia consisted of four

pillars: anaesthesia, resuscitation and critical care, pain therapy and pre-hospital emergency and disaster medicine.

Professor Počta from the department of anaesthesia of the University Hospital Kralovske Vinohrady became the first editor in chief of the journal Anestezie a neodkladná péče (now called Anaesthesia and Intensive Care Medicine) in 1989.

The Czech Society of anaesthesiology and Intensive care Medicine guarantees a high professional level of anaesthesiology in the Czech Republic, comparable to most other developed countries. Many Czech anaesthetists work abroad where they were awarded many professional and academic honours.

3. Types of anaesthesia and basic terms

J. Málek

3.1. Basic terms

- **Sedation** – decreased level of consciousness of various grades and relief of anxiety
- **Conscious sedation** – a drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation.
- **Deep sedation** - a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to maintain independent ventilatory function may be impaired.
- **General anaesthesia** - complete loss of all sensations either with loss of consciousness (general anaesthesia) or without (local anaesthesia). In case of general anaesthesia, protective reflexes and maintenance of free airways may be lost.
- **Analgesia** – suppression of pain
- **Anxiolysis** – relief of anxiety
- **Amnesia** ¬– loss of memory, which can be anterograde (before administration of a drug) or retrograde (after administration of a drug)
- **Analgesic sedation** – a combination of analgesia and sedation

3.2. Types of anaesthesia

- **General anaesthesia** – drug induced unconsciousness and insensitivity to pain. Depending on the route of administration, we can classify general anesthesia as:
    - **inhalational** – induced by inhalation of anaesthetic gasses or volatile anaesthetics
    - **intravenous** – induced by intravenous injection
    - **intramuscular** – induced by intramuscular injection
    - **balanced anaesthesia** – induced by a combination of various drugs and routes of administration. It consists of three main components:
        - Analgesia: morphine, fentanyl, sufentanil, alfentanil, remifentanil, nitrous oxide and others
        - Unconsciousness and amnesia: general anaesthetics and benzodiazepines
        - Muscle relaxation: suxametonium, atracurium, cisatracurium, vecuronium, rocuronium and others

- **other less common routes of administration**: rectal, buccal and nasal

- **Regional or local anaesthesia** – anaesthesia limited to only a part of the body. Regional anaesthesia can be induced by cold temperatures or compression, but the most common way is administration of local anaesthetics to block nerve transmission. Regional anaesthesia can be administered with a single injection or via a catheter for repeated or continuous administration as may be needed for postoperative analgesia. According to the site of administration, local anaesthesia can be classified as:
  - **Topical anaesthesia** – applied directly to the mucosa of the conjunctiva, airways or urethra or intact skin (only EMLA Cream)
  - **Infiltration anaesthesia** – applied directly to terminal nerve endings. Adrenaline is sometimes added to decrease systemic absorption and to prolong the anaesthesia. Adrenaline must not be applied near terminal arteries (fingers, toes or penis) and may be dangerous in well-perfused areas in patients with ischemic heart disease.
  - **Intravenous regional anaesthesia (Bier's block)** – an anaesthetic technique performed on an extremity where a local anaesthetic is injected intravenously and isolated from circulation in a target area. The technique usually involves exsanguination of the target region, which forces blood out of the extremity, followed by the application of pneumatic tourniquets to stop the blood flow. The anaesthetic agent is intravenously introduced into the limb and allowed to diffuse into the surrounding tissue while tourniquets retain the agent within the desired area
  - **Conductive anaesthesia** – applied directly to nerve structures
    - nerves
    - nerve plexus
    - neuroaxial (central)
      - subarachnoid (spinal) – to spinal cerebrospinal fluid
      - epidural – to the epidural space between dural sac and spinal canal wall (ligamentum flavum).

  Surgeons perform topical and infiltration anaesthesia and anaesthetists perform intravenous regional anaesthesia and conductive anaesthesia. Neurostimulation and ultrasound are frequently used for the detection of nerves. Neuroaxial anaesthesia results in hypotension and sometimes bradycardia because of blockade of the sympathetic nerve chain. Haemocoagulation disturbances are the main contraindication of this technique.

- **Combined anaesthesia** – concomitant use of general and local anaesthesia

4. Inhalational anaesthesia

J. Málek, J. Šturma

4.1. Introduction

Anaesthetic agents are inhaled via a breathing system and after absorption into the pulmonary circulation are transported to brain. The advantage of this is that the concentration of the anaesthetic in the inspired air can be rapidly and effectively increased or decreased to alter the depth of the anaesthesia. The disadvantage is the slower onset compared to intravenous administration. The speed of induction and recovery from general anaesthesia depends on the solubility of the anaesthetic in the blood. Recovery time is faster for less soluble agents.

Minimum alveolar concentration

Minimum alveolar concentration (MAC) is used to compare the strength, or potency, of anaesthetic gases or vapours. MAC is the concentration of a vapour in the alveoli of the lungs that is needed to prevent a motor response to a painful stimulus in 50% of subjects. The smaller the MAC the more potent the inhaled anaesthetic.

A special anaesthetic machine with dosing devices, called vaporisers, is used to administer inhalational anaesthetics.

The ideal anaesthetic agent:

- Non-flammable, non-explosive at room temperature
- Stable in light.
- Liquid and vaporisable at room temperature i.e. low latent heat of vaporisation.
- Stable at room temperature, with a long shelf life
- Stable with soda lime, as well as plastics and metals
- Environmentally friendly - no ozone depletion
- Cheap and easy to manufacture
- Pleasant to inhale and non-irritant
- Induces bronchodilation
- Low blood-gas solubility - i.e. fast onset
- High oil-water solubility - i.e. high potency
- Minimal effects on other systems - e.g. cardiovascular, respiratory, hepatic, renal or endocrine
- No biotransformation - should be excreted ideally via the lungs, unchanged
- Non-toxic to the operating theatre personnel

4.2. Inhalational anaesthetic gases

Nitrous oxide (N2O) is nowadays the only anaesthetic gas used. Nitrous oxide is a colourless gas with a slightly sweet odour and taste at room temperature and pressure. It is stored in a cylinder, compressed as a liquid or vapour below its critical temperature (36.5°C) to 50 atm. As nitrous oxide is discharged from a cylinder, it vaporizes, releasing energy in the form of heat (latent heat of vaporization). This process cools the cylinder, reducing the saturated vapor pressure and cylinder pressure. The pressure recovers when the cylinder is closed and it warms back to environmental temperature. Cylinder pressure does not accurately indicate the filling status of the cylinder, as the saturated vapor pressure will only decrease when all the liquid nitrous oxide is consumed and the tank is almost empty.

The analgesic effect of nitrous oxide is far better than its ability to induce unconsciousness. Nitrous oxide has a low anaesthetic potency, with a concentration of 105% required to produce the minimum alveolar concentration (MAC) for anaesthesia, a clearly unreasonable proposition at atmospheric pressure. However, its low solubility in blood (blood:gas partition coefficient) leads to a rapid equilibration of partial pressures between blood and inspired gas and rapid onset and offset of action. Nitrous oxide also improves the speed of onset of volatile agents by the 'second gas effect'. Nitrous oxide transfers across the alveolus rapidly because of its high lipid solubility. This leads to concentration of the remaining gases in the alveolus (volatile agent, oxygen, and nitrogen), increasing the driving pressure of volatile anaesthetic agent into the blood. In addition, the loss of volume associated with nitrous oxide uptake leads to an augmentation of ventilation. Providing a higher concentration of nitrous oxide or volatile anaesthetic agent further increases this effect. This is referred to as the 'concentration effect'. The second gas and concentration effects work to increase the speed of onset of anaesthesia when using nitrous oxide. Nitrous oxide does not trigger malignant hyperthermia and except for potentiation of postoperative nausea and vomiting has little side effects. Because of its higher blood solubility than nitrogen, nitrous oxide transfers faster into closed gas cavities than nitrogen is removed, leading to expansion of air or low-solubility gas-filled cavities (gut, middle ear, pneumocephalus, pneumothorax, cuffs of tracheal tubes. Nitrous oxide is used with oxygen as a part of an inhaled mixture for other volatile anaesthetics. For longer procedures, it is more appropriate to use an oxygen-air mixture. A 50:50 mixture of nitrous oxide and oxygen (Entonox) is used as an inhalation analgesic.

Xenon is a noble gas with an anaesthetic effect. Xenon is a nearly ideal anaesthetic agent; at a concentration of 70% mixed with 30% oxygen it induces general anaesthesia without side effects. Xenon anaesthesia is associated with remarkable cardiovascular stability, even in the presence of compromised myocardium. Xenon exhibits more potent analgesic action than nitrous oxide, the only other anaesthetic gas with true analgesic efficacy. It is used rarely because of high cost: it cannot be synthetized and is isolated from air, which contains 0.0000087% xenon (air in the room with volume 50 m3 contains 4 ml of xenon). The annual production is 10 million litres, of which use 750 000 litres are used for anaesthetics.

Oxygen is a biogenic gas, which has no anaesthetic effect, but is necessary as a part of all inhaled anaesthetic mixtures. It supports burning and long exposure of high concentration and dry oxygen is toxic. It is stored in cylinders, compressed as a gas to 150 atm, or as a liquid in high volume tanks.

4.3. Volatile anaesthetics

Volatile anaesthetics are easily vaporised chemicals that have anaesthetic effects. **Diethyl ether** is no longer used due to its extremely flammable nature, especially in the presence of enriched oxygen mixtures, and its many other side effects. The only volatile agents used nowadays are halogenated ethers. They have many common characteristics. Their safety margin is very low and so they must be delivered by precise vaporizers to avoid overdosing. They have no special analgesic effect; analgesia is dependent on the level of unconsciousness. They induce dose-dependent mild muscle relaxation, respiratory depression, low blood pressure, and sometimes arrhythmias. One of the most serious side effects is malignant hyperthermia. For this reason, volatile anaesthetics should not be used in people with a history of malignant hyperthermia in either themselves or their family members.

Modern volatile anaesthetics have only two levels of anaesthesia: shallow and deep, which can be clinically distinguished only by surgical stimulation. A special anaesthetic machine with concentration monitoring must be used. They are always administered in conjunction with air or pure oxygen. Often nitrous oxide is also used. They differ by physical properties and speed of onset and recovery.

Isoflurane is the oldest volatile agent from this group. Only about 0.25% of inhaled isoflurane is metabolized by the liver. The majority is excreted via the lungs. Isoflurance has toxic effects on parenchymal organs like the liver and kidney. The main disadvantage is its irritative effect the respiratory system, which prevents it from being used for induction of anaesthesia. It is usually used to maintain a state of general anaesthesia, which has been induced with another drug, such as thiopental or

propofol. To maintain anaesthesia, a concentration of 0.5-2.5% in oxygen and nitrous oxide is sufficient, when only oxygen or air is used, the concentration must be 1.0-3.5%.

Sevoflurane is one of the most commonly used volatile anaesthetic agents, particularly for paediatric anaesthesia. Together with desflurane, sevoflurane is replacing isoflurane and halothane in modern anaesthesiology. It is administered in a mixture of nitrous oxide and oxygen or air and oxygen. After desflurane, sevoflurane has the fastest onset and offset of all volative anaesthetics. Sevoflurane is a sweet-smelling, non-flammable anaesthetic that can be used as an inhalational anaesthetic for both induction and maintenance of general anaesthesia. It is the preferred agent for mask induction due to its less irritative effect on mucous membranes. VIMA is an abbreviation for volatile induction and maintenance anaesthesia. Induction using sevoflurane in concentrations of up to 5% in adults and up to 7% in children usually results in loss of consciousness and sufficient anaesthesia for performing surgery within 2 minutes. Inhalational induction is usually used in children and in adults when problems with the airways and/or intubation are anticipated. Some anaesthetists use “vital capacity” induction using 8% sevoflurane after pre-oxygenation of a patient. For maintenance of anaesthesia usually 0.5-3% sevoflurane is used. Recovery is rapid, in approximately 25% children a short-lasting delirium may appear.

Desflurane has the most rapid onset and offset of the volatile anaesthetic drugs used for general anaesthesia due to its low solubility in blood. Some drawbacks of desflurane are its low potency, its pungency and its high cost. It may cause tachycardia and airway irritability. Due to this airway irritability, desflurane is infrequently used to induce anaesthesia via inhalation techniques. Because of its low boiling point (23.5 °C), a special heated vaporizer has to be used. It has a low metabolic rate (0.02 %) and for maintenance of anaesthesia concentrations between 2.5% and 8.5% are needed.

4.4. VIMA

Volatile Induction and Maintenance Anaesthesia (VIMA) is used usually for inhalational anaesthesia with sevoflurane and nitrous oxide/oxygen or air/oxygen mixture. Be careful not to confuse VIMA with another acronym: TIVA (total intravenous anaesthesia).

4.5. Anaesthetic breathing systems and anaesthetic machine

J. Šturma

4.5.1. Anaesthetic machine

(Adapted from *https://academic.oup.com/bjaed/article/6/2/75/305203*)

Anaesthetic machines have six basic subsystems:

- gas supplies: pipelines and cylinders
- gas flow measurement and control (flowmeters)
- vaporizers
- gas delivery: breathing system and ventilator
- scavenging
- monitoring

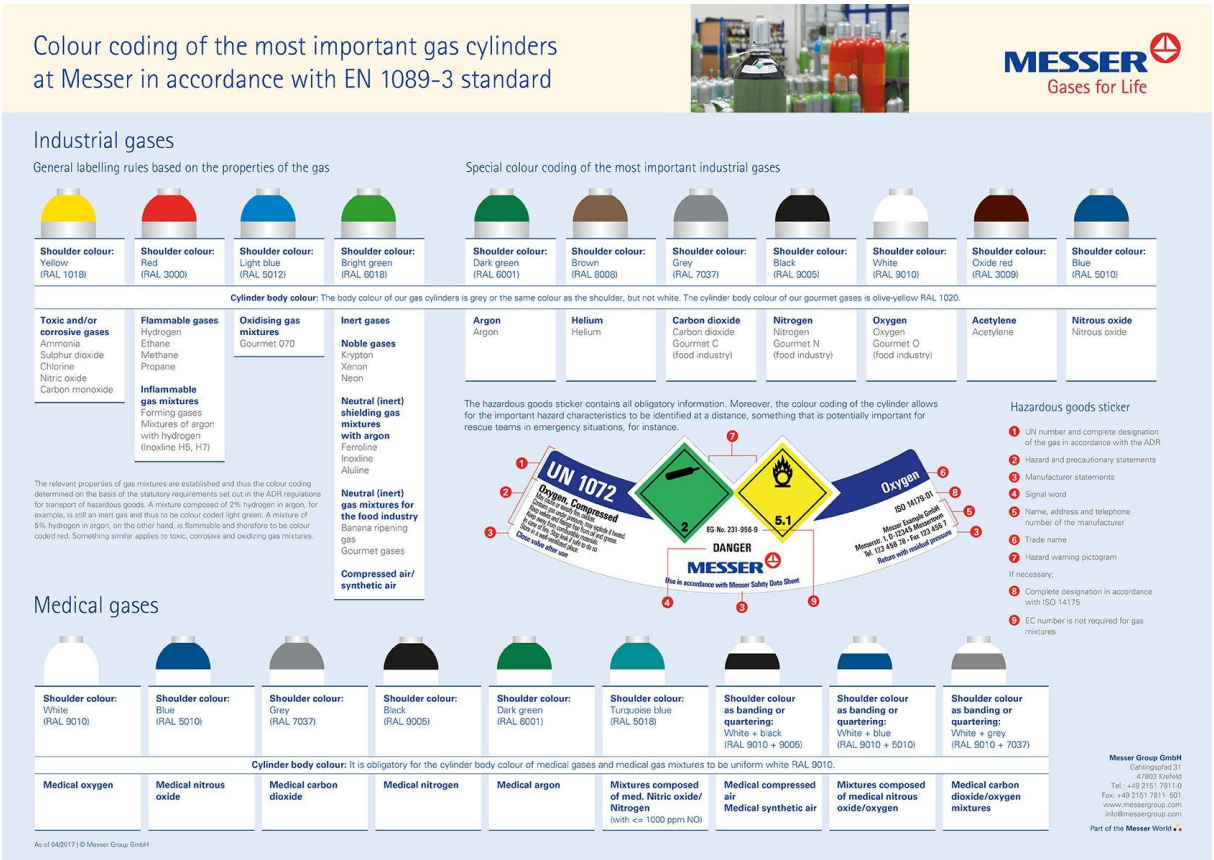
Video 1: Anaesthetic machine

Source of medical gases

Medical gases are stored in transportable cylinders in a central source from which a gas is fed into a labelled and colour-coded pipeline distribution network, which terminates in self-closing sockets in the wall.

To make sure the correct gases are used and not mixed up with one another the following precautions are taken:

- cylinders and sockets are colour and verbally coded
- various diameters and shapes of sockets and pipeline probes are used



Picture 3: Medical gases colour coding. Source: Twitter

Gas	U.S. Color Code	ISO Color Code
Carbon Dioxide	Grey	Grey
He-O_2	Brown and Green	Brown and White
Instrument Air	Red (USA Only)	
Medical Air	Yellow	Black and White
Nitrogen	Black	Black
Nitrous Oxide	Blue	Blue
O_2-He	Green and Brown	White and Brown
Oxygen	Green	White
Vacuum (Suction)	White	Yellow
WAGD (Evac)	Purple	Purple

Picture 4: Medical gases colour coding used in the USA and Europe. Source: Quora

Oxygen and nitrous oxide are compressed in cylinders under high pressure (oxygen 150 atm, nitrous oxide 50 atm). Modern machines have several primary and secondary regulators. Primary regulators reduce potentially dangerous high cylinder pressures to the machine working pressure. Secondary regulators level out gas delivery. Machine working pressures may vary by up to 20%, for example during periods of peak hospital demand. Pressure fluctuations can cause parallel changes in (and damage to) flowmeter performance. Secondary regulators set below the anticipated decrease in pressure will make the emergent pressure more uniform.

Gas flow measurement and control

Flow rate is measured by a flowmeter. Conventional flowmeters (rotameters) consist of a needle valve, valve seat and a conically tapered and calibrated gas sight tube containing a bobbin. Flowmeters may be mechanical or electronic. In a mechanical system, gas entering the sight tube lifts the bobbin in proportion to flow. The bobbin floats and rotates without touching the sides, giving an accurate indication of gas flow. Flow is read from the top of the bobbin. Some modern units may use microprocessors to control gas flow; flow is indicated electronically by a numerical display or 'virtual flow tubes'. Modern machines have interlocked oxygen and nitrous oxide flow controls. This prevents inadvertent delivery of a hypoxic inspired gas mixture, as the ratio of oxygen to nitrous oxide concentrations never decreases below 0.25. This can be achieved by mechanical, pneumatic or electronic mechanisms.

Vaporizers

Vaporizers sit on the back bar of the anaesthetic machine, downstream of the flowmeter block. Each is designed and calibrated for a specific anaesthetic vapour. The heated blended vaporizer was designed for desflurane.

Emergency oxygen flush is supplied from the high-pressure circuit upstream of the flowmeters and back bar, and provides flow between 35 and 75 litre min−1. All gas mixtures exit the machine through one outlet.

Breathing systems

Either circle systems or T piece configurations are used.

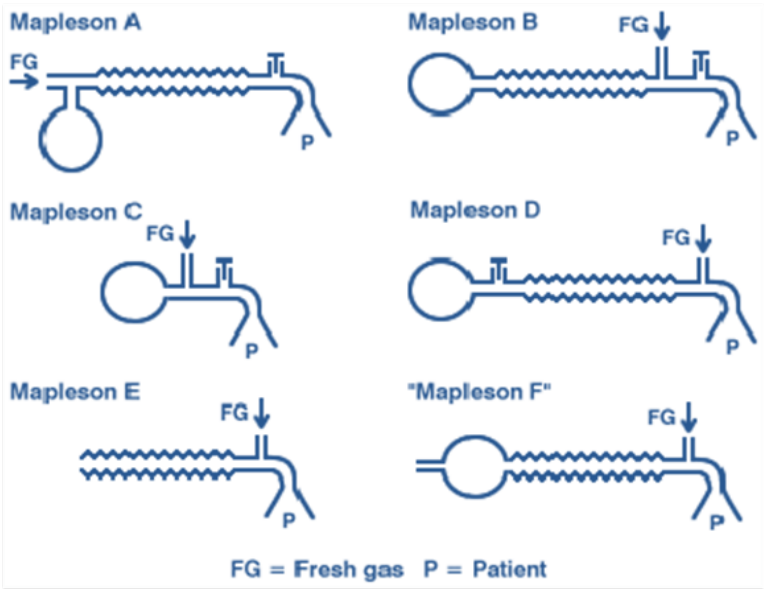
Circle consists of

- two one-way valves (inspiratory and expiratory)
- breathing tubes (inspiratory and expiratory part)
- Y – connection between tubes for insertion of mask, laryngeal airway or tracheal tube
- carbon dioxide absorber
- adjustable pressure limiting (APL) valve
- reservoir bag
- circuit pressure gauge
- switch to select manual or mechanical ventilation mode

The advantage of breathing circuits are preservation of heat and moisture and the possibility to use lower fresh gas input than is minute ventilation of a patient, e.g. they are more economic. To prevent hypercarbia during rebreathing, carbon dioxide absorbers are used. They are based on soda lime or barium lime and absorbs carbon dioxide by chemical reaction

$$2\ NaOH + H_2CO_3 \rightarrow Na_2CO_3 + 2\ H_2O$$
$$+$$
$$Ca(OH)_2 \rightarrow 2\ NaOH + CaCO_3$$

The disadvantage of circuits is resistance during spontaneous ventilation, which may be problem in children. In paediatric anaesthesia are some used one-way systems.



Picture 5: Mapleson classification of one-way breathing systems. Source The University of Sydney Nuffield Department of Anaesthetics Lectures and Study Notes Listing.

Ventilators

Ventilators may be integrated with the anaesthetic machine or configured later. These are often electronically controlled and pneumatically powered. The anaesthetist could vary minute volume by setting tidal volume and ventilatory frequency directly or by adjusting inspiratory time, inspiratory flow rate and the ratio of inspiratory to expiratory time. The newest models resemble critical care ventilators in their capabilities. These may perform self-test upon start-up (using dual processor technology), volume or pressure-controlled ventilation modes, assisted spontaneous ventilation and electronically adjustable PEEP.

Scavenging

Modern scavenging is used for collecting, transferring, receiving and disposal of waste gases from the breathing circuit:

Monitoring

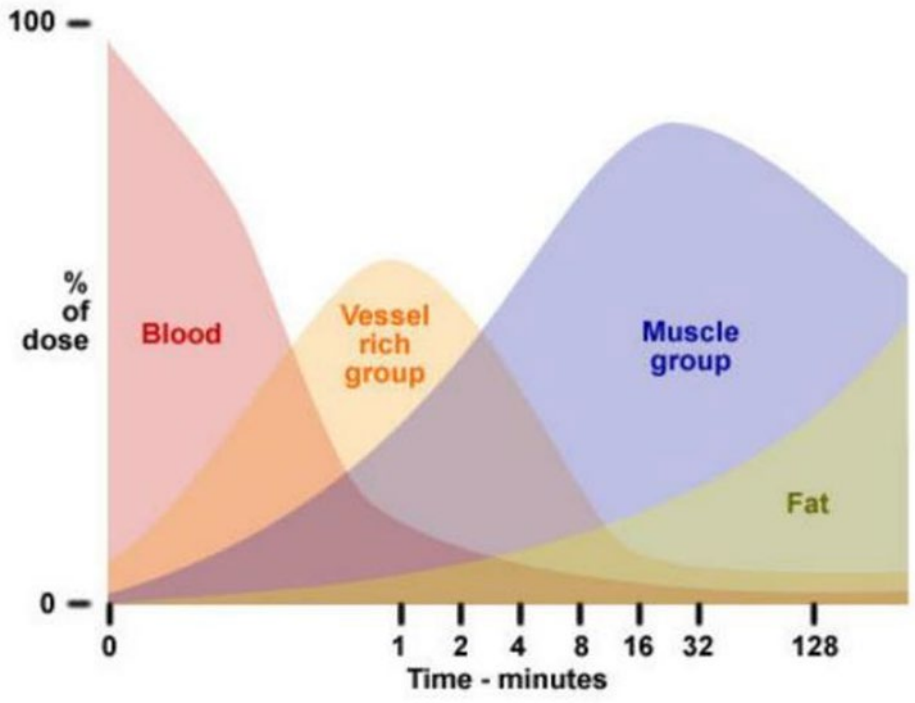
A full review of monitors is also beyond the scope of this article. Some anaesthetic machines conduct an automatic self-test on start-up. The test results are recorded and displayed. This is not intended to replace the pre-use check by an anaesthetist. Anaesthesia units must incorporate certain minimum equipment-related monitors. These monitors measure airway pressure, volume of expired gas and inspired oxygen concentration. Monitors for other anaesthetic gas concentrations and physiological parameters may be incorporated into the machine.

5. Intravenous anaesthetics, benzodiazepines

J. Málek, L. Hess

5.1. Intravenous anaesthetics

The main advantage of intravenous anaesthetics is their rapid onset. This is due to their high lipid solubility, which facilitates penetration of the blood–brain barrier, and the high proportion of the cardiac output (CO) that perfuses the brain. These agents also have a short duration of action due to rapid redistribution from the brain to other tissues, primarily muscle and fat (Figure 6).



Picture 6: Redistribution of thiopental after a single dose. Source SlideServe.

Thiopental is an ultra-short acting barbiturate. It is prepared as a powder and must be dissolved in water to the required 2.5 % concentration. It administered only through the intravenous route. As it is a strong alkali, it can cause pain or necrosis after accidental extra-vascular administration and intra-arterial administration may result in ischemic damage. Recovery occurs by redistribution and further doses become cumulative, each dose delaying recovery. The standard dose is 3 – 5 mg/kg and its duration is 3 – 5 min. After a dose of thiopental an apnoeic pause is frequently seen, this common side effect is due to cardiodepression and bronchoconstriction. It should not be used in patients with severe cardiac and pulmonary disease, in cases of hypovolemia, and in patients with a history of porphyria. Recently is has been replaced by propofol.

Metohexital is very similar to thiopental, but is more effective (the standard dose is 1 - 2 mg/kg) with a shorter effect (about 3 minutes). It is used for very short outpatient anaesthesia. It is no longer registered in the Czech Republic.

Etomidate is anaesthetic with a good safety profile. It has minimal side effects concerning circulation and breathing and allergic reactions are rare. It is used mainly for induction anaesthesia in cardiac patients and patients with pulmonary diseases. It is given in 0.3 mg/kg doses, which have duration of effect of 5 minutes. Side effects are pain during injection and myoclonus. Etomidate suppresses production of steroids in the suprarenal gland, but after a single dose, this effect is not significant.

Ketamine is a unique anaesthetic. It possesses sympathomimetic effects producing an anaesthetic state characterized by profound analgesia, normal pharyngeal-laryngeal reflexes, normal or slightly enhanced skeletal muscle tone, cardiovascular and respiratory stimulation, and occasionally a transient and minimal respiratory depression. The anaesthetic state produced by ketamine has been termed as "dissociative anaesthesia" in that it appears to interrupt selectively association pathways of the brain before producing somesthetic sensory blockade. Additionally, it has excellent analgesic effect in when given in doses a half or a quarter the size of its anaesthetic doses. It can be administered intravenously (1-5 mg/kg) or intramuscularly (3-10mg/kg) and its effect is longer than the previously described drugs (10 - 20 minutes when applied intravenously and 20 – 30 minutes when applied intramuscularly), and it can be administered repeatedly when half size or quarter size doses are given after a full sized first dose, but accumulation is likely. It is an optimal anaesthetic for pre-hospital emergency anaesthesia and disaster medicine. Side effects are possible hypertension, hypersalivation, increased intraocular and intracranial pressure, epileptiformic muscle spasms and vivid dreams or hallucinations. The incidence of these side effects can be decreased by not disturbing a patient during recovery and concomitant use of benzodiazepines (sometimes called ataralgesia). Ketamine can be used to prevent opioid-induced hyperalgesia and acute treatment of depression.

Propofol is a non-barbiturate, non-dissociative intravenous anaesthetic agent, and recently the most commonly used intravenous anaesthetic. Propofol is not water soluble, and is prepared as a milky white emulsion. Propofol is intended for intravenous use only and causes burning pain during injection. Propofol is a respiratory depressant, causes hypotension (occasionally severe), and direct cardiac depression. Muscle relaxation is usually fair and recovery is usually excellent (very complete). Propofol suppresses pharyngeal reflexes (makes insertion of laryngeal mask easier), has antiemetic effects and induces pleasant dreams, sometimes with sexual content. Convulsive twitching or muscle rigidity may be seen following induction at times but usually resolves spontaneously. Propofol should be given slowly (over a period of 60 seconds) to avoid hypotension and apnoea. The induction dose is 2 – 2.5 mg/kg. Propofol is rapidly metabolized by hepatic and extra-hepatic metabolic pathways and recovery depends on this rather than on redistribution. Propofol is, in general, non-cumulative, thus it can be used for prolonged anaesthesia by intermittent injection or by continuous infusion (see *Total Intravenous Anaesthesia - TIVA* further). Computer programs based on EEG and other physiologic monitoring results may be used to control infusion and maintain a constant depth of anaesthesia to prevent awareness.

5.2. Benzodiazepines

Benzodiazepines are a class of drugs primarily used for treating anxiety, but they also are effective in treating several other conditions, like convulsions and inducing sedation, sleep and anaesthesia. They have slower onset of effect, low cardiorespiratory side effects, the disadvantage is long duration and accumulation. They are receptor specific and act mainly at GABA receptors in CNS.

Drug	Dose	Duration	Terminal half-time	Notice
diazepam	0.3-0.6 mg/kg IV. 5-10 mg PO.	15-30 min	24-48 h	Induction of GA Premedication
midazolam	0.05-0.4 mg/kg IV or IM	15-30 min	1-3 h	Good bioavailability also after IM administration.
oxazepam	10-30 mg PO		6-25 h	Premedication
nitrazepam	10 mg PO.		18-34 h	Premedication

Dose: see table, they are administered in small increments according to desired effect.

Duration: individual, repeating doses lead to significant accumulation

CNS effect: with increasing dose anxiolysis > sedation > amnesia > central muscle relaxation > anticonvulsant effect > unconsciousness.

Circulatory effect: very small, decreases vascular resistance and in hypovolemic patients may induce hypotension. Midazolam may induce tachycardia, which compensates hypotension.

Respiratory effect: respiratory depression, mainly in patients with chronic pulmonary disease and/or combination with other anaesthetics and opioids.

Renal effect: 0

Liver effect: 0

Side effects: prolonged recovery, except midazolam is IM administration unpredictable and painful.

Contraindication: myasthenia gravis, use in geriatric patients (over 65 years).

Use: premedication, sedation in anaesthesia and in intensive care, rarely induction of GA.

Notice: benzodiazepines may induce agitation or confusion in seniors.

Antagonist

All effects of benzodiazepines except of amnesia can be antagonized by flumazenil (ANEXATE), which is titrated to desired effect. According to the dose, the effects of benzodiazepines are antagonized in reverse order to their appearance. The main disadvantage is extremely short effect (less than 60 minutes).

5.3. TIVA

Total Intravenous Anaesthesia (TIVA) refers to intravenous administration of all drugs used during anaesthesia (usually a combination of propofol, atracurium and remifentanil) and ventilation with oxygen/air mixture. The advantage is minimal environmental pollution. The disadvantage is great variability of effect and demands on monitoring, risk of awareness during surgery and higher cost. In spite of the use of short-acting drugs, the control of level of anaesthesia is more difficult compared to inhalational or balanced anaesthesia. For administration TIVA, Target Controlled Infusion (TCI) is usually used. With TCI systems, the clinician enters the desired target concentration. The computer calculates the amount of drug needed, which it then delivers as boluses and infusions in order to achieve and maintain the target concentration. The computer constantly calculates how much drug is in the tissue

and exactly how that influences the amount of drug required to achieve the target concentration by using a model of the pharmacokinetics of the drug selected and the patient covariates. Brain activity monitors are usually used to avoid awareness.

6. Opioids

J. Málek, L. Hess

Opioid analgesics act on opioid receptors present in the central nervous system and elsewhere. Analgesic effects are mainly attributed to μ-opioid receptors (supraspinal analgesia, euphoria, drug dependence, miosis, respiratory depression, bradycardia, and reduced bowel motility) and κ-opioid receptors (spinal analgesia, miosis and sedation). Based on their affinity (receptor binding strength) and intrinsic activity (efficacy – producing the typical effect after binding to the receptor), opioid analgesics can be divided into several groups:

- opioid agonists: display high affinity, as well as high intrinsic activity, induce the typical effects of opioids (morphine, pethidine, piritramide, fentanyl and its other derivatives)
- opioid antagonists: display strong affinity, but zero intrinsic activity, used as an antidote (naloxone)
- κ-opioid agonists: antagonists at μ-receptors and agonists at κ receptors (butorphanol, nalbuphine)
- partial μ-agonists: display high binding affinity, but lower intrinsic activity (buprenorphine).

In postoperative pain management, μ-opioid agonists are used almost exclusively (with the exception of nalbuphine). In general, more potent opioid analgesics show a more favourable ratio between the effective dose and the dose at which adverse effects occur. Weak opioids have a ceiling effect, i.e. increasing the drug dose does not increase its effectiveness. Strong opioids do not show this effect and the maximum dose is limited by their adverse effects (respiratory depression). Opioid analgesics are generally not able to completely prevent pain perception, but by affecting mood they suppress the discomfort associated with pain. Their affects on mood are the reason they are abused for recreational purposes. Therefore, special regulations apply to most opioid analgesics. Adverse effects of opioid analgesics include respiratory depression (at higher doses), nausea and vomiting, decreased intestinal motility and gastric emptying, increased sphincter tone, sphincter of Oddi spasm with bile stasis, decreased secretion of pancreatic juice and bile, urinary retention, sedation and in rare cases euphoria or dysphoria. The most feared complication, respiratory depression, first manifests as a decrease in the respiratory rate; a decline in SpO2 will only develop later, especially if the patient receives oxygen after surgery. Sedation and disorders of consciousness are late symptoms. When administering opioid analgesics, an antidote (naloxone) must always be available (see below). A lesser-known adverse effect is muscle rigidity. When administering opioid analgesics (intraspinally in particular), itching may appear. Opioids may cause a drop in blood pressure and bradycardia due to vagal nerve stimulation. Furthermore, the cardiovascular response to stress is inhibited, which may result in orthostatic collapse in some patients. After a prolonged administration of opioid analgesics, tolerance both to certain adverse effects (sedation, nausea) and to the analgesic effect develops, and the dose needs to be increased. Psychological dependence develops in connection with the indicated. Physical dependence always develops, usually after 20–25 days, sometimes even sooner, and withdrawal symptoms occur after rapid discontinuation of opioid treatment. Contraindications of opioid analgesics include hypersensitivity, intracranial hypertension, craniocerebral injury without artificial ventilation, treatment with monoamine oxidase inhibitors, porphyria. Normal doses of opioid analgesics for short-term post-operative pain management are safe in pregnancy and during lactation. However, as they cross the placental barrier, caution should be exercised in the period immediately before delivery to prevent neonatal respiratory depression. Paediatric administration generally requires enhanced monitoring of respiratory functions, particularly after surgery. Higher sensitivity to opioid administration has been reported in the elderly (risk of deeper sedation, confusion, hallucinations), and in patients with reduced function of kidneys and thyroid gland

6.1. Opioid agonists used in anaesthesiology

Long-acting opioids (lasting 4 to 8 hours) are used in premedication and postoperative pain therapy. In anaesthesia care these are only used in surgeries of long duration and in cases when patient will stay on artificial ventilation after the procedure. Short-acting opioids (lasting 2 to 60 minutes) are titrated during general anaesthesia to achieve analgesia during and after recovery without respiratory depression.

6.1.1. Morphine

Morphine is a prototypical strong opioid, which remains the gold standard against which all drugs that have strong analgesic effects are compared. Everything that has been stated in the section on general characteristics of opioid analgesics applies to morphine as well. Various routes of administration are available (including oral, intramuscular, subcutaneous, intravenous, epidural, spinal and intra-articular). In postoperative pain management, parenteral administration is preferred. Morphine is metabolized to morphine-6-glucuronide, an active metabolite, which is excreted by the kidneys. Therefore, renal insufficiency may lead to morphine accumulation and prolonged effect. For systemic analgesia, the dose is 0.1 mg/kg; the duration of action is about 4 hours.

6.1.2. Pethidine

In addition to its opioid effect, pethidine also has the characteristics of a weak local anaesthetic and alpha-2 agonist. Pethidine has many side effects, for which it is not suitable in postoperative pain management. Its effect is short-term at first, but it gradually accumulates in the body. Pethidine is metabolized to norpethidine, which is neurotoxic and can provoke seizures. Intramuscular, subcutaneous and intravenous routes of administration are available. Pethidine should not be used during lactation for an extended period, as it may cause neurobehavioral changes in infants. The dose is approximately 1 mg/kg every 4 hours, to a maximum dose per day of 300 mg in adults.

6.1.3. Fentanyl

Fentanyl was first synthesized by Paul Janssen in Belgium in 1959. Fentanyl provides some of the effects typical of other opioids through its agonism of the opioid receptors. As a mu-receptor agonist, it binds to receptor 50 to 100 times more strongly than morphine. Fentanyl can also bind to the delta and kappa opioid receptors but with a lower affinity. Its strong potency relative to morphine is largely due to its high lipophilicity. Because of this, it can more easily penetrate the central nervous system.

Dosage of fentanyl is strictly individual depending on age, body mass index, and general health state of a patient and duration of surgery. During induction to general anaesthesia in adults, the common dose is 50 to 200 μg. Bolus doses of 200 μg or more usually result in respiratory depression and sometimes muscle rigidity, so artificial ventilation is mandatory. Top-up doses during surgery are usually 25 – 100 μg, but the interval between doses is variable. The effect may be more intensive and longer in old patients and in children.

6.1.4. Sufentanil

Sufentanil is the most potent opioid used in humans. It is 5 to 10 times as potent as fentanyl and has a more rapid recovery after prolonged intravenous infusion. It is more lipid-soluble than fentanyl but has a smaller volume of distribution and a shorter elimination half-life. Cardiovascular effects are similar to effects found with fentanyl; however, sufentanil produces better hemodynamic stability during cardiac anaesthesia and exhibits a more favourable ratio of analgesia to respiratory depression. Sufentanil does not cause histamine release. High doses of sufentanil may reduce the dose of neuromuscular blocker required. As with fentanyl and alfentanil, sufentanil can be used for induction of anaesthesia after bolus administration and maintenance by infusion. The dose 0.5 μg/kg usually provides analgesic effect lasting 50 minutes. Additional doses are 10-25 μg on individual bases.

Sufentanil is registered for epidural use. It binds rapidly to spinal opioid receptors and only a small proportion penetrates into the cerebrospinal fluid. The onset of analgesia is fast and duration after a single dose is 60 to 90 minutes. It is routinely used for analgesia during childbirth, because epidural administration has little effect on the foetus and adaptation to a newborn. In some hospitals, it is administered in subarachnoid doses of 10 mcg. After neuroaxial administration, the most common side effect is pruritus and sometimes it causes nausea and vomiting.

6.1.5. Alfentanil

Alfentanil and remifentanil were developed in search of analgesics with a more rapid onset of action and predictable termination of effects. Alfentanil is 5 to 10 times less potent than fentanyl and has a shorter duration of effect and is 10 times more potent than morphine. Alfentanil has a rapid onset (1 to 2 minutes) of analgesic effect after intravenous administration. Its analgesic effect is terminated rapidly as a result of redistribution and lasts approximately 10 min. Owing to its short duration of analgesic effect, it is not an ideal choice for long procedures. For short procedures, the initial dose is 0.5 – 1.0 mg IV.

6.1.6. Remifentanil

Remifentanil, a fentanyl derivative, is an ultra-short acting, nonspecific esterase-metabolised, selective mu-opioid receptor agonist, with a pharmacodynamic profile typical of opioid analgesic agents. Notably, the esterase linkage in remifentanil results in a unique and favourable pharmacokinetic profile for this class of agent. Adjunctive intravenous remifentanil during general anaesthesia is an effective and generally well tolerated opioid analgesic in a broad spectrum of patients, including adults and paediatric patients, undergoing several types of surgical procedures in both the inpatient and outpatient setting. Remifentanil is efficacious in combination with intravenous or volatile hypnotic agents, with these regimens generally being at least as effective as fentanyl or alfentanil containing regimens in terms of attenuation of haemodynamic, autonomic and somatic intraoperative responses, and postoperative recovery parameters. The rapid offset of action and short context-sensitive half-time of remifentanil, irrespective of the duration of the infusion, makes the drug a valuable opioid analgesic option for use during balanced general inhalational or total intravenous anaesthesia (TIVA) where rapid, titratable, intense analgesia of variable duration, and a fast and predictable recovery are required. Its biological half-time is 8–20 minutes. Remifentanil is administered as infusion 0.5 - 1 □g/kg/min, sometimes after initial bolus starting dose 1 □g/kg. Maintenance dose is 0.04 □g/kg/min, according to surgical stimulation. Because of short clinical effect 5 - 10 min., long-acting analgesic must be administered before the end of surgical procedure to avoid severe postoperative pain after recovery.

6.1.7. Antagonists of opioids

Naloxone is a highly potent opioid receptor antagonist that is used to reverse the effect of opioid-induced respiratory depression. Intravenously, naloxone may be given in 0.1 mg increments, titrated to effect. The duration of effect of a single dose of 0.4 mg naloxone is only 30 to 45 minutes, which may be far less than the opioid agonist that is being reversed. Naloxone should be used with caution because it can precipitate severe pain or acute withdrawal in patients who are opioid tolerant. Tachycardia, hypertension, and acute pulmonary oedema may occur.

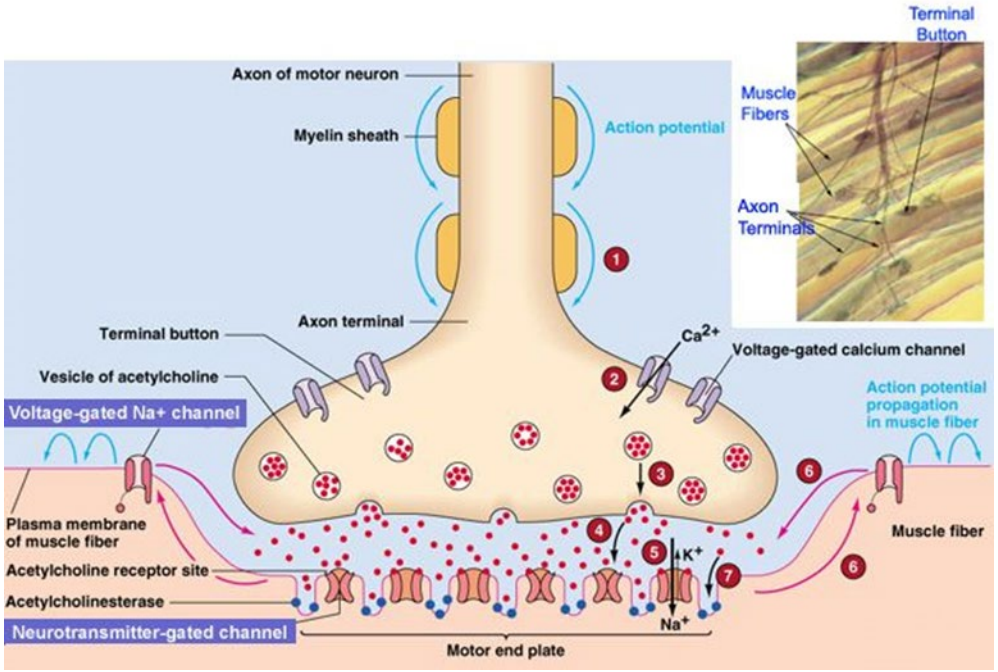
7. Muscle relaxants

J. Málek

A muscle relaxant is a drug that affects skeletal muscle function and decreases the muscle tone. It may be used to alleviate symptoms such as muscle spasms, pain, and hyperreflexia. The term "muscle relaxant" is used to refer to two major therapeutic groups: neuromuscular blockers and spasmolytics. Neuromuscular blockers act by interfering with transmission at the neuromuscular end plate and have

no central nervous system activity. They are often used during surgical procedures and in intensive care and emergency medicine to cause temporary paralysis. They are used together with anaesthetics and analgesics as part of balanced anaesthesia. Balanced means that the choice and dose of drugs of each individual group are balanced to provide optimal conditions for surgery while considering the specifics individual needs of the patient. They must be never used alone, as they cause only muscle paralysis without any anaesthetic or analgesic effect. When used artificial ventilation is obligatory.

Muscle relaxants are classified according to their action at neuromuscular junction. Acetylcholine is stored in pre-junctional nerve endings and transfers signals from the neuron to the muscle.



Picture 7: Neuromuscular junction. Source Pinterest

Normally, a nerve impulse arrives at the motor nerve terminal, initiating an influx of calcium ions, which causes exocytosis of synaptic vesicles containing acetylcholine. Acetylcholine then diffuses across the synaptic cleft. It may be hydrolysed by acetylcholine esterase or bind to the nicotinic receptors located on the motor end plate. The binding of two acetylcholine molecules results in a conformational change in the receptor that opens the sodium-potassium channel of the nicotinic receptor. This causes sodium and calcium ions to enter the cell and potassium ions to leave, leading to depolarization of the end plate and subsequently muscle contraction. Following depolarization, the acetylcholine molecules are removed from the end plate region and are enzymatically hydrolysed by acetylcholinesterase.

Normal end plate function can be blocked by two mechanisms. According to their activity at neuromuscular junction, there are two types, depolarizing and nondepolarizing.

Depolarizing muscle relaxants acts as acetylcholine receptor agonists. They bind to the acetylocholine receptors and generate an action potential. As they are not metabolised by acetylcholinesterase, they remain bound and desensitize the receptors so they can no longer initiate action potentials and cause muscle contraction. As the muscle relaxant continues to bind to the acetylcholine receptor, the end plate cannot repolarize, resulting in a phase I block. The acetylcholine receptor can also undergo conformational and ionic changes after a period of time, resulting in a phase II block.

Nondepolarizing muscle relaxants act as competitive antagonists. They bind to the acetylcholine receptors but are unable to induce ion channel openings. They prevent acetylcholine from binding and thus end plate potentials do not develop.

Both of these classes of neuromuscular blocking drugs are structurally similar to acetylcholine, the endogenous ligand, in many cases containing two acetylcholine molecules linked end-to-end by a rigid carbon ring system, as in pancuronium (a nondepolarizing agent).

7.1. Depolarizing muscle relaxants

The only drug from this group is suxamethonium.

Suxamethonium is a depolarizing neuromuscular blocker widely used for muscle relaxation during induction of general anaesthesia. At a dose of 1 to 1.5 mg/kg, suxamethonium causes extremely rapid muscular paralysis, and optimal intubating conditions are obtained within 30 to 60 seconds. Paralysis is preceded by a brief period of intense muscle fasciculation and rigidity. The drug is rapidly metabolized by plasma cholinesterase, which results in a duration of effect of 5 to 10 minutes following a standard dose. The use of suxamethonium is limited by a range of adverse effects, some of which are life threatening.

In normal subjects, suxamethonium causes a small rise in serum potassium of about 0.5 mmol/l. However, in certain disease states (stroke, paraplegia, muscular dystrophy, critical illness polymyoneuropathy, prolonged and severe intraabdominal infections, the first 2-3 days after head injury, trauma and burns, prolonged immobility), a massive rise in serum potassium sufficient to cause life-threatening ventricular arrhythmias can occur. An alternative to suxamethonium should also be considered in patients with prolonged immobility.

The usual response to a single intravenous dose of suxamethonium 1 – 1.5 mg/kg is deep muscular paralysis for about 6 minutes, after which plasma enzymes rapidly destroy it. About 1 in 2500 of the population has a defect these enzymes (cholinesterase, butyrylcholinesterase or pseudocholinesterase) and is thus abnormally sensitive to the action of suxamethonium, so that muscle paralysis and apnoea persist. Suxamethonium sensitivity is an autosomal recessive trait. Other side effects of suxamethonium include bradycardia, muscle pains, raised intraocular pressure, and raised intragastric pressure. Suxamethonium can also trigger malignant hyperpyrexia.

Suxamethonium is indicated primarily for rapid-sequence intubation because intubating conditions are obtained with sufficient speed that a period of bag-mask ventilation is not required. Recently, for this indication is some used high dose of rocuronium, which may be rapidly reversed by sugammadex.

7.2. Nondepolarizing muscle relaxants

Nondepolarizing muscle relaxants have only biding capacity, but no intrinsic activity. They only block acetylocholine receptors from acetylocholine. They are pure competitive antagonists. Their effect may be reversed by neostigmine. They are synthetic derivates of an arrow poison curare and differ by speed of onset and recovery, metabolic degradation and side effects.

7.2.1. Long-acting

D-tubocurarin has nowadays only historical importance.

Pancuronium is rarely used for the risk of tachycardia and hypertension because of release of noradrenaline.

Pipecuronium has few side effects, but may cumulate after repeated doses.

7.2.2. Intermediate-acting

Vecuronium is very safe, sometimes used as a component of TIVA

Atracurium is degraded partly by so-called Hofmann's elimination - degradation to inactive parts by body temperature and pH. It means it is independent on metabolic activities of parenchymatous organs (liver and kidney). It can be used for non-emergency intubation and TIVA. Its main side effect is hypotension.

Cis-atracurium is a monoisomer of atracurium with fewer side effects

Rocuronium can be quickly antagonized in a unique way by sugammadex so it can be used for rapid intubation. High doses are used in this situation, which can be reversed very quickly by sugammadex in case of necessity.

7.2.3. Short-acting

Mivacurium is nondepolarising muscle relaxant, which is rapidly metabolized by plasmatic cholinesterase, similarly to suxamethonium.

7.3. Monitoring effect of muscle relaxants

The most frequently used is peripheral nerve stimulator, also known as a train-of-four monitor, is used to assess neuromuscular transmission when neuromuscular blocking agents are given to block musculoskeletal activity. By assessing the depth of neuromuscular blockade, peripheral nerve stimulation can ensure proper medication dosing and thus decrease the incidence of side effects. Electric impulses (usually 50 mA) used in durations of 0.2 – 1ms depolarize all muscle fibres. Train of four consists of 4 impulses given in intervals 0.5 seconds. When depolarising muscle relaxants are all of the four muscle contractions (twitches – T1 to T4) in the set of four are reduced in strength by the same amount. When a non-depolarizing agent is given, a pattern known as fading is observed. There is a reduction in the amplitude of the evoked responses, with each contracting being successively weaker. As the non-depolarizing block becomes more intense, T4 disappears followed by T3, T2, and finally T1. The reverse is true during recovery from non-depolarizing block: T1 reappears first followed by T2, T3, and finally, T4.

Video 2: Monitoring muscle relaxation

7.4. Antagonization of non-depolarizing muscle relaxants

It is necessary that normal muscle tone must be recovered after the end of surgery and before terminating artificial ventilation. At least 90 % of neuromuscular receptors must recover to allow a safe level of spontaneous ventilation. Clinical signs (head lifting for 5 seconds, sticking out one's tongue, measuring grip strength) are unreliable, so neurostimulation is recommended to assess the level of recovery. Because waiting for spontaneous recovery is usually not possible, pharmacological decurarisation is used.

In case of non-depolarizing muscle relaxants, the standard way is to increase the amount of acetylocholine available to recover normal neuromuscular transmission. This is achieved by neostigmine, which temporarily blocks acetylcholine esterase, so that more acetylcholine is available at the neuromuscular junction. Because acetylocholine stimulates not only receptors at the neuromuscular junctions but also parasympathetic receptors, its muscarinic action must be blocked to prevent parasympathomimetic reaction (bradycardia, bowel and intestinal spasms, hypersalivation and hypersecretion of bronchial glands). Thus atropine or glyccopyrolate are given first. The onset of decurarisation is slow (several minutes) and lasts 20 – 30 minutes. The risk of so-called recurarisation occurs when long-acting muscle relaxants are used.

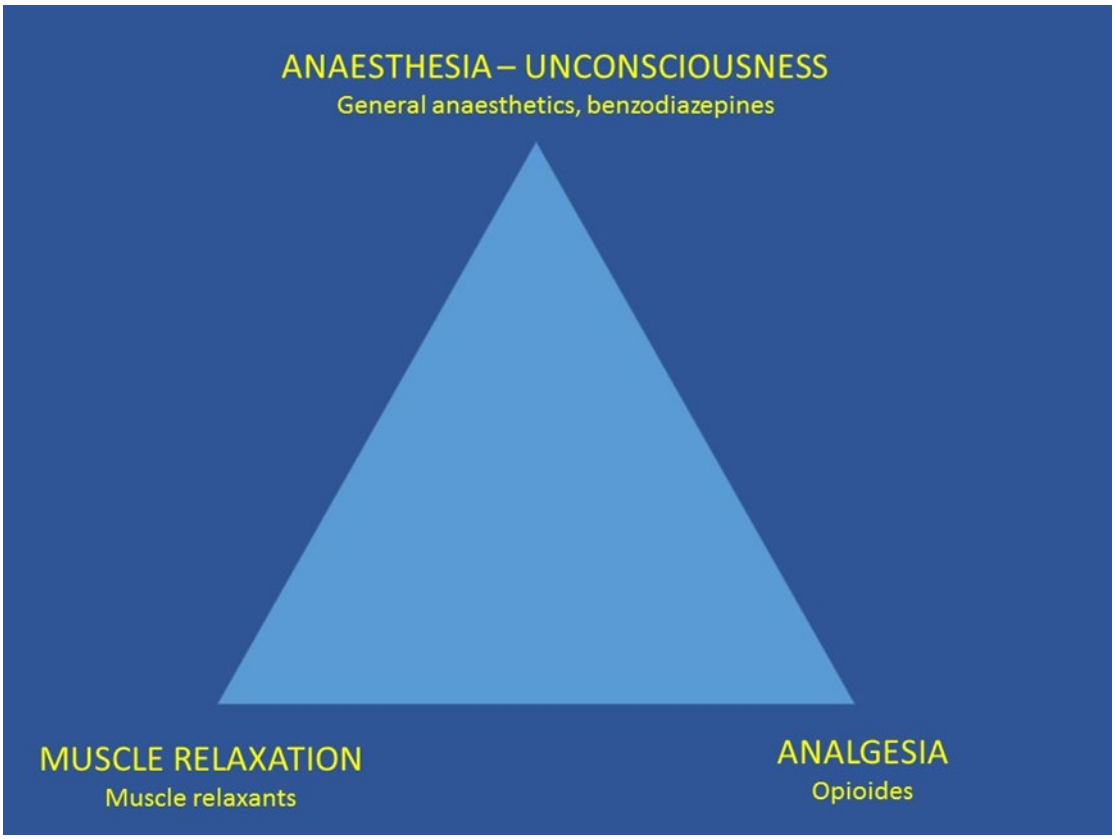
Sugammadex is modified gamma cyclodextrine, which a site inside its ring which binds selectively to rocuronium. It eliminates rocuronium from the blood and the following complex is excreted by urine. It has no side effects caused by increased level of acetylocholine. Its onset is very rapid and recurarisation is very improbable. The main limiting factor of its use is its price.

The depolarizing muscle relaxant suxamethonium has no antidote. This means that in case of prolonged blockade due to a genetic defect in pseudocholinesterase, anaesthesia and artificial ventilation must be continues until non-specific esterases degrade it. This can last up to several hours.

8. Balanced anaesthesia

J. Málek

Balanced anaesthesia means that the choice and dose of drugs of each individual group are balanced to the best condition for performing surgery and to react on individual needs of each patient. Various groups of drugs are used to provide different effects during surgery. The three components of general anaesthesia are unconsciousness, analgesia and muscle relaxation. Balanced anaesthesia refers to using smaller doses of different drugs to potentiate their desired effects and decrease unwanted side effects.



Picture 8: Balanced anaesthesia

9. Local anaesthetics

(source: *https://emedicine.medscape.com/article/873879-overview#a2*)

D. Mach

Local anaesthetics produce anaesthesia by inhibiting excitation of nerve endings or by blocking conduction in peripheral nerves. They achieve this by reversibly binding to and inactivating sodium channels. Sodium influx through these channels is necessary for the depolarization of nerve cell membranes and subsequent propagation of impulses along the course of the nerve. When a nerve loses depolarization and the capacity to propagate an impulse, the individual loses sensation in the area supplied by the nerve.

Local anaesthetics have the highest affinity for sodium channels in the open state, followed by the inactivated state and lastly the resting state. The open state of the sodium channel is the primary target of local anaesthetics. The blocking of propagated action potentials is therefore a function of the frequency of depolarization. The mechanism for differential block, the block of pain perception without motor block, is still unclear. Physiologic activity of local anaesthetics is a function of their lipid solubility, diffusibility, affinity for protein binding, percent ionization at physiologic pH, and vasodilating properties.

Lipid solubility is an important characteristic. Potency is directly related to lipid solubility, because 90% of the nerve cell membrane is composed of lipids. Increased lipid solubility leads to faster nerve penetration and blockade of sodium channels. Diffusibility of the local anaesthetic through tissue other than nerve tissue also influences the speed of action onset.

Protein binding is related to the duration of action. The more firmly the local anaesthetic binds to the protein of the sodium channel, the longer the duration of action.

Local anaesthetics exist in ionized and non-ionized forms, the proportions of which vary with the pH of the environment. The non-ionized portion is the form that is capable of diffusing across nerve membranes and blocking sodium channels. Anaesthetics a proportion greater non-ionized forms have a faster onset of action. Local anaesthetics differ in respect to the pH at which the ionized and non-ionized forms are present at equilibrium, but this pH is generally in the range of 7.6-8.9. The more closely the equilibrium pH for given anaesthetic approximates the physiologic pH of tissues (e.g. 7.35-7.45), the more rapid the onset of action. A decrease in pH shifts equilibrium toward the ionized form, delaying onset of action. This explains why local anaesthetics are slower in onset of action and less effective in the presence of inflammation, which creates a more acidic environment. Contrastingly, the addition of sodium bicarbonate is used clinically to increase the pH of local anaesthetic solutions thereby enhancing onset of action. Overzealous alkalinisation, however, can cause local anaesthetic molecules to precipitate from solution.

All local anaesthetics, with the exception of cocaine, are vasodilators. Vasodilation occurs via direct relaxation of peripheral arteriolar smooth muscle fibres. Greater vasodilator activity of a local anaesthetic leads to faster absorption and, thus, a shorter duration of action. To counteract this vasodilatation, epinephrine is often included in local anaesthetic solutions.

9.1. Side effects of local anaesthetics

9.1.1. Allergic reaction

Although extremely rare, allergic reactions may occur with use of local anaesthetics. This is usually a reaction to the anaesthetic or the preservative used in the solution. Allergic reactions are uncommon in the amino ester group and extremely rare in the amino amide group.

Most reactions to local anaesthetics are actually caused by anxiety, panic attacks, vasovagal responses, or accidental intravascular injection. True allergic reactions occur in less than 1% of all reactions to local anaesthetics.

The cause of hypersensitivity reactions is believed to be a breakdown product created by the action of serum pseudocholinesterases on the amino ester paraaminobenzoic acid (PABA). PABA is very antigenic and is capable of sensitizing lymphocytes and eliciting formation of antibodies for a humoral immune response.

Hypersensitivity reactions may be type I reactions manifested by a spectrum of symptoms from local or systemic urticaria to anaphylactic shock, or type IV reactions manifested by contact dermatitis or anaphylactoid reactions. The patient may develop hypotension, tachycardia, hives, angioedema, dyspnoea, bronchospasm with wheezing, or rhinorrhoea. Ceasing the operation immediately at the onset of any signs or symptoms of a severe allergic reaction is important. Antihistamines and corticosteroids are first-line treatments, to be administered concomitantly with activation of advanced cardiac life support protocols and the Emergency Medical Services system.

If a patient has a reaction to a local anaesthetic, assuming that he or she is also sensitive to other agents in the same class is the safest route. Most patients with a hypersensitivity reaction to an amino ester can probably be treated safely with an amino amide. However, many commercial amino amide preparations contain methylparaben as a preservative. Methylparaben is chemically similar to PABA and is capable of eliciting a hypersensitivity reaction. The extremely rare cases of hypersensitivity reactions to amino amides probably are related to the methylparaben preservative rather than to the amino amide. Mepivacaine commercial preparations do not contain methylparaben and can usually be substituted safely in this situation.

The diagnosis of an allergic reaction to local anaesthesia is based on these symptoms and signs: shock, cardiac arrest (88 %), erythema (45 %), bronchospasm (36 %), angioedema (24 %) and other skin reactions. The differential diagnosis includes primary cardio-insufficiency, asthma, pneumothorax and others.

Immediate treatment

- Stop administration of potential allergens.
- Call for help.
- Secure airways, give 100% oxygen 10–15 l/min
- Use antishock position (not in dyspnoea)
- Give adrenaline 0.5 mg IM, or titrate incremental doses 50 – 100 µg IV
- Give infusions (balanced solutions)

Consecutive therapy

- Antihistaminics: chlorfenamine10–20 mg slowly IV
- Corticosteroids: hydrocortisone 100–300 mg IV
- Catecholamines: in circulatory instability
- Adrenaline 0.05 µg/kg/min or
- Noradrenaline: 0.05–0.1 µg/kg/min
- If necessary, intubate and ventilate.
- In bronchospasm, use inhalational betasympathomimetics.
- In significant metabolic acidosis give bicarbonate

9.1.2. Toxic reaction

Toxicity is related to the peak circulating levels of local anaesthetics. Circulating levels are determined by the rates of absorption, distribution, and metabolism, all of which vary considerably from agent to agent. As previously described, the rate of absorption depends on the chemical structure, dose, presence or absence of epinephrine, speed of administration, local tissue vascularity, and technique of administration. Distribution of local anaesthetic following absorption into the bloodstream occurs in 3 phases. Initially, uptake occurs by highly vascular tissues such as the lungs and kidneys. Subsequently, the local anaesthetic appears in less vascularized tissues such as muscle and fat. Finally, the drug is metabolized. Metabolism of local anaesthetics depends on the chemical structure. Amino esterases are degraded primarily by plasma pseudocholinesterases. Amino amides are cleared primarily by hepatic metabolism with renal excretion.

Adverse reactions may occur following administration of local anaesthetics and usually result from administration of too much of the drug. Adverse reactions may also occur following injection of vascular sites or from accidental direct intravascular injection of the drug. Deaths following local anaesthetic administration are always a result of overdosage. Tissue toxicity can be achieved by all local anaesthetics if “high” concentrations are used. Adverse reactions occur primarily in the CNS (neurotoxicity) and cardiovascular system (myotoxicity) because these tissues are also composed of excitable membranes, the target of local anaesthetic action.

In the CNS, a progression of signs and symptoms may be observed in the patient. The patient may report light-headedness, tinnitus, circumoral numbness, a metallic taste, or double vision. Upon examination, the patient may become drowsy or slur speech and may develop nystagmus. At higher levels of anaesthetics, the patient may become anxious and develop fine tremors of the muscles of the hands and/or face. These tremors may worsen and coalesce into a grand mal seizure. Ultimately, the patient may experience generalized CNS depression leading to hypoxia, acidosis, and respiratory arrest.

Local anaesthetics decrease the rate of depolarization of cardiac tissue, which is the rationale behind the use of lidocaine in treatment of ventricular arrhythmias. At higher concentrations, amplitude of the cardiac action potential is decreased, and the velocity of conduction is reduced. At toxic doses, the negative inotropic effects of local anaesthetics may lead to bradycardia, ventricular fibrillation, or asystole. Other cardiovascular effects include hypotension, which occurs via the direct vasodilating effects of local anaesthetics on peripheral arteriolar smooth muscle.

Recognizing signs and symptoms of an adverse reaction to local anaesthetics and administering emergency care in relation to the severity of the reaction are essential. Above all, seek help immediately. With severe life-threatening reactions, immediately curtail the procedure. Activate advanced cardiac life

support (ACLS) protocols immediately, including intubation and defibrillation if indicated. Hypotension may require intravenous fluids and vasoconstrictor drugs for circulatory support. Control seizure activity with diazepam 5-10 mg IV. Succinylcholine may be required to stop ongoing tremors, but its use requires intubation and mechanical ventilation. Atropine and epinephrine may be indicated to treat bradycardia.

All guidelines recommend to use ”lipid resuscitation” in treatment of LA toxicity, e.g. IV administration of concentrated lipid emulsion, like Intralipid 20% 1 ml/kg during 1 min. If no effects appears, the dose can be repeated 2times within 3-5 min. and next followed by 0.25 ml/kg/min till haemodynamic stabilisation. There is no use to give more than 8 ml/kg, but it is necessary to prevent hypoxia and metabolic disorders.

Minimum equipment for safe administering RA

1. manual rescue bag, face masks and source of oxygen
2. equipment for intubation
3. suction
4. IV cannulas, infusions
5. thiopental, diazepam
6. atropine, ephedrine, adrenaline

Intravenous access should be always available for case of emergency.

9.2. Local anaesthetic drugs

D. Mach

All local anaesthetics have an intermediate chain linking an amine on one end to an aromatic ring on the other. The amine end is hydrophilic, and the aromatic end is lipophilic. Variation of the amine or aromatic ends changes the chemical activity of the drug. Two basic classes of local anaesthetics exist, the amino amides and the amino esters. Amino amides have an amide link between the intermediate chain and the aromatic end, whereas amino esters have an ester link between the intermediate chain and the aromatic end. Amino esters and amino amides differ in several respects. Amino esters are metabolized in the plasma via pseudocholinesterases, whereas amino amides are metabolized in the liver. Amino esters are unstable in solution, but amino amides are very stable in solution. Amino esters are much more likely than amino amides to cause allergic hypersensitivity reactions. Commonly used amino amides include lidocaine, mepivacaine, prilocaine, bupivacaine, etidocaine, and ropivacaine and levobupivacaine.

Commonly used amino esters include cocaine, procaine, tetracaine, chloroprocaine, and benzocaine. An easy way to remember which drug belongs in which category is that all of the amino amides contain the letter "i" twice, as does the term "amino amides." Newer additions to clinically available local anaesthetics, namely ropivacaine and levobupivacaine, represent exploitation of the S enantiomer of these chemicals to create anaesthetics which are less toxic, more potent, and longer acting amides are metabolized in the liver. Amino esters are unstable in solution, but amino amides are very stable in solution. Amino esters are much more likely than amino amides to cause allergic hypersensitivity reactions.

9.2.1. Cocaine

Cocaine, a compound indigenous to the Andes Mountains, West Indies, and Java, was the first anaesthetic to be discovered and is the only naturally occurring local anaesthetic in leaves of Erythroxylon coca; all others are synthetically derived. Cocaine was introduced into Europe in the 1800s following its isolation from coca beans in 1859. Because of toxicity and risk of addiction it is used very rarely, mainly as a topical anaesthetic in ENT as a 10 % solution or 30 % paste. It has significant vasoconstriction and sympathomimetic effects.

9.2.2. Amino ester local anaesthetics

9.2.2.1. Procaine

Procaine is the only used amino ester in Czech Republic. It has a low toxicity and is available as 1%, 2% and 10% solutions. Procaine has a high risk of allergic reaction because of PABA production. It can be used for infiltration anaesthesia, intravenous analgesia and conductive anaesthesia of thin nerves.

9.2.3. Amino amide local anaesthetics

9.2.3.1. Lidocaine

Lidocaine is the most commonly used local anaesthetic worldwide and is also a class Ib anti-arrhythmic agent. It is used for infiltration as 0.5–1% solutions, for peripheral nerve blockades as 1–2% solutions and for epidural blockade as 1– 2% solutions. It is also available as plasters, sprays and gels and is part of a topical anaesthetic mixture for skin anaesthesia (EMLA cream).

9.2.3.2. Trimecaine

Trimecaine is used in Czech Republic instead of lidocaine. It is used for infiltration and conductive anaesthesia similarly lidocaine. The disadvantage of lidocaine and trimecaine are their vasodilation effects, which decreases the duration of anaesthesia and increases the systemic absorption and risk of toxic reactions. Adrenaline (1 : 200 000) is frequently used as an adjunct during infiltration anaesthesia to induce vasoconstriction. Adrenaline is contraindicated in circulatory anaesthesia near terminal arteries (fingers, penis) and for Bier´s blockade. Care must be taken during use of adrenaline in patients with hypertension and ischemic heart disease. Maximal doses for infiltration are 3-4 mg/kg without adrenaline, 5-7 mg/kg with adrenaline.

9.2.3.3. Mepivacaine

In the Czech Republic mepivacaine in registered for use in dentistry only. Maximal dose is 7 mg/kg. Onset of anaesthesia is rapid (2 - 3 min) and the duration is 30 - 160 min.

9.2.3.4. Bupivacaine

Bupivacaine is a long-acting local anaesthetic indicated for local infiltration, peripheral nerve block, sympathetic nerve block, and epidural, subarachnoid and caudal blocks. It is more potent than lidocaine, but much more cardiotoxic. It is contraindicated for Bier´s blockade for this reason. Bupivacaine is a racemic mixture of D and S enantiomers; S form has lower toxicity. The onset is rather slow but the duration of anaesthesia may be several hours. The concentration for infiltration is 0.25% for peripheral nerve blockades and 0.375–0.5% for epidural anaesthesia. Bupivacaine is particularly useful for pain relief, particularly for labour pains, as its sensory nerve blockade is more marked than its motor blockade. The maximal dose is 2 mg/kg.

9.2.4. Amino amide local anaesthetic of 3rd generation – „chiral–caines“

Modification of the S-enantiomer of bupivacaine (ropivacaine and levobupivacaine) led to the creation of less toxic, more potent and longer acting local anaesthetics.

9.2.4.1. Ropivacaine

Ropivacaine is chemically similar to bupivacaine but less effective and also less toxic. It is available as 0.2%, 0.5%, 0.75% and 1% solutions. Motor block is less pronounced compared to bupivacaine. It is used for the same indications as bupivacaine. The maximal dose is 3 mg/kg.

9.2.4.2. Levobupivacaine

Levobupivacaine is an S-enantiomer of bupivacaine with less anaesthetic potency and less cardiotoxicity. Use is similar to bupivacaine.

9.2.5. Articaine

Articaine is a unique local anaesthetic because it has both amide and ester structures. It is similar to lidocaine. In the Czech Republic it is used only in denistry. The effective half-life is only 30 minutes, which is much shorter compared to the 90 minutes duration of lidocaine.

9.3. Adjuvant drugs to local anaesthetics

D. Mach

Adjuvant drugs are used to prolong or improve characteristics of local anaesthetics.

9.3.1. Adjuvant drugs used in neuroaxial blockades

The only registered drugs for neuroaxial use are opioids. They prolong duration of analgesia and potentiate the effect of local anaesthesia used in low concentration to avoid motor block (e.g. postoperative or obstetric analgesia). The main risk is respiratory depression, which can be early, occurring 30–120 minutes after administration, as can occur when the lipophilic sufentanil is used, or delayed, occurring 4 – 18 hours after administration (morphine). The less lipophilic morphine can be transported by the cerebrospinal fluid circulation from spinal area to brain receptors. This transport occurs much less when more lipophilic drugs are used because they remain fixed to the spinal nerve structures.

Intrathecal morphine

Delayed respiratory depression is dose-dependent. Maximum safe dose is 0.1–0.25 mg. Pure morphine („preservative-free“) must be used.

Epidural morphine

There is a risk of both early and delayed respiratory depression. Epidural dose is 1-5 mg; concomitant use of epidural and parenteral administration of morphine can increase the risk of respiratory depression and should not be used.

Epidural sufentanil

Respiratory depression is less probable. The dose is 10–50 µg in combination with LA.

9.3.2. Adjuvant drugs used in peripheral blockades

There are more adjuvant drugs used in peripheral blockades.

Adrenaline

Adrenaline is recently the only used vasoconstriction agent used do decrease plasmatic absorption and prolong effect of LA (*see Trimecaine* above).

Opioids

The existence of opioid receptors on peripheral nerves is still discussed. Sometimes sufentanil 5 µg is used.

Clonidine

Clonidine is used in peripheral nerve blocked in spite of it is of label (non-registered) use. In dose 25–75 µg, clonidine is used to prolong duration of anaesthesia.

10. Combined anaesthesia

Combination of general and regional anaesthesia is used for better analgesia and decreasing the dose of general anaesthesia and systemic opioids. Combined anaesthesia results in a greater suppression of the stress reaction to surgery and allows analgesia to be prolonged into the postoperative period.

11. Preanaesthesia evaluation

J. Málek, J. Šturma

Preanaesthesia evaluation is defined as the process of clinical assessment that precedes the delivery of anaesthesia for surgical and for nonsurgical procedures. The preanaesthesia evaluation is the responsibility of the anaesthesiologist. Preanaesthesia evaluation consists of the consideration of information from multiple sources that may include the medical records, patient interviews, physical examinations, and findings from laboratory tests and radiological and other examinations. As part of the preanaesthesia evaluation process, the anaesthesiologist may choose to consult with other healthcare professionals to obtain information or services that are relevant to perioperative anaesthetic care. Preoperative tests, as a component of the preanaesthesia evaluation, may be indicated for various purposes, including but not limited to (1) discovery or identification of a disease or disorder that may affect perioperative anaesthetic care; (2) verification or assessment of an already known disease, disorder, medical or alternative therapy that may affect perioperative anaesthetic care; and (3) formulation of specific plans and alternatives for perioperative anaesthetic care.

The assessments made in the process of preanaesthetic evaluation may be used to educate the patient, organize resources for perioperative care, and formulate plans for intraoperative care, postoperative recovery, and perioperative pain management. The evaluation consists of

- **History**: previous anaesthesia and complications, diabetes, pulmonary disease, chronic hypertension, previous myocardial infarction, history of smoking, high body mass index, extremes of age, pharmacological history
- **Physical examination**: minimal assessment of the airways, lungs and heart, with documentation of vital signs
- **Laboratory and auxiliary results**: ECG in asymptomatic patients over 40 years old, urine tests in all patients. All other tests are indicated for a specific clinical indication or purpose. For example, assessment of warfarin therapy effects would be considered an indication for specific coagulation studies.

Test results obtained from medical records within one month of surgery are generally acceptable if the patient's medical history has not changed substantially and the patient is classified as ASA 1 and 2. More recent test results may be desirable when the medical history has changed or when test results may play a role in the selection of a specific anaesthetic technique (e.g. regional anaesthesia in the setting of anticoagulation therapy), or in high risk patients (ASA 3 or higher)

11.1. ASA physical status classification

ASA is an abbreviation for the American Society of Anaesthesiologists. The ASA physical status classification system is a system for assessing the fitness of patients before surgery. In 1963 the American Society of Anaesthesiologists adopted the five-category physical status classification system; a sixth category was later added, but is not used in the Czech Republic.

1. **Healthy person.**
2. **Mild systemic disease.**

3. **Severe systemic disease.**
4. **Severe systemic disease that is a constant threat to life.**
5. **A moribund person who is not expected to survive without the operation.**
6. **A declared brain-dead person whose organs are being removed for donor purposes.**

The letter "E" is added in case of emergency surgery (e.g. ASA 2E)

The risk of mortality increases with ASA status (0.06% at ASA 1 to 51% at ASA 5) and emergency surgery multiplies the risk by 1.5 – 2. In elective surgery, the benefit/risk ratio must be always considered.

11.2. Premedication

Although premedication was initially developed to prevent adverse effects of anaesthesia, we now use premedication primarily to increase the general wellbeing of patients and patient satisfaction after surgery. The main aims of premedication are

- To relieve anxiety
- To decrease the metabolic rate
- To decrease salivation and secretion, volume and acidity of gastric juice
- To suppress parasympathetic and sympathetic reflexes
- To induce analgesia and sedation

Various drugs are used to achieve these aims.

- Anxiolysis: Both psychological and pharmacological approaches are effective in decreasing preoperative anxiety: personal interview with the anaesthetist, benzodiazepines, alpha2 sympathomimetics
- Sedation: benzodiazepines and alpha2 sympathomimetics. Barbiturates are no longer used.
- Anterograde amnesia: benzodiazepines
- Antiemetics: neuroleptics, H1 antagonists, 5-HT3 antagonists
- Decrease of volume and acidity of gastric content: prokinetics, H2 blockers
- Decrease of hypersalivation: parasympatholytics
- Analgesia: opioids

Sedatives and anxiolytics are frequently used on the evening before surgery. This administration is sometimes called pre-premedication. The most commonly used drugs are benzodiazepines, but they are contraindicated in seniors, because they can induce confusion, delirium and even aggressiveness, and there are also contraindicated in patients with myasthenia gravis. In the evening, long-acting benzodiazepines are used, like temazepam, oxazepam etc. In the morning short-acting drugs, like midazolam are used. Except for benzodiazepines, alpha2-agonists, antidepressants, and anticonvulsants are all effective in reducing preoperative anxiety.

Prevention of aspiration pneumonitis caused by regurgitated gastric juice from a full stomach in patients who didn't fast or in parturient women is always a challenge for anaesthetists. Apart for fasting, appropriate measures to prevent aspiration include gastric decompression, acceleration of gastric emptying, and application of the technique of rapid sequence intubation along with Sellick's manoeuvre. Premedication that can inhibit gastric juice secretion and reduce gastric juice volume and acidity, such as H2-receptor antagonists (cimetidine, ranitidine) or proton pump inhibitors (omeprazole) are used. Prokinetics (such as metoclopramide) are used to decrease the volume of gastric content.

Various drugs are used to provide for prophylaxis against postoperative nausea and vomiting (PONV). About one-third of surgical patients who receive a general anaesthesia consisting of inhalational anaesthetics and opioids experience PONV. Several risk factors are for PONV are female sex, age < 50 years, a history of PONV and/or travel sickness, opioid use in the postanaesthesia care unit and non-smokers. The pathophysiology of PONV is complicated, and several kinds of receptors and their

mediators have been implicated in PONV: (1) serotonin type 3 (5-HT3) receptor; (2) dopamine type 2 receptor; (3) histamine type 1 receptor; (4) muscarinic cholinergic type 1 receptor; (5) steroid receptor; and (6) neurokinin type1 (NK1) receptor. Based on these findings, modern PONV prophylaxis adopts the principle of multimodal approach to treat high-risk patients with at least two or three different kinds of receptor antagonists, rather than just increasing the dosage of one single receptor antagonist, to prevent the occurrence of PONV. Current antiemetic medications that have been proved to be effective for PONV prophylaxis are the following: phenothiazines (chlorpromazine and prochlorperazine), butyrophenones (droperidol and haloperidol), benzamides (metoclopramide), anticholinergics (scopolamine, antihistamines (hydroxyzine and dimenhydrinate, 5-HT3 antagonists (ondansetron, dolasetron, granisetron, tropisetron, and palonosetron, NK-1 antagonists (aprepitan, and steroids (dexamethasone).

Parasympatholytics (anticholinergics) are used to prevent hypersalivation, secretion of bronchial glands and bradycardia during induction of general anaesthesia. The most frequently used are atropine or glycopyrronium.

Analgesics are rarely used in premedication except in situation when a patient already suffers from pain before surgery. Usually opioids like morphine or piritramide are used.

Routes of administration

Historically premedication was administered only intramuscularly, which can be painful and a source of fear in children. Recently peroral administration is preferred; because of using a small volume of clear water to swallow the medication does not increase the risk of aspiration. In patients with gastrointestinal emergencies, the oral route is contraindicated, so the subcutaneous or intramuscular route still used, or in some cases the intravenous route.

Peroral administration is a standard in children. Drugs that can be administered perorally include atropine, midazolam, tramadol 45-60 min before induction to general anaesthesia to achieve the effect. Children are sedated, without fear and have amnesia.

11.3. Immediate period before anaesthesia

Before any anaesthesia, obligatory control is necessary. Issued by the WHO the anaesthesia checklist contains the following items:

- Is the identity of the patient confirmed?
- Is the site of surgery signed?
- Has the patient signed an informed consent form for surgery?
- Is an experienced and trained assistant available to help you with anaesthesia induction?
- Has the patient had no food or drink for the appropriate time period?
- Is there intravenous access that is functional?
- Is the patient on a table that can be rapidly tilted into a head-down position in case of sudden hypotension or vomiting?

Equipment check

- If compressed gas will be used, is there enough gas and a reserve oxygen cylinder?
- Anaesthetic vaporizers are connected?
- Breathing system that delivers gas to the patient is securely and correctly assembled?
- Breathing circuits are clean?
- Resuscitation equipment is present and working?
- Laryngoscope, tracheal tubes and suction apparatus are ready and clean?
- Needles and syringes are sterile?
- Drugs are drawn up into labelled syringes?
- Emergency drugs are present in the room, if needed?

Fasting before scheduled surgery and anaesthesia is 6 hours for solid food and 2 hours from clear fluids. This does not apply in some situations (severe pain, trauma, obstetric patients and patients with prolonged stomach emptying or GIT problems.

Emergency anaesthesia and surgery allows only a limited time to prepare a patient. As soon as a patient is identified as an emergency and/or trauma patient, the operating theatre staff and anaesthesiologist should be notified. Ideally, the anaesthesiologist should be involved in the initial evaluation and management of the patient. The time available is minutes in case of life-threatening trauma to hours in cases of acute abdomen, but it should be used to obtain maximum information concerning history from the patient, drugs used, previous surgeries, anaesthesia and their complication, laboratory and medical examination and correction of adverse factors, if possible. The mortality of emergency patients is 1.5 to 2 times higher than in patients of the same ASA classification patients with scheduled surgery.

12. Basic anaesthesia techniques

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12.1. Airway management techniques

The main catastrophes in anaesthesia are attributed to loss of oxygenation, which can be caused by:

- failed ventilation (38%)
- unrecognized intubation of the oesophagus (18%)
- failed intubation (17%)

In total 85% of these complications result in death or severe brain injury.

12.1.1. Facemask

Facemask and bag ventilation are essential skills each anaesthetist must master. Even more skill is necessary in children because incorrect technique may close the soft part of the throat and may result in inability to ventilate the child. Basic techniques are used: head tilt and chin lift (if no concerns about cervical spine injury, jaw thrust, good head position, achieved by combining lower cervical spine flexion, head extension at the atlanto-occipital joint, positioning the ears anterior to the sternum (“sniffing morning air” position) and good seal of the mask against the face. Several acronyms have been formed to help predict who will be difficult to ventilate. MOANS stands for "mask seal, obesity, age (elderly), no teeth, stiffness." OBESE stands for "obese, bearded, edentulous, snoring, elderly".

Video 3: Face mask

12.1.2. Airways

Video 4: Oral and nasal airways

Oropharyngeal airways (Guedel 1933) are used to improve free passage of air into the hypopharynx during facemask and bag ventilation or as an anti-biting block during bronchoscopy or anaesthesia. Before insertion, the patient must be in deep anaesthesia to prevent laryngeal spasm, cough or vomiting. The technique of insertion is demonstrated in the video.

Nasopharyngeal airways are rarely used because of risk of bleeding from the nasopharynx or nose.

Cuffed Oro-Pharyngeal Airway - C.O.P.A. (Greenberg 1992) is the last modification of Guedel's airway equipped with a high-volume cuff for fixation in the mouth. It is rarely used.

12.1.3. Tracheal tube and tracheal intubation

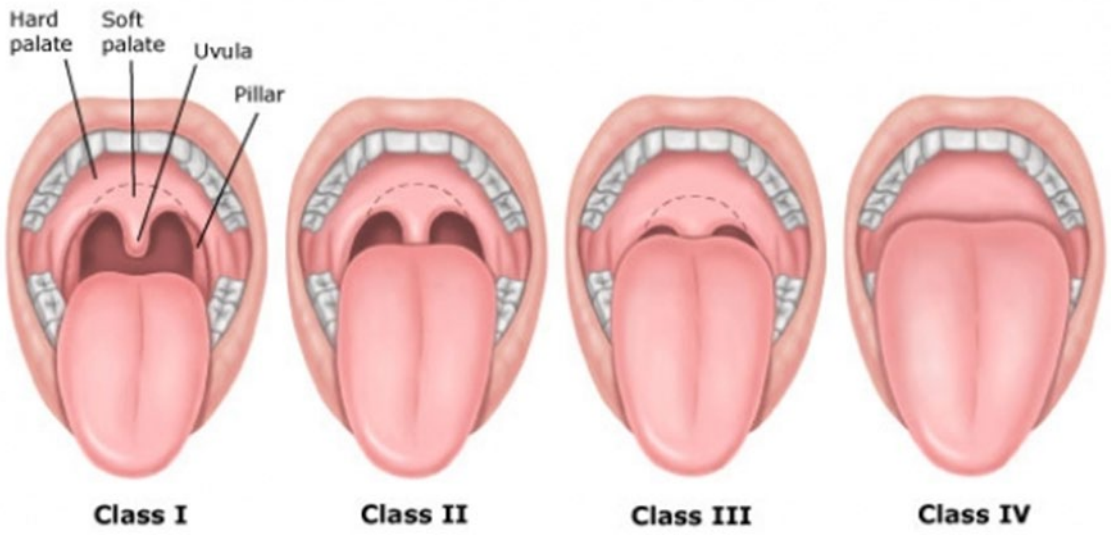
Tracheal tube is the gold standard technique for securing the airway during anaesthesia and surgery.

The advantages of tracheal intubations are:

- Keeps airway open
- Protects airway from gastric content, blood or tissue debris aspiration
- Enables positive pressure ventilation
- Enables suction from the trachea

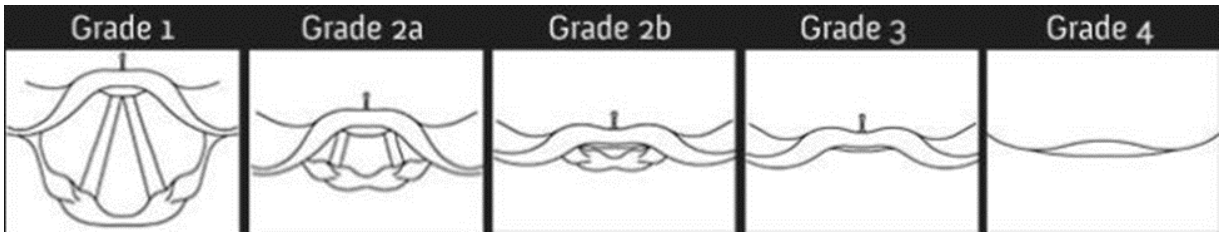
The main disadvantage is that intubation is a skill that must be learned and practiced, because it is not always easy. There are several techniques to predict difficult intubation. The most commonly used are the Mallampati score (1985), which is assessed before anaesthesia induction and the Cormack and Lehan score (1984), which is assessed during direct laryngoscopy.

The Mallampati score is assessed while the patient is awake and sitting upright with the head in the neutral position, mouth opened as wide as possible and the tongue maximally protruded. The airway can be classified according to the structures visible in the hypopharynx (Fig. 9). The higher the number, the more difficult the intubation is expected to be.



Picture 9: Mallampati score. Source: **RMH ICU Online Learning**

Cormac Lehan score classifies visualization of the laryngeal structures at the time of laryngoscopy. Just as the visualization of the hypopharyngeal structures has been classified, the extent to which the laryngeal structures are visualized is also graded from I to IV. Again, the higher the number, the more difficult the intubation is expected to be.



Picture 10: Cormac Lehan score. Source **OpenAirway**

Tracheal intubation involves several steps (*see video 5*). Patient must always be unconscious (in deep anaesthesia, usually with muscle relaxation).

1. Preoxygenation + denitrogenation by breathing 100% oxygen for 2 – 3 min
2. Induction of general anaesthesia
3. Positioning the patient
4. Opening the patient's mouth
5. Direct laryngoscopy
6. Insertion of the tracheal tube through the vocal cords and removing the laryngoscope
7. Confirmation of correct placement and securing the tube

Optimizing the position of the patient's head and neck before attempting laryngoscopy is an important step. The patient's head and neck should be positioned into the "sniffing position", which is produced

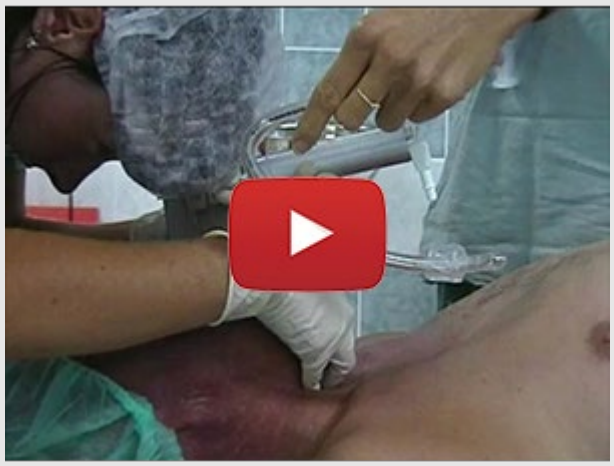
by a combination of thoraco-cervical flexion and atlanto-occipital extension. This enables one to align the axes of the patient's mouth, pharynx, and larynx and allows direct visualization of the larynx during laryngoscopy. The laryngoscope is held in the left hand, the right hand is used to open the patient's mouth and, later, to advance the tube. The tip of the laryngoscope blade is advanced to the base of the tongue following the natural curve of the oropharynx and tongue. The blade should be inserted to the right of the tongue's midline, so that the tongue moves toward the left and out of the line of vision. Pushing the tongue into the back of the oropharynx should be avoided, as this will also obscure vision. Once the tip of the blade lies at the base of the tongue (just above the epiglottis), firm, steady upward and forward traction to the laryngoscope is applied. Maximal care must be taken to avoid pressure on the upper teeth because of risk of damaging them.

Intubation is performed with the left hand controlling the laryngoscope blade, while the right hand opens the mouth and then passes the tip of tracheal tube through the vocal cords. When the epiglottis partially obscures the view of the glottis, an assistant may be used to apply cricoid pressure. This manoeuvre moves the larynx posteriorly and helps to bring the vocal cords into view. A malleable stylet, shaped so that it forms a distal anterior J curve, can also be helpful in guiding the tip of the tube through the laryngeal inlet. Sometimes so-called BURP manoeuvre is used: an assistant applies Backword Upright Right-side Pressure on the larynx. The cuff of the tracheal tube should be observed passing through the vocal cords. The laryngoscope is removed and the cuff of the tube is inflated. Immediate absolute proof that the tube is in the tracheal lumen may be obtained by observing the tube passing through the vocal cords, observing carbon dioxide (ETCO2) returning with each respiration, or by visualizing the tracheal lumen through the ETT using a fiberoptic scope. Indirect confirmation that the trachea is intubated with a tracheal tube includes: listening over the epigastrium for the absence of breath sounds with ventilation, observing the chest to rise and fall with positive pressure ventilation, and listening to the apex of each lung field for breath sounds with ventilation. If the tube is positioned in the tracheal lumen and the patient is breathing spontaneously, the reservoir bag will fill and empty with respiration. Decreased air entry to one lung field may indicate that the tube is in a mainstem bronchus (usually the right one). In this case, the tube must be repositioned only. If no breath sounds are detected, the patient must be ventilated and a new attempt should be done. Several guidelines have been published for difficult intubation (see further).

Video 5: Tracheal tubes and tracheal intubation

Several special tubes are used for certain surgical procedures. To prevent kinking and blocking the tube during surgery of the face and throat, a special shaped tubes are used, such as RAE tubes (Ring, Adair, Elwyn), U shaped tubes for laryngectomy, armoured tubes, which are reinforced with a metal spiral and fire resistant tubes, which as used for laser ENT surgeries.

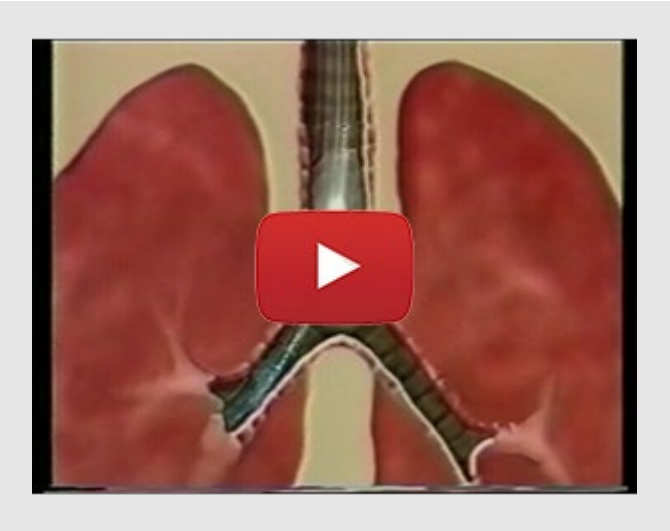
Video 6: Armoured tracheal tube



Video 7: RAE tracheal tube

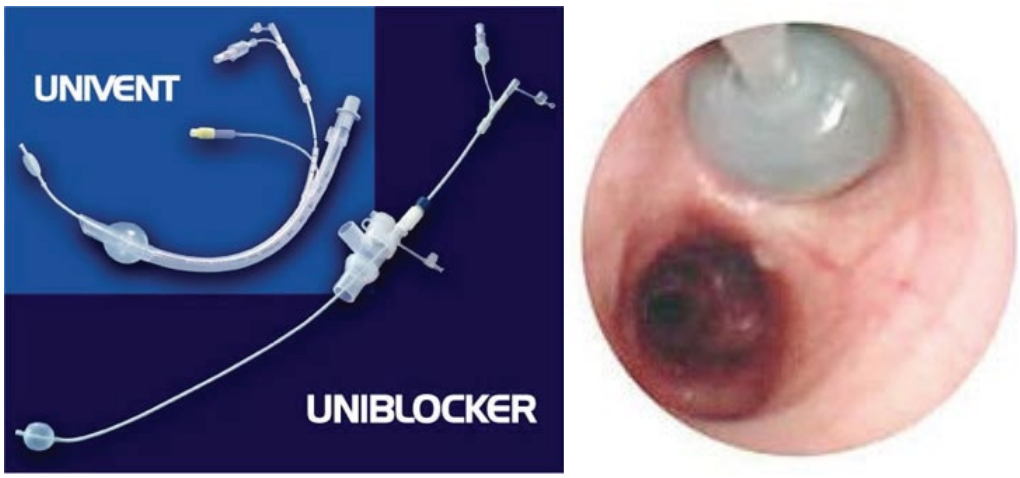
Special tubes are used for lung surgery. A double lumen tube is used to selectively intubate a single lung. One lumen terminates in trachea, the second one in a main bronchus (left or right). Each lung can be ventilated independently which is used for surgery or for prevention of overflowing septic mucus from one lung to the other. The correct position of the tube is verified by auscultation or by bronchoscopy.

The former tubes (left introduced by Carlens – 1949, right introduced by White - 1960) had a carinal hook for correct positioning. Recently more modern biluminal tubes (left and right introduced by Robertshaw - 1962) have become more popular.



Video 8: Double lumen pulmonary tube

The other possibility to separate both lungs is a bronchial obturator. The position is again confirmed by bronchoscopy (see picture 11).



Picture 11: Bronchial obturator

An alternative way for standard intubation is using special equipment, like laryngoscopes with different blades, videolaryngoscops or bronchoscopy.

Rapid sequence induction and intubation

A rapid sequence induction is used when a patient who requires general anaesthesia has risk factors for gastric aspiration. All patients are at risk of aspirating gastric contents when general anaesthesia is induced, because it impedes the patient's protective airway reflexes. For this reason, all patients requiring elective surgery are asked to abstain from eating solid foods for at least 6 hours and clear liquids for at least 2 hours prior to the procedure. The aim is to intubate and inflate the cuff of the tracheal tube as soon as possible after the protective reflexes are lost (e.g. after induction of GA). Patients who have any of these predisposing risks for gastric aspiration and who require a general anaesthetic, should have measures taken to prevent aspiration during the perioperative period. The three key components of a rapid sequence induction are: (1) preoxygenation, (2) the application of cricoid pressure with loss of consciousness, (3) tracheal intubation with a cuffed tracheal tube. Without a cuffed tracheal tube, the patient is at risk of pulmonary aspiration of gastric contents. Before induction, suction must be checked. Two appropriately sized tubes of different sizes with an introducer, a laryngoscope and laryngoscope blade must be prepared. Sometimes cricoid pressure is applied to compress oesophagus between the cricoid cartilage and cervical spine. This is called Sellick's manoeuvre and is applied by an assistant

with the induction of anaesthesia. Its purpose is to reduce the risk of passive regurgitation and aspiration before an endotracheal tube can be placed. Cricoid pressure is only released when the tracheal tube cuff has been inflated, and the tube position confirmed by auscultation of both lung fields and measurement of carbon dioxide in the exhaled gases (ETCO2).

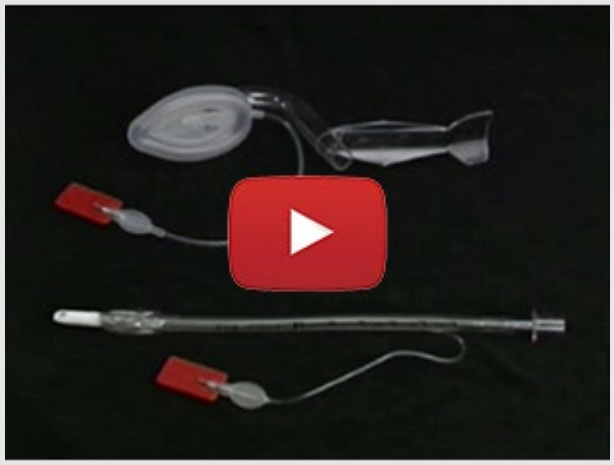
12.1.4. Supraglottic airway devices

Supraglottic airway devices were introduced in the 1908s. The first laryngeal mask was invented by Dr. Brain in Great Britain in 1983. The main advantages to tracheal intubation are easier insertion, no risk of tracheal or laryngeal injury and less discomfort in the mouth and throat compared. The main disadvantage of supraglottic airway devices is that they do not reliably protect from aspiration of gastric content and the maximum sealing pressure is 20 – 25 cm H2O.

12.1.4.1. Laryngeal masks

Since the first use many different types were developed, like classical laryngeal mask (LP), intubating laryngeal mask, LM Proseal, LM Supreme, I-gel, Cobra, Slipa, etc. (see videos bellow)

Video 9: Laryngeal mask



Video 10: ILMA - Intubating laryngeal mask

Video 11: Laryngeal mask Proseal

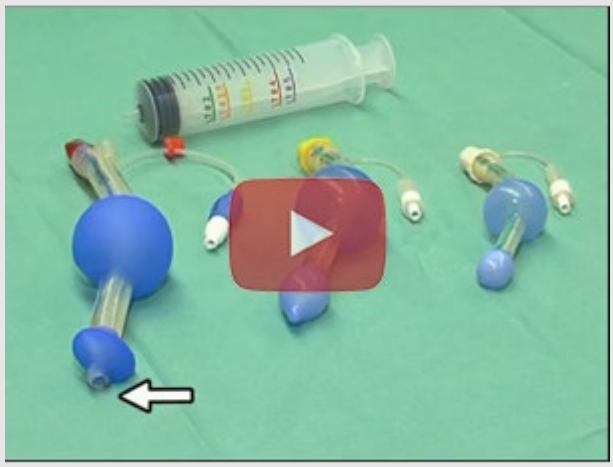
Video 12: Laryngeal mask Supreme

Video 13: Laryngeal mask I-Gel

12.1.4.2. Combitube and Laryngeal tube

Combitube (OOA – oesophageal obturator airway, Werman - 1987) was introduced for use in the prehospital setting by personnel not trained in tracheal intubation. It is a biluminal tube inserted blindly and according to the tip position enabling either indirect (the ventilating tip is in oesophagus - 80 % of insertions) or direct (the ventilating tip is in trachea - 20 % of insertions) pulmonary ventilation. The second tip is blind and has a high-volume cuff to seal Combitube in the mouth. Additionaly to the other disadvantages of supraglottic devices, the combitube presents a risk of injury of oesophagus and/or larynx. It is rarely used.

The successor of Combitube is the laryngeal tube. It has just one lumen and is easier to introduce and inflate.

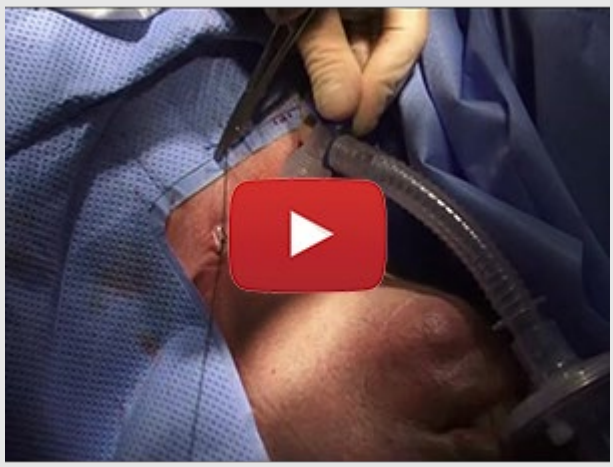


Video 14: Laryngeal tube

12.1.5. Invasive securing of airways

12.1.5.1. Tracheostomy

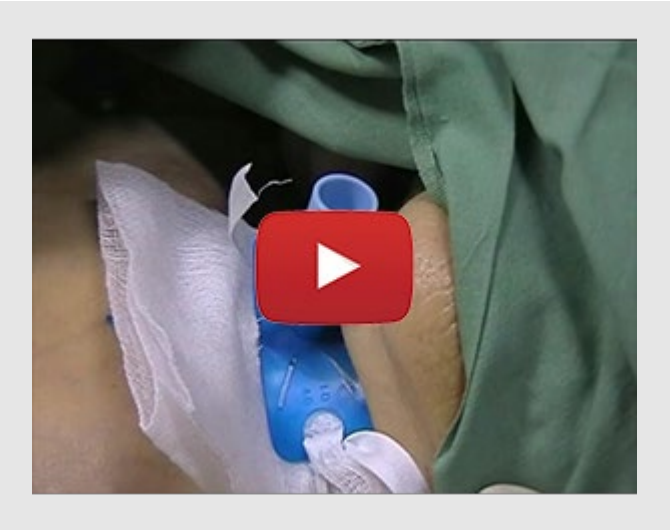
Tracheostomy is a surgical procedure, which consists of making an incision on the anterior aspect of the neck and opening a direct airway through an incision into the trachea. The resulting stoma is used for insertion of a tracheostomic cannula. It is used as a long-term or even permanent (after e.g. laryngectomy) access to airways. Because the procedure takes some time, it is rarely used as an emergency procedure. It can be performed as on open technique or as percutaneous dilatational tracheostomy, which is used mainly at the ICUs.



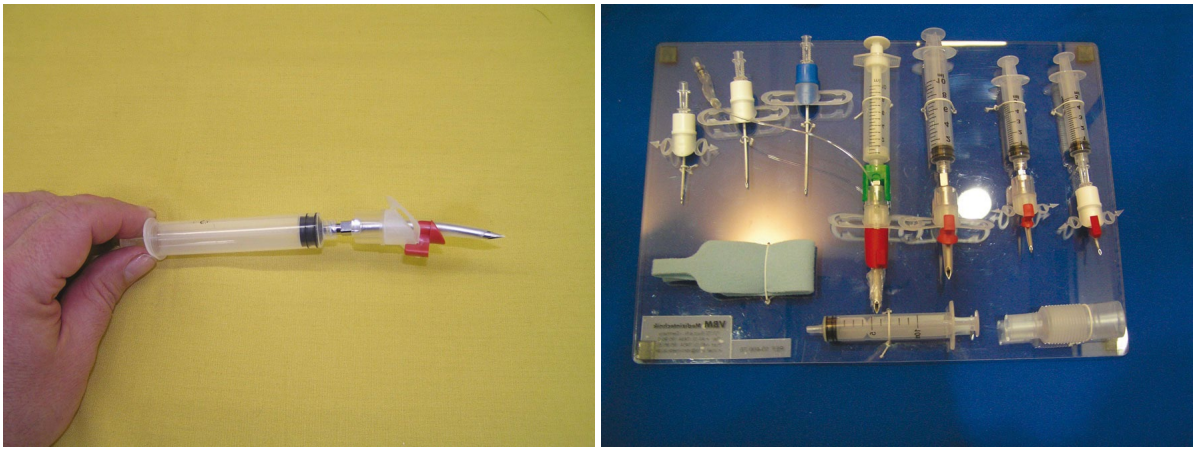
Video 15: Tracheostomy

12.1.5.2. Cricotomy and surgical cricotomy

These techniques are used as a part of a "cannot intubate, cannot ventilate" scenario. Surgical technique enables a cuffed tracheal tube to be inserted through an artificial opening after which mechanical ventilation can be initiated.



Video 16: Coniopunction

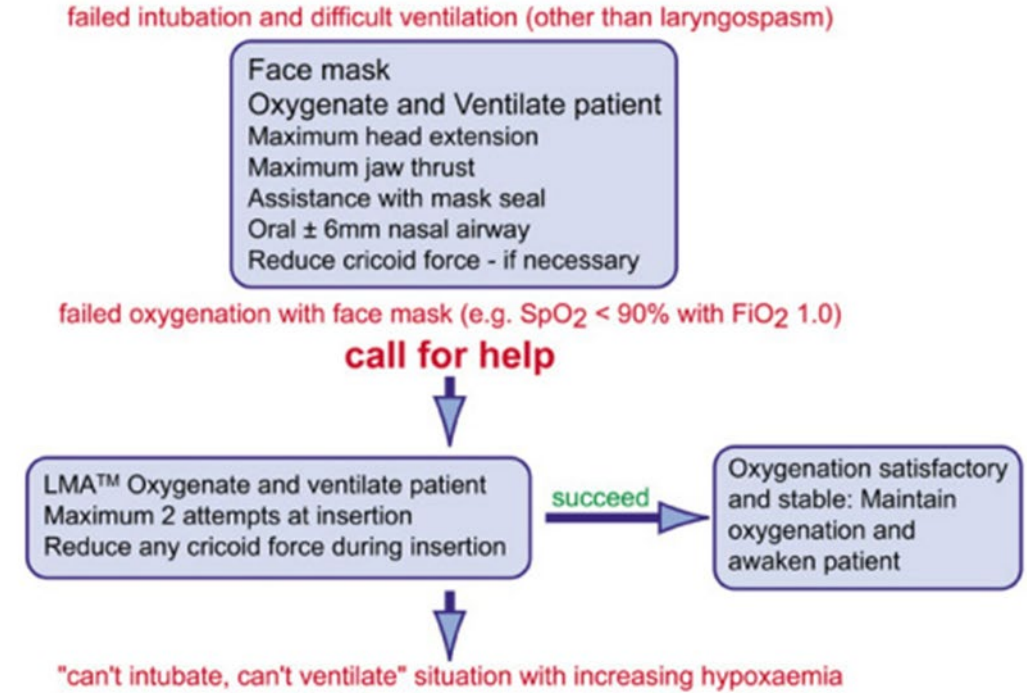


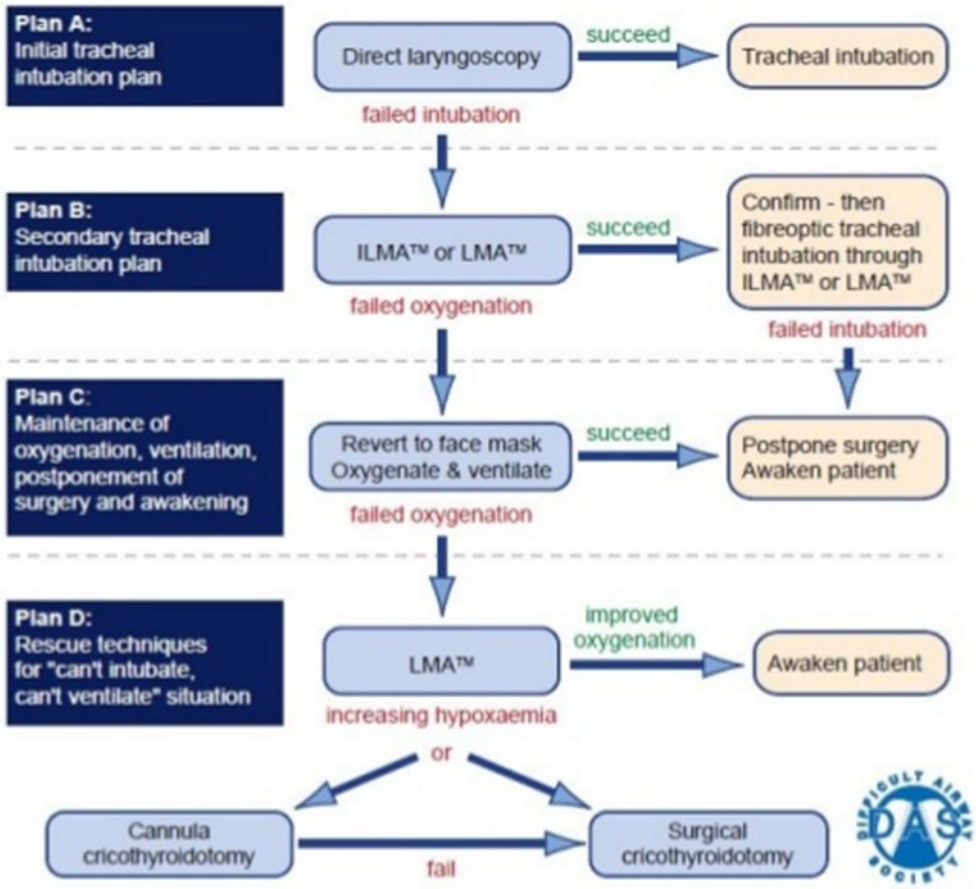
Picture 12: Set for coniopunction

12.1.6. Difficult intubation

The main risk for the patient during induction to GA is the situation "cannot intubate, cannot ventilate". Various guidelines we introduced how to solve this life-threatening situation. The guidelines of Difficult Airway Society of Great Britain are presented (*http://www.das.org/*).

Failed intubation, increasing hypoxaemia and difficult ventilation in the paralysed anaesthetised patient: Rescue techniques for the "can't intubate, can't ventilate" situation





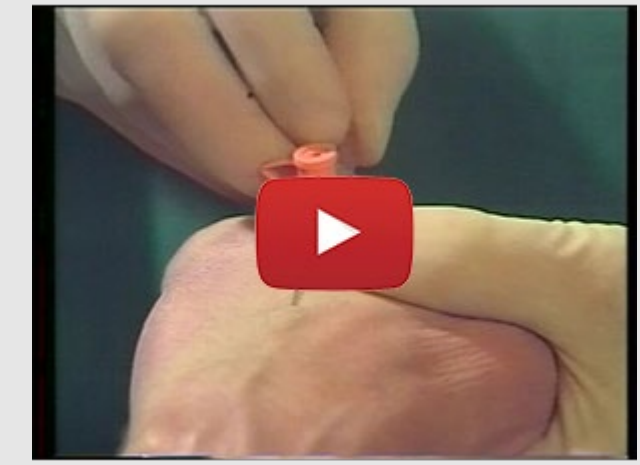
12.2. Venous access

J. Málek

Reliable venous access is used not only for administering anaesthetic drugs, but also for treatment of complications and fluid therapy.

12.2.1. Peripheral vein cannulation

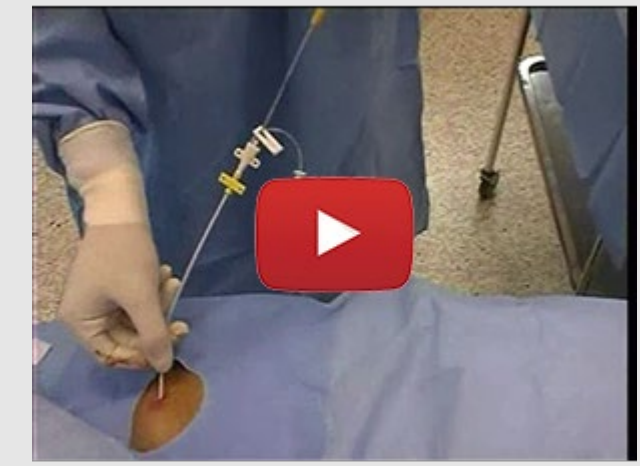
Peripheral vein cannulation is a standard procedure. *See video 17*.



Video 17: Peripheral vein cannulation

12.2.2. Central vein cannulation

Central vein cannulation is used for a long-term vein access, administration of concentrated and hyperosmotic solutions a measuring of central venous pressure. The most common insertion veins used are the subclavian and internal jugular veins. Less frequently the femoral vein is used (e.g. in patients with burns on the neck and chest). Ultrasound can be used to guide the cannulation.



Video 18: Central vein cannulation

12.2.3. Intraoseal access

Intraoseal access is a provisional vascular access used mainly in emergency situations. It must be changed to standard venous access within 24 hours.

Video 19: Intraoseal access

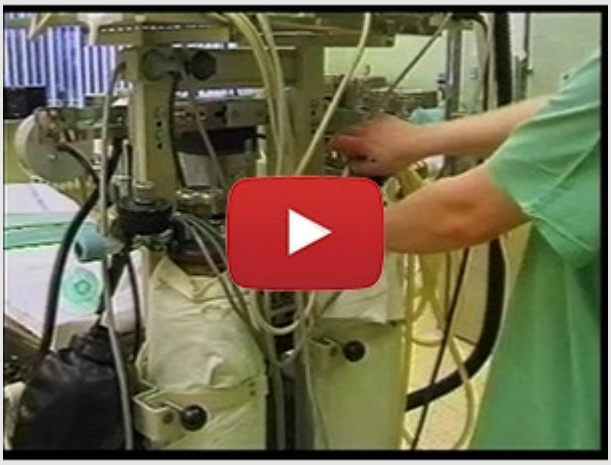
12.3. Arterial cannulation

Arterial cannulation is a procedure frequently performed in acute and critical care settings. It is used for invasive blood pressure monitoring, for frequent arterial blood sampling or in patients which non-invasive blood pressure monitoring is not possible such as patients with large surface area burns, severe hypotension, multiple extremity fractures, or morbidly obese patients. The most common insertion sites are the radial, brachial, and femoral arteries. Allen's test is used to assess collateral blood flow to the hand in case of radial artery cannulation. Traditionally, it is performed by asking the patient to clench the fist tightly. The ulnar and radial arteries are then compressed by the clinician's thumbs simultaneously. The fist is then unclenched, and the palm should appear white. The compression is then released from the ulnar artery while maintaining pressure over the radial artery. Once the compression is released colour should return to the palm usually within 10 seconds. The test is repeated on the same hand while releasing the radial artery first and continuing to compress the ulnar artery. The two commonly utilized techniques are the catheter-over-needle technique, or the Seldinger technique.

Video 20: Arteria radialis cannulation

13. Phases of general anaesthesia

J. Šturma



Video 21: Course of general anaesthesia

Anaesthesia consists of three main periods:

13.1. Induction to general anaesthesia

General anaesthesia is usually induced in a preparation room adjacent to the operating theatre, in an operating theatre or in a dedicated anaesthetic room adjacent to the theatre. However, it may also be conducted in other locations, such as an endoscopy suite, radiology department, cardiology department, emergency department, or in an ambulance, or at the site of a disaster where extrication of the patient may be impossible or impractical.

Venous access is performed, infusions started and monitors applied. Pre-induction values of blood pressure, pulse and SpO2 are obtained. Most general anaesthetics are induced either intravenously or by inhalation. Intravenous injection works faster than inhalation, taking about 10–20 seconds to induce total unconsciousness.

Induction to anaesthesia, as well as recovery are the most critical periods for complications. All equipment and drugs to treat them must be available.

13.2. Maintenance of general anaesthesia

Maintenance of general anaesthesia is a period of monitoring the state off the patient, the situation during surgery, applying fluids and transfusions. The anaesthesia chart is used to notice vital functions, drugs administration and all events.

13.3. The end of anaesthesia – recovery.

The end of administration of anaesthetic drugs and use of antidotes, if applicable.

13.4. Postoperative anaesthetic care

Routine post anaesthetic observations are an essential requirement for patient assessment and the recognition of clinical deterioration in post-operative patients. Sufficient monitoring and care is of paramount importance for the safe outcome of patients in the immediate post-operative period. Postoperative care units are part of many hospitals and serve for a safe recovery. Patients are transferred to a standard ward, if stable without strong pain, vomiting and other complications, to ICU is further monitoring is necessary or to critical care unit, in some vital function must be supported (mechanical ventilation, use of vasopressors etc.).

14. Locoregional anaesthesia

J. Málek, P. Michálek

Locoregional anaesthesia eliminates pain by blocking the nerve fibres that govern sensitivity and body movement at the level of nerve endings, nerves, nerve plexuses or spinal nerve roots. This objective is achieved by the administration of local anaesthetics that temporarily and reversibly interrupt nerve transmission. Depending on the concentration of local anaesthetic, all sensations are blocked, or motor functions and sensations of pulling and pushing are preserved.

14.1. Topical (superficial, mucosal) anaesthesia

Topical anaesthetics are widely used in numerous medical and surgical sub-specialties such as anaesthesia, ophthalmology, otorhinolaryngology, dentistry, urology, and aesthetic surgery. They cause superficial loss of pain sensation after direct application. Standard local anaesthetics do not penetrate intact skin until specially prepared. Only limited products can be used for skin application such as AMLA cream.

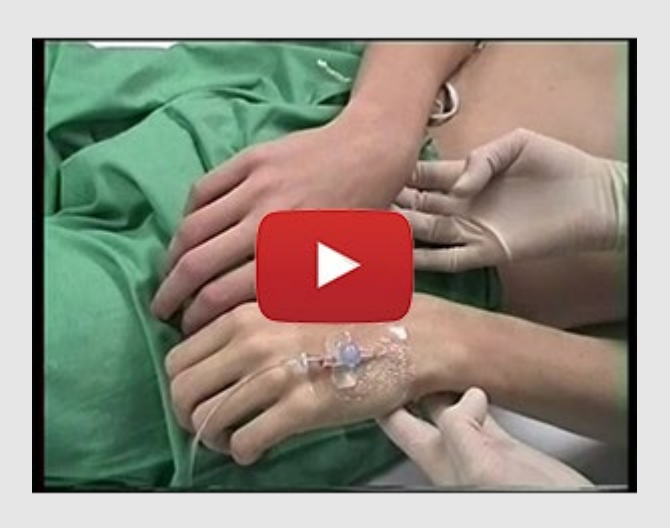
14.2. 14.2. Infiltration anaesthesia

The aim of local infiltration is to anaesthetize nerve endings in a finite area of tissue by the injection of local anaesthetics. This stands in contrast to conductive peripheral nerve blocks, in which nerve axons are the target and the injection may take place in an area distant to the surgical site (see further). Infiltration anaesthesia is used for minor procedures. Vasoconstrictors play a very important role in providing optimal local anaesthesia in dermatologic surgery by slowing mobilization of the anaesthetic and thus prolonging its effect, reducing peak blood levels, and providing haemostasis. Epinephrine (adrenaline) is the most common vasoconstrictor used in local anaesthetics. It should not be used in in ring blocks in the regions of terminal arteries, like fingers and the penis. Care must be taken in cardiac patients. The most commonly used concentrations of epinephrine in dermatologic surgery are 1:100,000 and 1:200,000. Addition of epinephrine in concentrations of 1:50,000, 1:100,000, and 1:200,000 were all shown to have the same effects on vasoconstriction, and may prolong the anaesthetic duration of lidocaine and bupivacaine by approximately 200%.

14.3. Intravenous regional anaesthesia (Bier's block)

The technique of intravenous regional anaesthesia (IVRA), or "Bier's block," was first introduced in 1908 by the German surgeon August Bier. A Bier block essentially consists of injecting local anaesthetic solutions into the venous system of an upper or very rarely lower extremity that has been exsanguinated by compression or gravity and that has been isolated by means of a double cuff tourniquet from the

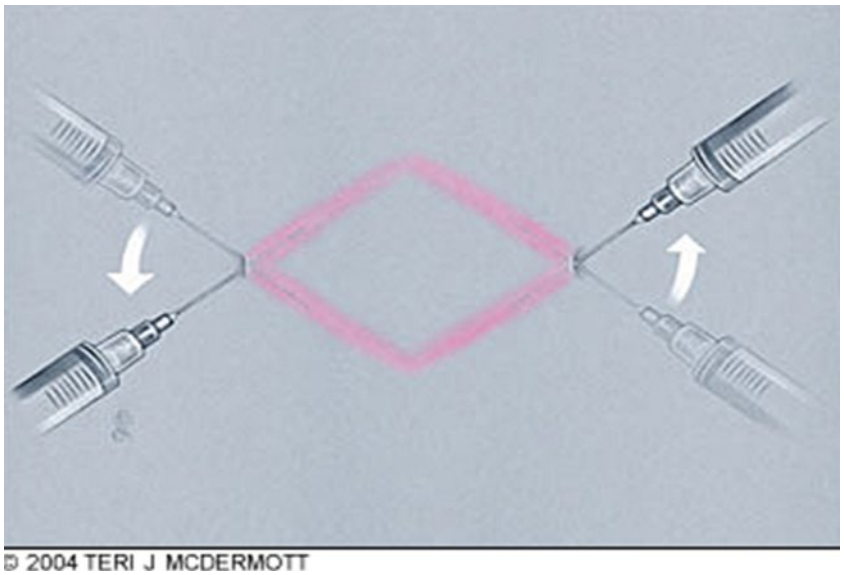
central circulation. As it has a lower risk of producing a toxic reaction, the technique is used more frequently in the upper extremity, because of lower volume of local anaesthesia needed compared to the lower extremity. One peripheral vein catheter is inserted into a peripheral vein as distally as possible and a second on the other extremity to treat possible complications. A double-pneumatic tourniquet is placed on proximally on the upper arm. The entire arm is elevated to allow passive exsanguination and a rubber Esmarch bandage is wound around the arm spirally from the fingertips of the hand to the distal cuff of the double tourniquet to exsanguinate the arm. The pneumatic cuff is inflated to 50–100 mm Hg above systolic arterial blood pressure, after which the Esmarch bandage is removed. Exsanguinated empty veins are filled with local anaesthetic, which rapidly diffuses to surrounding tissues and induces anaesthesia. About 25–30 minutes after the onset of anaesthesia or when a patient complains of tourniquet pain, the distal cuff is inflated and the proximal cuff is deflated to minimize the development of tourniquet pain. Less toxic LA must be used, such as lidocaine. Bupivacaine is contraindicated because of its toxicity. Unintentional deflation of the tourniquet or the presence of a vascular communication even with an intact, functioning tourniquet may result in severe systemic toxicity. The tourniquet should not be deflated until at least 30 minutes has elapsed from the time local anaesthetic (and adjuvants, if used) is injected into the isolated venous system.



Video 22: Bier´s block

14.4. Field anaesthesia

In a field block, anaesthetic is infiltrated to the subcutaneous area surrounding the operative field. The needle is inserted at two points, and anaesthetic solution is injected along four lines (walls) that surround the area to be anaesthetized The shape of the anaesthetic field can be modified by changing the number and direction of the anaesthetic walls.



Picture 13: Field anaesthesia, source https://www.aafp.org/

14.5. Conduction anaesthesia

Peripheral conduction anaesthesia consists of administering local anaesthesia directly to peripheral nerves or nerve plexuses. The knowledge of topographical anatomy is essential for success. Nerve structures can be identified by electric stimulation or by ultrasound.

Neuroaxial or central conduction anaesthesia consists of administering local anaesthesia to spinal nerve structures. According to the site of administration can be classified as

a) epidural
b) subarachnoid
c) combined

Absolute contraindications of neuroaxial anaesthesia are

- patient refusal
- infection
- known allergy
- bleeding disorders
- increased intracranial pressure
- hypovolaemia

Relative contraindications of neuroaxial anaesthesia are

- refusal of a surgeon with the method
- systemic neurovascular disease and multiple sclerosis

14.5.1. Conduction anaesthesia for the upper extremity

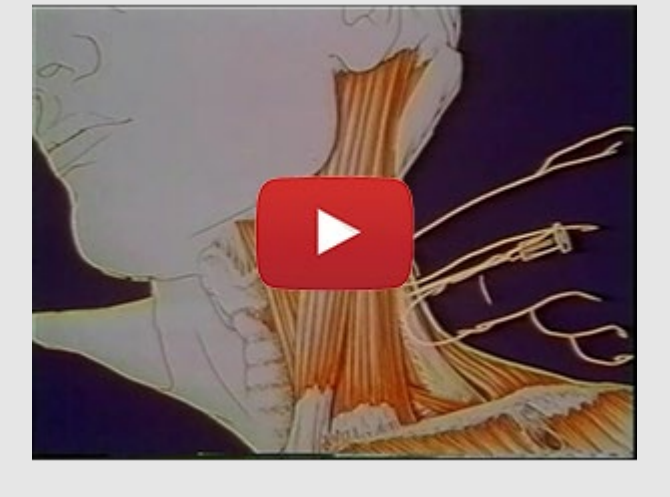
For relevant anatomy see *https://teachmeanatomy.info/upper-limb/nerves/brachial-plexus/*

Two methods are used for detection of nerves: (1) neurostimulation, (2) ultrasound. Electrical nerve stimulation in regional anaesthesia is a method of using a low-intensity (up to 5 mA) and short-duration (0.05 to 1 ms) electrical stimulus at 1- to 2-Hz repetition rate to obtain a defined response (muscle twitch or sensation). It is used to locate a peripheral nerve or nerve plexus with an insulated needle before injecting local anaesthetic in close proximity to the nerve to block nerve conduction for surgery or acute pain management. Stimulating current 0.3 mA means that the tip of the needle is in the close proximity of the nerve. Electrical nerve stimulation can be used for a single-injection technique, as well as for guidance during the insertion of continuous nerve block catheters.

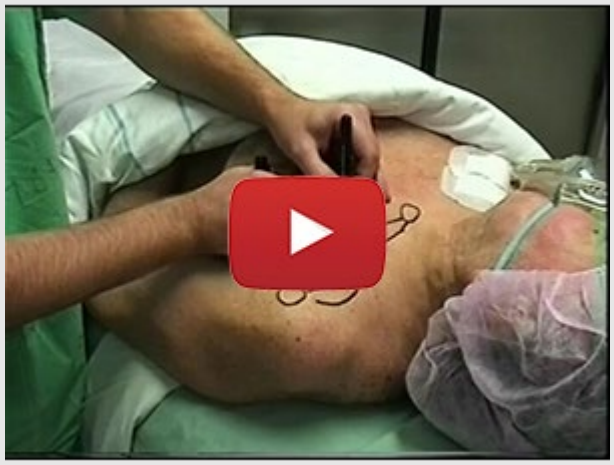
More recently, ultrasound guidance in combination with nerve stimulation ("dual monitoring") has become a common practice to guide needle placement and robust medicolegal documentation of nerve block procedures.

Video 23: Neurostimulator

Nerve structures for upper extremity are accessible from the origin at C5 to T1 spinal segments to periphery. Substantial number of blockades were described since the use of ultrasound. The most commonly used blockades are interscalenic, supra- and infraclavicular, axillar, midhumeral, wrist and single fingers. Some of them are presented on videos.



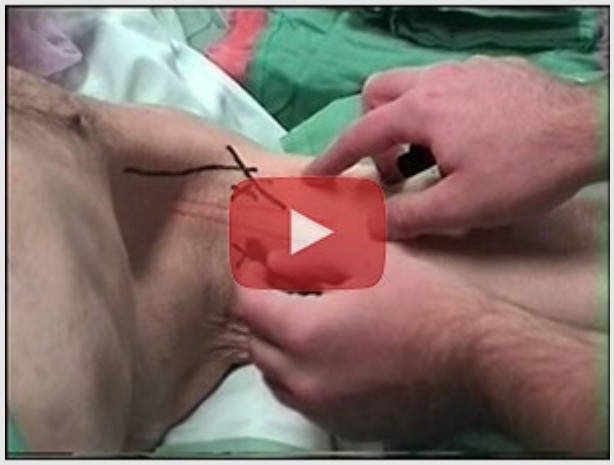
Video 24: Interscalene blockade



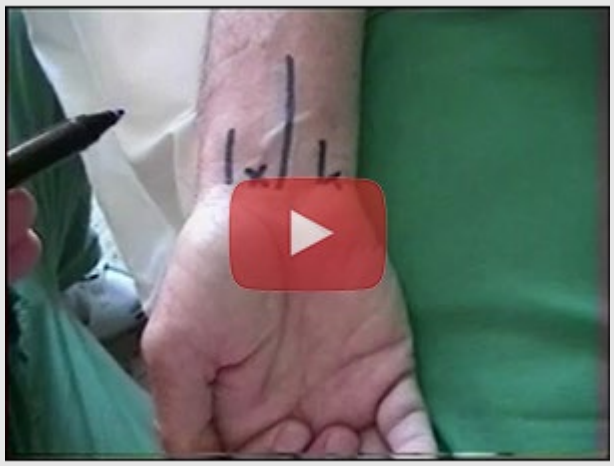
Video 25: Infraclavicular blockade

Video 26: Continuous infraclavicular blockade

Video 27: Ultrasound-guided brachial plexus blockade



Video 28: Axillar blockade



Video 29: Wrist block

14.5.2. Conduction anaesthesia for lower extremity

For relevant anatomy, see *https://teachmeanatomy.info/lower-limb/nerves/*

The 3 in 1 block

Orientation points are anterior superior iliac spine, pubic tubercle, inguinal ligament and the pulse of the femoral artery. The insertion point is 1 to 1.5 cm lateral from the femoral artery. Administration 30 ml of local anaesthesia is needed for the 3 in 1 blockade. Blocked nerves are femoral nerve, the lateral cutaneous femoral nerve and the obturator nerve.

Video 30: Femoral 3 in 1 blockade

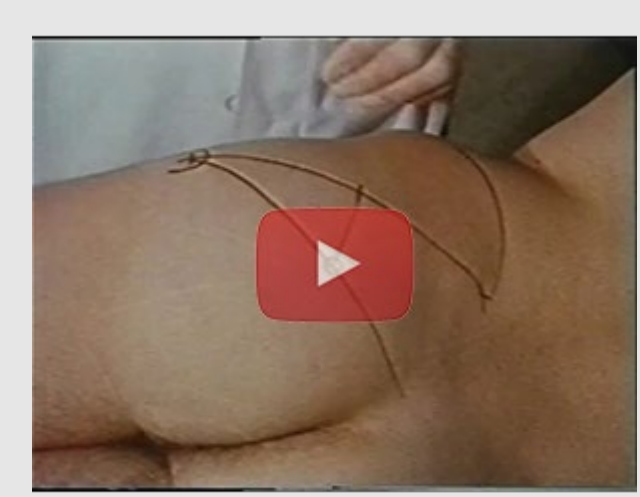
Fascia iliaca block

This technique is used for analgesia for femoral neck and joint surgery. See *https://www.youtube.com/watch?v=2rCiAbtLmZ8*

For anaesthesia of the calf and foot the sciatic nerve must also be blocked.

Sciatic nerve block

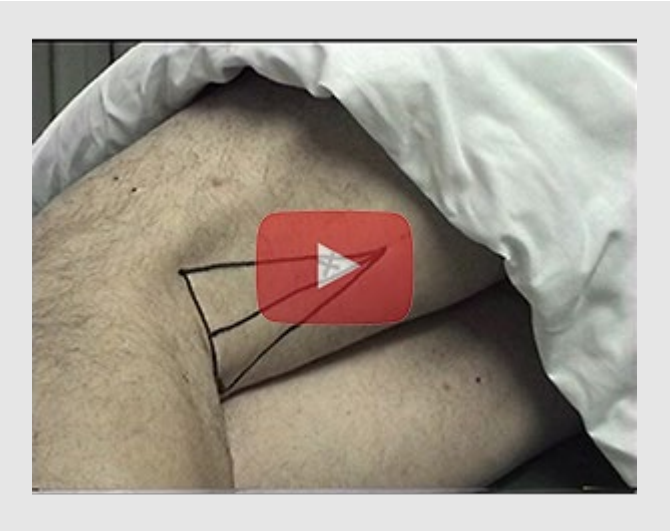
Several techniques are used. Usually 15-20ml of local anaesthetic is used.



Video 31: Ischiadic nerve blockade

Popliteal block

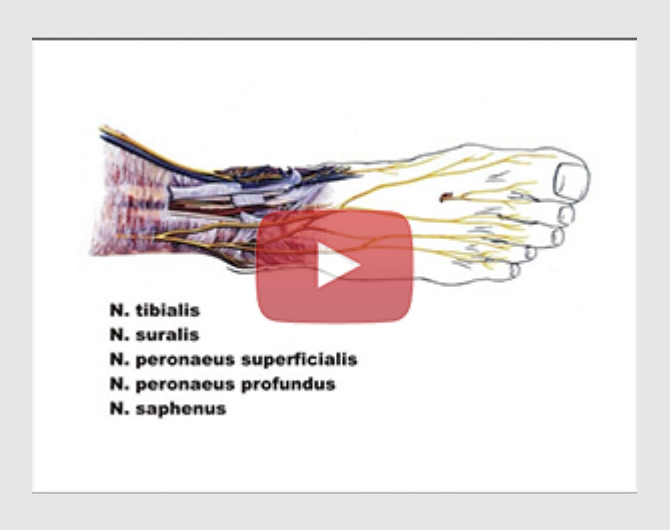
The sciatic nerve is blocked in the popliteal fossa before it divides into the tibial nerve and the common fibular nerve. About 30 ml of local anaesthetic is used.



Video 32: Popliteal sciatic block

Foot block

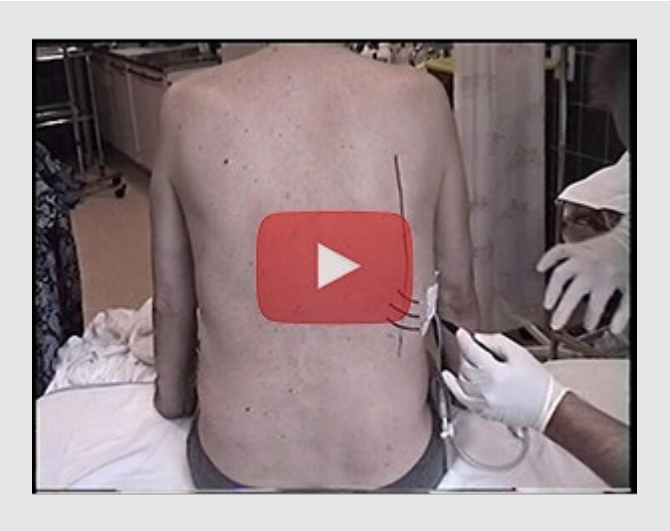
Five peripheral nerves (n. tibialis, n. peroneus profundus, n. peroneus superficialis, n. suralis, n. saphenus) innervate foot. All must be blocked for anaesthesia of foot. The disadvantage is the need to give multiple injections, which may be quite painful.



Video 33: Foot block

14.5.3. Conduction anaesthesia of the trunk

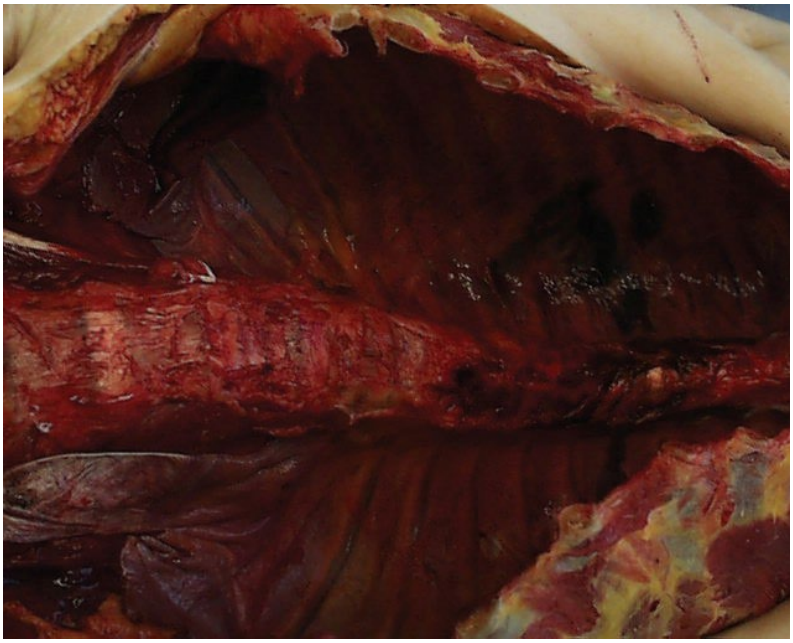
The most commonly used are intercostal blockades.



Video 34: Intercostal nerve blockade

Paravertebral blockade

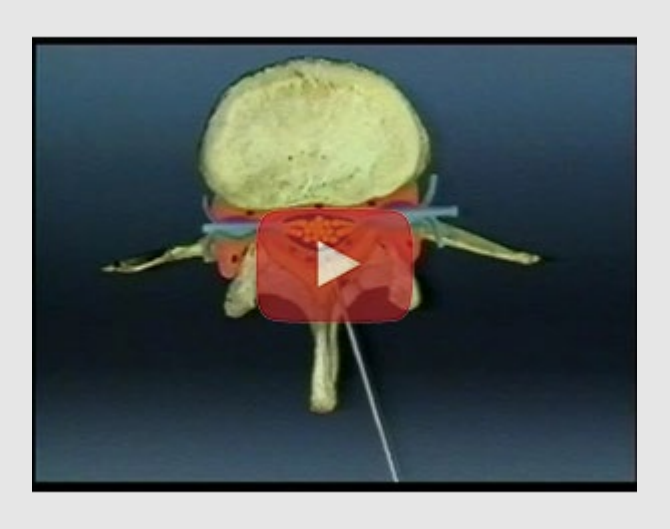
This technique is an alternative to thoracic epidural analgesia for one-sided thoracic surgeries. See https://youtu.be/A3_XutibfYU



Picture 14: Spread of dye after bilateral paravertebral administration in a cadaver

14.5.4. Neuroaxial anaesthesia

Neuroaxial anaesthesia is performed by placing a needle between vertebrae and injecting medication into the epidural space (for epidural anaesthesia) or the subarachnoid space (for subarachnoid or colloquially spinal anaesthesia). Despite the fact that these techniques are classified as regional anaesthesia, the extent of blockade is large and the haemodynamic effects are significant. Block of the sympathetic chain results in hypotension and sometimes bradycardia.



Video 35: Epidural anaesthesia

Main contraindications

Absolute contraindications

- Patient refusal
- Uncorrected hypovolemia
- Increased intracranial pressure
- Infection at the site of injection
- Allergy to local anaesthetic
- Coagulopathy
- Platelet count < 100,000
- Uncooperative patient
- Spine abnormalities and surgeries
- Sepsis
- Unstable spine due to trauma
- Positioning problems
- General anaesthesia (controversial)

Because of the rare occurrence of spinal hematoma associated with neuroaxial anaesthesia in patients taking anticoagulants, the American Society of Regional Anaesthesia and Pain Medicine (ASRA) have developed a consensus statement.

Drug	Catheter Insertion	Catheter Removal
NSAIDs	No contraindication; may increase frequency of spontaneous haemorrhagic complications when combined with warfarin, heparin, or thrombolytics	No contraindication
Ticlopidine (Ticlid)	Discontinue 14 days before epidural block	
Clopidogrel (Plavix)	Discontinue 7 days before epidural block	
GP IIb/IIIa inhibitors*	Discontinue 8-48 hours before epidural block	
Heparin	**SC/IV:** Do not heparinize until at least one hour after the epidural block **IV infusion:** Discontinue heparin infusion for 2-4 hours and check partial thromboplastin (PTT) prior to block	Wait 2-4 hours after last SC heparin dose or discontinuing IV heparin infusion; check PTT prior to removal

Warfarin (Coumadin)	Discontinue 4-5 days prior to neuroaxial manipulation; INR should be **normal** prior to block	May remove catheter when INR is ≤ 1.5 after discontinuing warfarin
Low molecular weight heparin (LMWH)†	Wait for 12-24 h after the last dose	Remove 2 hours prior to first LMWH dose, which is given 24 hours post surgery, provided that haemostasis is adequate
Thrombolytics‡	Data limited; follow fibrinogen levels; original contraindications called for avoidance of drugs for 10 days following puncture of noncompressible vessels	No definite recommendations; measure fibrinogen level to help decide between catheter removal or maintenance
Herbals	No definitive recommendations; watch for "3 Gs" (ginseng, garlic, ginkgo biloba) that are known to either have antiplatelet properties or enhance effect of antiplatelet drugs	

* GP IIb/IIIa inhibitors include tirofiban (Aggrastat), eptifibatide (Integrilin), abciximab (ReoPro)

† LMWHs include ardeparin (Normiflo), dalteparin (Fragmin), danaparoid (Orgaran), enoxaparin (Lovenox), and tinzaparin (Innohep)

‡ Thrombolytics include urokinase, streptokinase, endogenous t-PA formulations (alteplase and tenecteplase)

14.5.4.1. Epidural anaesthesia

Local anaesthesia is introduced to the epidural space, which is between the dural sac and spinal canal wall. The epidural space extends from hiatus canalis sacralis to the foramen magnum and contains venous plexuses and adipose tissue, which enables penetration of local anaesthesia and insertion of epidural catheters. Epidural blockade is performed under strict aseptic condition in the sitting position. The patient is instructed to arch forward like an angry cat to decrease lumbar lordosis. Another possible position is the lateral decubitus position with maximum flexion of the spine. The main problem is detection of the epidural space, because only indirect methods can be used. Recently, loss of resistance to air or preservative-free normal saline is the most common method; rarely the hanging drop technique is used. The special Tuohy needle and low-resistance syringes are used for a single-shot and special marked catheter for continuous method are used. For more detail *see video 35* or visit *https://emedicine.medscape.com/article/149646-overview#a7*.

Based on the concentration of local anaesthesia used both motor and sensory blocks are achieved, or with decreasing concentration only loss of pain sensation and sensation to warm and cold. This is useful in postoperative and obstetric analgesia as the patients can walk and rehabilitate without feeling pain. Large volumes of local anaesthesia are used (16 – 20 ml), so there is a risk of inadvertent intravascular (results in toxic reaction) or subarachnoid (results in total spinal blockade with hypotension, bradycardia and respiratory failure) injection. For this reason, the total dose is divided to test doses (4 – 5 ml) to detect any problem and the rest is inserted slowly in incremental doses. Onset of effect is 10 – 20 minutes. Patient must be carefully monitored until the anaesthesia wears off.

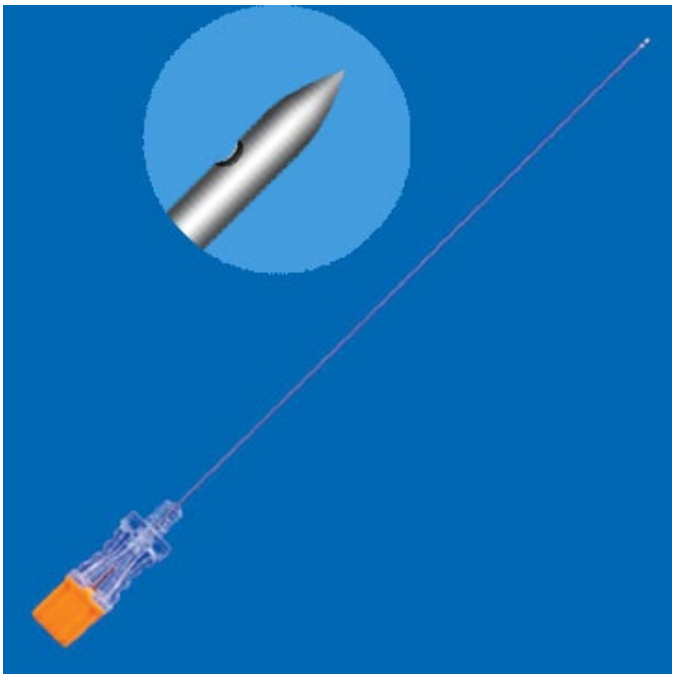
Caudal anaesthesia is special type of epidural anaesthesia. The local anaesthetic is applied epidurally via the hiatus canalis sacralis using a standard needle. Caudal epidural anaesthesia has many applications, in anaesthesia it is used mainly for perioperative analgesia in babies and children. In adults, the hiatus sacralis has many variations and its detection is difficult. If the caudal technique is used for chronic pain therapy in adults, ultrasonography is usually used.

14.5.4.2. Subarachnoidal (spinal) anaesthesia

Video 36: Subarachnoid (spinal) anaesthesia

Indications for spinal anaesthesia include lower abdominal, perineal, and lower limb surgery. The spinal cord terminates in adults at the level of vertebra L1, so puncture must be below this vertebral interspace. Local anaesthesia is administered directly into the spinal cerebrospinal fluid. Problems with catheters have been reported, so usually only the single-shot method is used. A thin needle is used, sometimes with a special pencil-point design to avoid post-dural puncture headache (PDPH – see further). The appearance of cerebrospinal fluid in the hub of the needle confirms correct placement of the needle in the subarachnoid space. Usually 2 – 4 ml of local anaesthesia are used. **Isobaric local anaesthesia** remains at the site of injection and spreads only by diffusion. **Hyperbaric local anaesthesia** is more heavy the cerebrospinal fluid and will move in the direction of the pull of gravity. The extent of anaesthesia can be manipulated by positioning the patient (*see video 36*). A very special type of subarachnoid anaesthesia is the saddle block. A small amount of hyperbaric local anaesthesia is used and the patient is kept sitting for 8 to 10 minute. The local anaesthesia moves to sacral segments only and after that local anaesthesia is bond to nerve structures and the patient can be moved without changing the extent of anaesthesia. The advantage is absence of hypotension. The indications for this type of anaesthesia are anorectal surgery, e.g. pilonidal sinus, haemorrhoidectomy, anal fissure, and anal fistula operations.

Postdural puncture headache (PDPH) is a complication of dural puncture. Risks factors include the female sex, young age, pregnancy, vaginal delivery, low body mass index, and being a non-smoker. Needle size, design, and the technique used also affect the risk. The reason is reduced cerebrospinal fluid pressure due to loss of cerebrospinal fluid in the epidural space through the dural puncture site. Decreased cerebrospinal fluid pressure creates a loss of the cushioning effect normally provided by intracranial fluid. The resulting traction placed on intracranial pain-sensitive structures elicits pain. A diagnostic hallmark of PDPH is a postural headache that worsens with sitting or standing, and improves with lying down. The headache may be accompanied by neck stiffness, tinnitus, hypoacusis, photophobia, and nausea.



Picture 15: Atraumatic spinal needle. Source image.made-in-china.com

Preventive measures are the use of thin needles (25 – 27 G) with atraumatic pencil-like tip. The patient must be requested not to sit or walk 12-24 after spinal anaesthesia puncture. Conservative therapies such as bed rest, hydration, and caffeine are commonly used as prophylaxis and treatment. If not effective, a blood patch is used. Autologous blood injected into the epidural space above the hole in dural sac is thought to seal the dural defect. Usually 10 – 20 ml of blood is used.

14.5.4.3. Comparison of subarachnoid and epidural anaesthesia

	Subarachnoid (SA)	**Epidural (EPI)**
Injection Location	lumbar only	anywhere
Duration of Block	brief	prolonged
Procedure Time	brief	longer
Quality of Motor Block	high	not as good as spinal
Disadvantages SA	increased risk of hypotension, dural puncture headache	
Advantages SA	easy detection, rapid onset, low volume of LA = toxic r. improbable	
Disadvantages EPI	difficult detection, long onset, risk of toxic reaction and total spina anaesthesia in unrecognised intravascular or SA puncture	
Advantages EPI	ability to produce segmental block, greater control over analgesia, possibility of long term analgesia	

14.5.5. Combined subarachnoid and epidural anaesthesia

Combination has advantages of both techniques: rapid onset, complete loss of sensations and motor blockade and the possibility to use epidural catheter. Usually two techniques are used.

Needle though needle technique includes use of separate epidural and spinal needles. Typically, the epidural space is located with a conventional epidural needle and technique, and then a long spinal needle is passed through the epidural needle until cerebrospinal fluid appears in the hub of the spinal needle. Drug is administered via the spinal needle into the subarachnoid space, the spinal needle is removed, and finally an epidural catheter is inserted into the epidural space. Separate needle technique

is performed by using two separate needles with the separate needle technique (SNT), with spinal block and epidural catheter placement at either a single or two different interspaces. If the epidural catheter is placed first, proper placement can be tested before administration of spinal medications, potentially decreasing the risk of accidental intravascular or intrathecal catheter migration. Placing the epidural catheter first may also reduce the risk of neural damage, which may occur when the catheter is inserted after subarachnoid block, because paraesthesia and other warning signs of improper needle placement may be absent after administration of spinal medications.

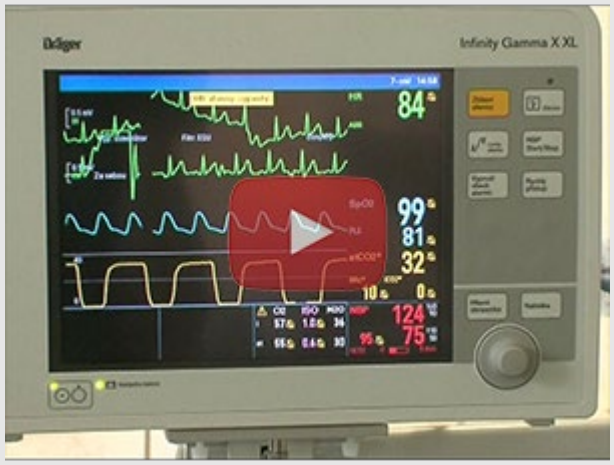
15. Monitoring and documentation in anaesthesia

J. Šturma, J. Málek

Anaesthesia documentation represents a detailed account of the patient's anaesthesia care during various phases of anaesthesia, including preanaesthesia assessment and evaluation, informed consent, anaesthesia services, and postanaesthesia care (source *https://www.aana.com/docs/default-source/practice-aana-com-web-documents-(all)/documenting-anesthesia-care.pdf?sfvrsn=ac0049b1*). The primary purpose of anaesthesia documentation is to capture accurate and comprehensive information to communicate a patient's anaesthetic experience. The patient's chart is a legal document. The formal record of anaesthesia care is also referenced for reimbursement, quality improvement, and review by external organizations. Documentation of anaesthesia care is transitioning from the handwritten record to an automated, electronic medical record (EMR) to provide a legible record, limit variability in the documentation of information, and provide greater access to information to optimize patient outcomes. Anaesthesia Care Documentation includes the following: *https://www.aana.com/docs/default-source/practice-aana-com-web-documents-(all)/documenting-anesthesia-care.pdf?sfvrsn=ac0049b1*:

- Name and facility identification number of the patient
- Name of all anaesthesia professionals involved in the patient's care
- Immediate preanaesthesia assessment and evaluation (e.g., change in health status, re-evaluation of nothing-per-os status)
- Anaesthesia safety checks (e.g., check of equipment, drugs supply, gas supply)
- Monitoring of the patient (e.g., oxygenation, ventilation, circulation, body temperature, skeletal muscle relaxation)
- Airway management techniques
- Name, dosage, route, and time of administration of drugs and anaesthetics
- Technique(s) used and patient positioning (e.g., document who positioned the patient, type of position used)
- Name and amounts of IV fluids (e.g., when applicable blood and blood products)
- Intravenous/intravascular lines inserted (e.g., techniques for insertion, location)
- Any complications, adverse reactions, or problems during anaesthesia
- Status of the patient at the conclusion of anaesthesia
- Documentation in a timely and legible manner

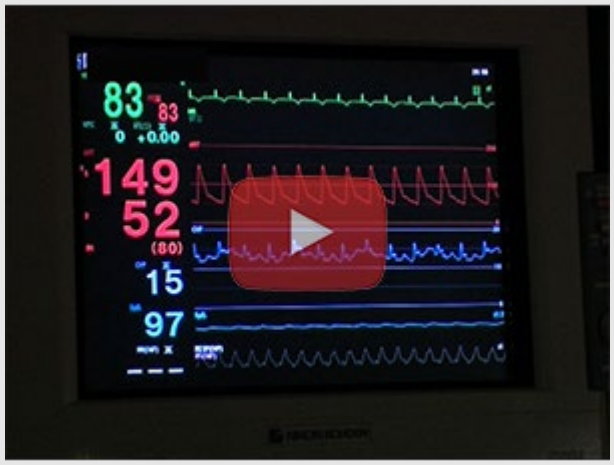
The anaesthetic team in the Czech Republic consists of an anaesthetist and a specialised anaesthetic nurse, who must be present during anaesthesia. Basic monitoring consists of physical assessment, electrocardiogram, non-invasive blood pressure pulse oximeter and in case of mechanical ventilation or use of special aids for airways also end-tidal carbon dioxide. It is recommended to monitor temperature, invasive blood pressure, urine output, neuromuscular blockade monitor, depth of anaesthesia monitor and others according to the type of the surgery.



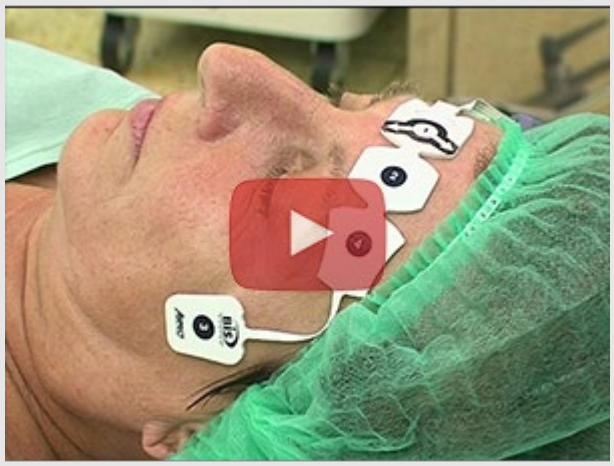
Video 37: Vital function monitor

Video 38: Monitoring of muscle relaxation (TOF)

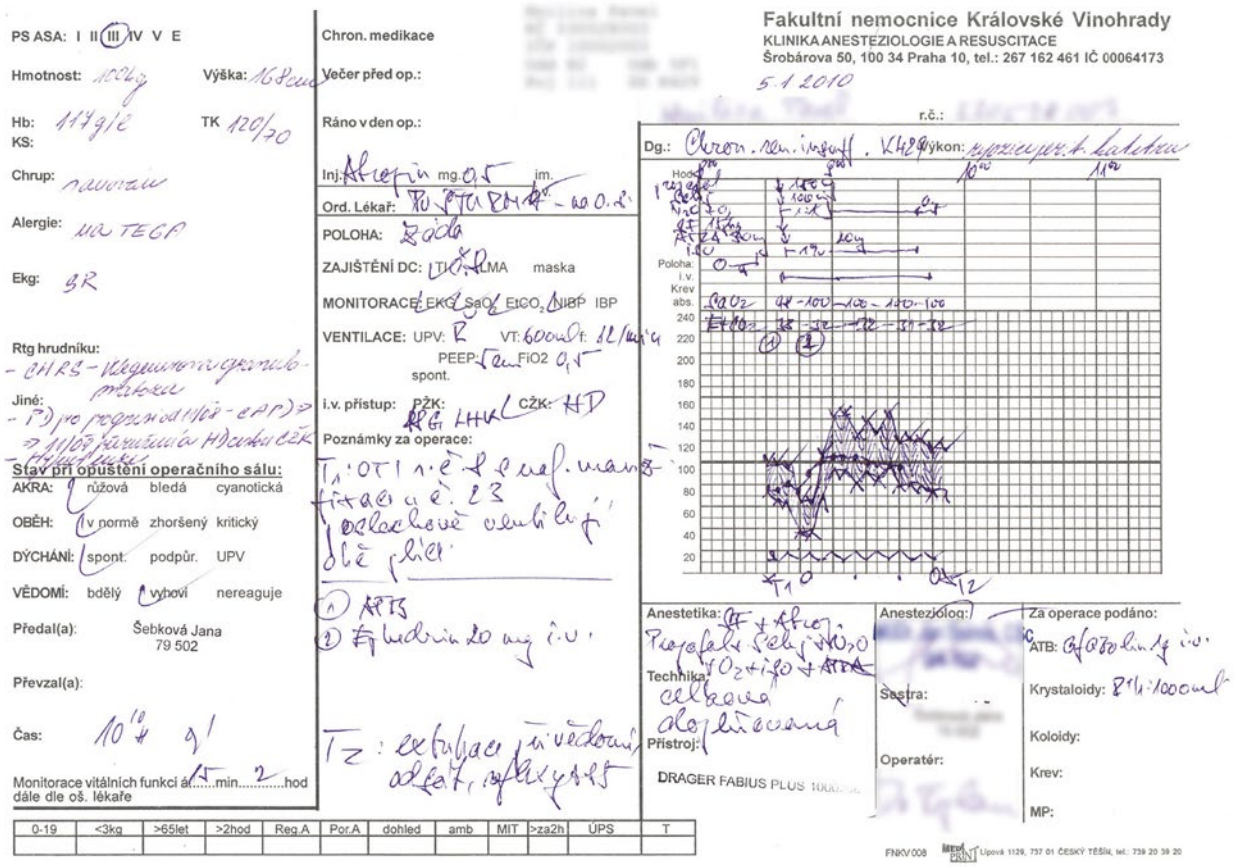
Video 39: Analysis of inspired and expired mixture



Video 40: Haemodynamic monitoring



Video 41: Depth of anaesthesia monitoring



Picture 16: Atraumatic spinal needle. Source [image.made-in-china.com]

16. Postoperative pain therapy

J. Málek and working group ČSARIM

Relief of pain and suffering, particularly when caused by medical treatment, should be a priority for all medical professionals. Postoperative pain is a typical example of acute pain. All surgical procedures are associated with a certain level of postoperative pain. Fear of postoperative pain is one of the greatest concerns of patients undergoing surgery. A number of studies conducted in countries with a highly-developed health care system demonstrated that even in the first decade of the 21st century, postoperative pain was not managed well in one-third to one-half of patients. Despite recent progress, there is still potential for further improvement of analgesic therapy. We would like to emphasize that untreated postoperative pain is a highly preventable issue, which can be in majority of cases easily solved. Nowadays, there is an abundance of medications, dosage forms, acute pain management techniques, and ample data on postoperative pain treatment. The main challenge is to put this knowledge into everyday practice. Possible reasons for inadequate postoperative pain management include limited financial resources, lack of time and personnel, but also reluctance to address this issue, organizational aspects of the health care facility, and lack of simple and clear guidelines for the treatment of postoperative pain. Providing such easy-to-follow recommendations is one of the objectives of this chapter. For more information see *https://www.wfsahq.org*. The availability of postoperative analgesia to anyone who needs it requires high-quality postoperative pain management, as well as accepting and understanding the fact that good analgesia is not only necessary, but also a fundamental right of every patient suffering from pain and a basic duty of any health care facility that treats these patients. In

addition to this ethical point of view, there are other medical and economical aspects associated with a frequently reported reduced morbidity, more rapid recovery and discharge of the patient from hospital.

Pathophysiological response to tissue damage and stress is characterized by pulmonary, cardiovascular, gastrointestinal and urinary dysfunction, impaired muscle metabolism and function, neuroendocrine, immune and metabolic changes. Most of these effects may be mitigated by analgesic therapeutic procedures.

Changes in respiratory functions

Surgical procedures in the epigastrium and chest reduce vital capacity, functional residual capacity, tidal volume, residual volume, and forced expiratory volume in one second. As a reflex response, abdominal muscle tone increases and diaphragm function is limited. This results in reduced lung compliance, muscle stiffness and the inability to breathe deeply and expectorate. In more advanced cases, this is followed by hypoxemia, hypercapnia, retention of secretions, atelectasis, and pneumonia. Increased muscle tone contributes to increased oxygen consumption and lactate production. Dilated bowel due to postoperative ileus and overly tight bandage may further restrict ventilation. The patient is afraid to breathe deeply and expectorate out of fear that doing so might provoke pain.

Cardiovascular changes

Sympathetic stimulation causes tachycardia, increase in stroke volume, cardiac work, and myocardial oxygen consumption. In susceptible individuals, this leads to an increased risk of ischemia, or even myocardial infarction. The patient restricts physical activity out of fear of pain, which is followed by venous stasis, subsequent platelet aggregation, possible venous thrombosis and venous thromboembolism.

Gastrointestinal and urinary changes

Typical changes associated with postoperative pain include nausea, vomiting, intestinal hypomotility or even paralysis and hypomotility of the ureters and bladder, which can result in problems with urination. Opioid analgesia may also contribute to these symptoms. However, this must not be an argument against properly performed analgesia.

Neuroendocrine and metabolic changes

Suprasegmentally reflex responses increase sympathetic tone, stimulate the hypothalamus, increase the production of catecholamines and catabolic hormones (cortisone, adrenocorticotropic hormone - ACTH, antidiuretic hormone - ADH, growth hormone, glucagon, aldosterone, renin, angiotensin II) and reduce the secretion of anabolic hormones (insulin, testosterone). This leads to sodium and water retention, increase in blood glucose, free fatty acids, ketone bodies, and lactate. Metabolism and oxygen consumption increase and metabolic substrates are mobilized from stores. If this process continues, a catabolic state and negative nitrogen balance result. Acute pain may produce fear and anxiety, followed by anger, resentment, and negative relationship with physicians and nurses. Pain induces or exacerbates insomnia, which further hinders mental and physical recovery.

The crucial point of successful pain therapy is pain measurement, pain treatment and re-evaluation of effectivity and side effects. The most widely used method of numerical assessment of pain intensity is the visual analogue scale (VAS), where patients specify the intensity of pain by indicating a point along a continuous horizontal line, with numbers from 0 to 10 on the other side. In Numeric Rating Scale (NRS) the patient uses numbers to quantify the intensity of pain – 0 means no pain and 10 corresponds to the worst pain imaginable. In the elderly, NRS is superior to VAS, as these patients understand the numerical scale better. Pain intensity should not exceed VAS/NRS 3, as VAS 4 needs to be treated. Pain assessment is also performed with respect to the movement of the patient –VAS score often increases with movement, depending on the range of motion. VAS is also used to evaluate the efficacy of treatment (e.g. 5/2 means 5 before treatment and 2 after treatment; or for example 7/4/2). An alternative to a numerical scale is the expanding colour circle sector or Faces Pain Scale, which shows facial expressions ranging from the state of well-being to worst pain possible. This scale is preferred in young children, who are not able to accurately describe or quantify the intensity of pain. Acute pain should be routinely monitored in intensive care as well. In non-cooperative, critically ill patients, Behavioural Pain

Scale or Critical-Care Pain Observation Tool are recommended. Monitoring pain by observing changes in vital signs is the last possibility.

16.1. Therapy

16.1.1. Non-pharmacological methods

These methods (psychologic intervention, hypnosis, cooling, immobilisation, massage, acupuncture and transcutaneous electrical nerve stimulation (TENS) have little contraindications and side effects, but little efficacy. There are used as an adjuvant of pharmacotherapy.

16.1.2. Systemic pharmacotherapy

Oral administration is the most commonly used route of administration in medicine. Its main advantages are non-invasiveness, ease of use and self-administration. Many analgesics are only available in oral form. In postoperative analgesia, its main drawback is that the patient must be able to swallow and absorb the medication. Another problem is the slow onset of action and more difficult dose titration, which in practice may lead to underdosing rather than over-dosing. **Rectal administration** has similar problems, but is very much popular among patients. **Intramuscular injection** is the most common route of administration for analgesics in the postoperative period. In most patients, it is possible to achieve satisfactory analgesia despite major differences in absorption from the site of administration and despite the fact that administration may be unpleasant and painful. It is important to remember that this route of administration is contraindicated in postoperative blood coagulation disorders. **Subcutaneous administration** instead of intramuscular is recommended for opioids. Compared to the previously mentioned methods, **intravenous administration** has the advantage of a faster onset of action, efficacy at lower doses and easier dose titration. On the downside, venous access must be secured, a higher risk of wrong dose has been reported in literature and there is a greater risk of side effects.

Patient-controlled analgesia (PCA) is a method, which allows patients to administer analgesics (opioids) themselves, most commonly in the vein or epidural space, although other routes of administration have been reported as well (subcutaneous, transdermal iontophoretic, etc.). Basic parameters, which are set by the physician in advance and cannot be changed by the patient, include bolus dose administered when the patient pushes the button, lock-out interval – time during which the machine will not administer a further dose despite any further demands made by the patient, and usually the maximum dose to be given per 4 or 6 hours. The patient should be given a loading dose of the analgesia to effectively relieve pain before starting PCA. PCA requires patient cooperation (it may be used in children over 6 years of age) and physical ability to operate the device. 69

Video 42: Patient-controlled analgesia

Regional administration of analgesics

The advantage of regional administration of analgesics is that it largely eliminates their systemic effects (depending on the absorption into the circulation). The techniques range from wound infiltration before closure to various blockades of the individual nerves (intercostal nerve blockade, lower limb nerve blockades, paravertebral blockade), neural plexuses (brachial and cervical plexus blockades), and central nerve blockades (epidural and spinal). In general, regional administration provides better analgesia than systemic administration. The duration of action depends on whether it is a single-injection or catheter technique. A disadvantage is that they are more technically challenging and more invasive.

Combination of systemic and regional analgesia

Analgesic effects of regional analgesia are potentiated by systemic non-opioid analgesics. The effect of the local anaesthetic is potentiated and pain is suppressed in areas that the local anaesthetic does not reach.

Multimodal analgesia

Multimodal analgesia combines analgesic drugs from different classes and employs analgesic techniques that target different mechanisms of pain. It is recommended in the treatment of pain because its synergistic effect maximizes pain relief at lower analgesic doses, thereby reducing the risk of adverse drug effects. Reasonable combinations are only using drugs from different groups e.g. non-opioid analgesics (analgesics-antipyretics), non-steroidal anti-inflammatory drugs (NSAID) and opioids. Drugs from the same group should not be combined. For example, combining ibuprofen with diclofenac or combing tramadol with morphine is not recommended.

16.2. Drugs

16.2.1. Non-opioid analgesics

Paracetamol (acetaminophen) is an analgesic and antipyretic agent that lacks anti-inflammatory properties, has good gastrointestinal tolerability and is suitable for both paediatric and adult patients. It has minimal side effects. One of its advantages is that it does not significantly affect blood clotting, not even in patients receiving oral anticoagulants (thus it may be used in haemophiliacs), and it does not affect blood glucose levels. In postoperative analgesia, paracetamol is used for mild to moderate pain and in combination with other medications (opioids in particular) to treat severe pain.

It is available in a variety of forms (oral, rectal, intravenous). The intravenous form is designed particularly for postoperative analgesia. Intravenous administration has the advantage of a rapid onset of action. If intravenous paracetamol is administered before the end of surgery, analgesia is already effective after recovery from anaesthesia. Adults and adolescents receive 0.5–1 grams of per-oral or per-rectal of paracetamol as needed in intervals of at least 4 hours, to a maximum daily dose of 4 grams, the maximum single dose is 1 gram. In long-term treatment (over 10 days), the dose per day should not exceed 2.5 grams. Paracetamol can be administered during pregnancy and lactation. In children, the total dose per day should not exceed 50 mg/kg of body weight; it is divided into 3–4 individual doses. The dose for single administration is 10–15 mg/kg of body weight. Paracetamol solution is administered as a 15-minute intravenous infusion. The minimum interval between each administration must be at least 4 hours. In adults and adolescents weighing more than 50 kg, 1 gram of paracetamol is administered up to four times a day and the maximum dose per day is 4 grams. In children weighing more than 33 kg (approximately from 11 years of age) or in adults and adolescents weighing less than 50 kg, the single dose is 15 mg/kg, the maximum dose per day is 60 mg/kg (not exceeding 3 g). In children weighing more than 10 kg (approx. from 1 year of age) and less than 33 kg, the single dose is 15 mg/kg; the maximum dose per day is 60 mg/kg (not exceeding 2 g). In term newborn infants, infants, toddlers and children weighing less than 10 kg (approx. until 1 year of age), the single dose is 7.5 mg/kg and the maximum daily dose must not exceed 30 mg/kg of body weight. Overdose by even relatively low doses of paracetamol can cause serious liver damage and may sometimes result in acute renal tubular necrosis. Nausea, vomiting, lethargy, and sweating may occur within 24 hours.

Metamizol (dipyrone) is an analgesic and antipyretic agent with spasmolytic properties. Although it is also available in oral form, in postoperative analgesia it is primarily given as an infusion. In children aged 3 to 11 months, only intramuscular injections can be used. Metamizol must not be used during the third trimester of pregnancy and during lactation (lactation is to be avoided during administration and for 48 hours after the administration of metamizol). Besides allergy, contraindications include hematopoietic disorders, allergic asthma induced by nonsteroidal anti-inflammatory drugs, hepatic porphyria, and glucose-6-phosphate dehydrogenase deficiency. Caution is advised in patients with other forms of asthma, chronic urticaria, alcohol intolerance, in the elderly, and in case of hypotension and hypovolemia. The most feared, albeit rare adverse effect is a severe, life-threatening anaphylactic/anaphylactoid reaction, which occurs most frequently in the form of a skin reaction. Allergic reactions may develop even several hours after administration. Furthermore, isolated hypotension may occur. Rare cases of leukopenia have been noted. Dosage in adults: the single dose is 8–16 milligrams per kilogram of body weight for oral administration, 6–16 milligrams per kilogram of body weight for parenteral administration and the maximum daily dose is 5 grams, in children usually 10–15 mg/kg up to four times a day. In children aged 3-11 months, only intramuscular injection may be used. Rapid infusion administration causes hypotension, which is more pronounced if hypovolemia is present. The dose of should be given in a 500 ml infusion.

16.2.2. Nonsteroidal anti-inflammatory drugs (NSAIDs)

Most of the presumed effect of NSAIDs is caused by the inhibition of cyclooxygenase (COX), which catalyses the formation of prostaglandins from arachidonic acid. Cyclooxygenase is present in the human body in two forms: COX-1 and COX-2. While COX-1 is considered a constitutive enzyme responsible for the synthesis of prostaglandins, which play an important role in the homeostasis of the human body (gastrointestinal mucosal blood flow, gastric mucosa protection, renal perfusion, platelet aggregation, protection of the endothelium), COX-2 is mainly induced during inflammation and participates in the production of proinflammatory cytokines and pain mediators.

The strict differentiation of the two isoenzymes as COX-1 – beneficial and COX-2 – harmful has been recently challenged and it seems that the situation is much more complex than originally thought. Nevertheless, based on the assumed effect on platelet function, NSAIDs can be divided into 3 groups, in which the risk of bleeding complications decreases with increasing selectivity of COX-2 inhibition,

which is particularly important in the immediate perioperative period. Due to their adverse effects, NSAIDs are generally not recommended in patients over 65 years of age. This applies in particular to long-term administration (more than 3 weeks). In acute postoperative pain management, short-term administration of NSAIDs (up to 1 week) is possible, or NSAIDs can be used in combination with proton pump inhibitors.

16.2.2.1. Non-selective COX inhibitors

Diclofenac has excellent analgesic properties and is particularly effective for pain with an inflammatory component and pain after tooth extraction. Its adverse effects are similar to other NSAIDs. Diclofenac is contraindicated in pregnancy and during lactation. It is available in oral and injectable forms for IM administration or infusion in adults only. For oral administration the initial dose in adults is 100–150 mg per day; 75-100 mg is usually sufficient in less severe conditions and in children over the age of 12. The total daily dose is divided into 2–3 single doses and should not exceed 150 mg/24h in adults. Children weighing more than 20 kg (the only indication is juvenile chronic arthritis) are administered 1–3 mg/kg of body weight per day, divided into 2–3 doses. Adults – intramuscular (IM) injection: deep intramuscular administration of 75 mg of diclofenac into the upper outer quadrant of the gluteal muscle, 150 mg in case of severe pain. Adults – intravenous (IV) infusion: diclofenac must not be given as an IV bolus. The total dose per day should not exceed 150 mg of diclofenac. Infusions should not be administered for more than two days. The combination of diclofenac with a centrally acting muscle relaxant called orphenadrine should produce, in addition to analgesic and anti-inflammatory effects, a spasmolytic effect on skeletal muscles. This is beneficial after orthopaedic surgical procedures and after any procedure causing predominantly somatic pain, as it suppresses reflex muscle spasm, which would otherwise exacerbate the pain.

Ibuprofen is used to treat pain in patients over 3 months of age (weight > 6 kg). Its side effects are typical for the whole group of NSAIDs, but are considered mild. Ibuprofen is contraindicated in the third trimester of pregnancy and is not recommended in the first and second trimesters either. However, it can be used during lactation. Ibuprofen is also registered in injectable form, but for adults only. The total daily dose for adults should not exceed 2,400 mg, divided into 3–6 doses. The total dose per day for children under the age of 12 is 20–35 mg/kg of body weight, divided into 3–4 doses.

Ketoprofen is a nonsteroidal anti-inflammatory drug used to treat pain in patients over the age of 15. When administered orally, ketoprofen has high bioavailability (up to 90% in comparison with IV administration). Parenteral treatment should not last for more than 48 hours, the dose is 200 mg once or twice a day injected deep into the muscle or given in an infusion over 30 to 60 minutes. Contraindications include severe kidney or liver disease; other contraindications and adverse effects are common with other NSAIDs.

Naproxen is only available in oral form for the treatment of acute pain in patients over the age of 12. The dose of 550 mg up to three times a day effectively treats mild to moderate postoperative pain. In combination with a weak opioid, it may be used to treat severe pain. Naproxen is not suitable in pregnancy, but may be used during lactation. Adverse effects are identical to those of other drugs in this group. Piroxicam is available in injectable (only IM) and oral form. In comparison to other drugs in this group, it seems to have higher risks (adverse effects on the gastrointestinal tract and a higher risk of skin reactions, including life-threatening bullous reaction). The advantage is once a day dosing.

Piroxicam can be used to treat acute postoperative pain in patients over the age of 14. Contraindications include pregnancy and lactation. A dose of 40 mg of piroxicam is administered once a day to treat severe pain, 20 mg to treat mild pain. The duration of the treatment should be individualized, usually 1 or 2 days are recommended. In 2011, a warning was issued that piroxicam may in rare cases cause Stevens-Johnson syndrome and toxic epidermal necrolysis.

16.2.2.2. Selective COX-2 inhibitors – coxibs

Parecoxib is the only medication in this group, which is specifically designed for short-term postoperative pain management in patients over the age of 18. The adverse effects and contraindications are similar to other NSAIDs. Parecoxib is contra-indicated for the treatment of pain after coronary artery bypass surgery, in the third trimester of pregnancy, and during lactation. Other restrictions are similar

to those of other NSAIDs. Its availability in an injectable form is beneficial for the perioperative period, even if there are concerns about impaired platelet function (spinal block, ENT procedures, endoscopic urological procedures). Parecoxib is administered intravenously or intramuscularly in a dose of 40 mg with a maximum daily dose of 80 mg.

Celecoxib is not registered for the treatment of postoperative pain, yet it is sometimes used due to its reduced effect on bleeding (e.g. after ENT procedures and endoscopic urological procedures). It is contraindicated in pregnancy and during lactation. Celecoxib is only available in oral form; the dose for adults is 200 mg per day, in 1–2 doses.

16.2.2.3. Preferential COX-2 inhibitors

Meloxicam is available in injectable (only IM) and oral form. The approved indications do not include acute postoperative pain; however, especially the oral form is sometimes used in adults. Adverse effects are common with other NSAIDs. Contraindications include pregnancy and lactation. The advantage of meloxicam is its long duration of action. The dose is 15 mg once a day. In 2011, a warning was issued that meloxicam may in rare cases cause Stevens-Johnson syndrome and toxic epidermal necrolysis.

Nimesulide is registered for the treatment of acute pain in patients over the age of 12. Due to the risk of hepatotoxicity, treatment should be restricted to a minimum. Contraindications include impaired liver function and severe renal insufficiency. Nimesulide is used as a second-line therapy for chronic pain. It is only available in oral form; the dose is 100 mg twice a day.

16.2.3. Opioid analgesics

Opioids are still cornerstones of systemic analgesia. Weak opioids have a ceiling effect, i.e. increasing the drug dose does not increase their effectiveness. Strong opioids do not show this effect. The maximum dose is limited by their adverse effects (respiratory depression). Opioid analgesics are generally not able to completely relieve severe pain, but by affecting mood, they suppress the discomfort associated with pain. Because of these effects on mood, opioids may be abused for recreational purposes with all the related adverse effects. Therefore, special regulations apply to most opioid analgesics.

Adverse effects of opioid analgesics include respiratory depression (at higher doses), nausea and vomiting, decreased intestinal motility and gastric emptying, increased sphincter tone, sphincter of Oddi spasm with bile stasis, decreased secretion of pancreatic juice and bile, urinary retention, sedation, in rare cases euphoria or dysphoria. The most feared complication – **respiratory depression – first manifests as a decrease in the respiratory rate; a decline in SpO2 will only develop later, especially if the patient receives oxygen after surgery**. Sedation and disorders of consciousness are late symptoms. When administering opioid analgesics, an antidote (naloxone) must always be available (see below). A lesser-known adverse effect is muscle rigidity. When administering opioid analgesics (intraspinally in particular), itching may appear. Opioids may cause a drop in the blood pressure and bradycardia due to vagal nerve stimulation. Furthermore, the cardiovascular response to stress is inhibited, which may result in orthostatic collapse in some patients.

16.2.3.1. Weak opioid analgesics

Tramadol has several unique features. It acts by binding to opioid receptors, but also by inhibiting the reuptake of serotonin and noradrenalin. Tramadol is metabolized to O-desmethyltramadol, which is a more potent opioid. It is available in many forms for parenteral, oral, and rectal administration. Tramadol alone is only effective for mild pain, but in combination with NSAIDs or non-opioid analgesics it has more potent analgesic effects. On the downside, nausea, vomiting and dizziness frequently develop. Tramadol may increase the effect of selective serotonin reuptake inhibitors – SSRIs (risk of life-threatening serotonin syndrome), tricyclic antidepressants, antipsychotics, and other drugs that lower the seizure threshold, and may provoke seizures as well.

Tramadol should not be administered together with monoamine oxidase inhibitors. Concurrent administration of a 5-HT3 receptor antagonist (such as ondansetron) reduces the effect of tramadol. Patients over 1 year of age are given 1–2 mg/kg every 4–6 hours. The daily dose in adolescents and adults should not exceed 400 mg.

Strong opioids

Morphine is a prototypical strong opioid, which remains the gold standard against which all drugs that have strong analgesic effects are compared. Everything that has been stated in the section on general characteristics of opioid analgesics applies to morphine as well. Various routes of administration are available (oral, intramuscular, subcutaneous, intravenous, epidural, spinal, and intra-articular). In postoperative pain management, parenteral administration is preferred. Morphine is metabolized to morphine-6-glucuronide, an active metabolite, which is excreted by the kidneys. Therefore, renal insufficiency may lead to morphine accumulation and prolonged effect. For systemic analgesia, the dose is 0.1 mg/kg, the duration of action is about 4 hours.

Piritramide exhibits similar effects to morphine, but has a longer duration of action (about 6 hours). Its elimination is not dependent on renal function. For intramuscular or subcutaneous administration, the recommended single dose is 15–30 mg in adults and 0.05–0.2 mg/kg in children. For intravenous administration (only when a particularly rapid onset of action is required), the recommended dose in adults is 7.5–22.5 mg administered slowly (10 mg per minute). A single dose for children is 0.05–0.1 mg/kg of body weight. If the effect is not sufficient, intramuscular, subcutaneous or intravenous administration may be repeated every 6–8 hours. The dose should be reduced in the elderly and in patients with impaired liver function or in poor physical condition.

Pethidine (meperidine) in addition to its opioid effect, pethidine also has the characteristics of a weak local anaesthetic and alpha-2 agonist. Pethidine has many side effects, for which it is not suitable in postoperative pain management. Its effect is short-term at first, but it gradually accumulates in the body. Pethidine is metabolized to norpethidine, which is neurotoxic and can provoke seizures. Intramuscular, subcutaneous and intravenous routes of administration are available. Pethidine should not be used during lactation for an extended period of time, as it may cause neurobehavioral changes in infants. The dose is approx. 1 mg/kg every 4 hours, to a maximum dose per day of 300 mg in adults.

Fentanyl, sufentanil, alfentanil, remifentanil are short-acting opioids. In systemic analgesia, are administered by titration or continuously with the possibility of adding a bolus, mostly IV, until the desired effect is achieved. Their use is limited to operating rooms, recovery rooms and intensive care units. Non-traditional ways of fentanyl administration, which were previously used for postoperative analgesia, are currently unavailable.

16.2.4. Locoregional methods of analgesia

As has been shown, uncontrolled postoperative pain adversely affects respiration, circulation, gastrointestinal functions, metabolism, wound healing, etc. This is particularly evident in patients undergoing major abdominal and thoracic procedures, as well as extensive orthopaedic surgery. Postoperative pain management with locoregional anaesthesia techniques is a highly effective solution. According to many studies, these methods are more effective (lower pain score) and at the same time reduce the incidence of adverse effects associated with systemic analgesics. Pain management using locoregional anaesthesia techniques can also influence the final outcome of the surgical procedure (e.g. range of motion in the joint after surgery). Inadequate postoperative analgesia probably contributes to the transition of acute post-operative pain to chronic pain. In this context, breast surgery, thoracotomy, cholecystectomy, inguinal hernia surgery, and amputation surgery are often mentioned. In comparison with systemic analgesia, locoregional techniques provide additional benefits. With proper timing and execution, these methods may reduce the risk of pain chronification. Techniques used are the same as described in *chapter 14*.

16.3. Recommendations for various types of surgical procedures in adults

16.3.1. Surgical procedures with anticipated mild postoperative pain

In pre-operative period, long-acting analgesic (opioid, coxib), which will extend to postoperative period, can be used. During surgery, infiltration of the wound with LA can be used. In postoperative period, NSAID and non-opioid analgesics (metamizol or paracetamol) are preferred. In case of necessity, weak opioid can be used; in case of insufficient effect, a single dose of strong opioid can be given.

16.3.2. Surgical procedures with anticipated moderate postoperative pain

In pre- and peri-operative period, the same methods are used. In postoperative period, routine combination of week opioids and non-opioids should be used, sometimes combined with NSAID. In case of insufficient effect, strong opioid instead of week opioid in regular intervals should be used.

16.3.3. Surgical procedures with anticipated severe postoperative pain

This group includes surgical procedures, which require the use of high doses of opioid analgesics to treat acute postoperative pain, or systemic analgesia alone is no longer sufficient and it is necessary to combine systemic administration of analgesics with continuous locoregional analgesia techniques. Theoretically, even in severe postoperative pain, it is possible to use high doses of strong opioid analgesics that do not have a ceiling effect. However, this would result in a significant increase in complications, the most serious concern being ventilation (sedation, hypoventilation, atelectasis, hypercapnia, hypoxemia). Therefore, a combination with continuous locoregional analgesia techniques is preferable. Locoregional anaesthesia or analgesia only affects the part of the body, which is the source of the pain, and allows us to significantly reduce the amount of systemically administered analgesics. In case of systemic analgesia, PCA is a good choice.

16.4. Postoperative pain management in the elderly

Elderly patients do not form a homogeneous group, as interindividual differences increase with age. The biological age is more important than the chronological age. Aging brings about both physiological changes (loss of neurons, thinning of the myelin sheath, changes in the secretion of neurotransmitters and changes at receptor level, changes in the volume of distribution, hyperproteinaemia, decreased performance of parenchymal organs) and pathophysiological changes (dementia, complicating diseases). Comorbidity and polypharmacy are common in old age. An increased sensitivity to drugs affecting the CNS has been reported in the elderly and postoperative delirium is more common in geriatric patients than in younger ones. It may be caused both by some analgesics (inducing central anticholinergic syndrome), or by pain due to insufficient analgesia. On the other hand, nausea, vomiting, and itching induced by opioid analgesics are less frequent.

While virtually all techniques of postoperative pain management may be applied, it is necessary to reduce the dose of the medication used (e.g., the dose of morphine should be half the standard dose; in general, the dosing intervals extend as well). When administering opioid analgesics, it is advisable to use intravenous administration by careful titration. Multimodal analgesia reducing the opioid requirement is beneficial and preference is given to locoregional analgesia techniques. Non-pharmacological methods may reduce the demands on pharmacotherapy (positioning, thermal comfort, early individualized rehabilitation). The safety and quality of postoperative pain management in the elderly is dependent on a careful monitoring of these patients. After 65 years of age, the toxicity of NSAIDs increases significantly (gastropathy, nephrotoxicity, cardiovascular toxicity, coagulopathy). While their short-term administration is not contraindicated, non-opioid analgesics, such as paracetamol

or metamizol, are preferred. Ketamine is not recommended due to a higher risk of psychotomimetic effects. When using other medications, it is necessary to pay attention to contraindications or limitations arising from complicating diseases and drug interactions.

16.5. Postoperative pain management in children

High-quality postoperative pain management is an essential prerequisite for a successful care of a paediatric patient after surgery. It aims to eliminate postoperative pain and thereby reduce perioperative stress of the child and minimize any negative memory traces, which may significantly affect communication with health professionals, hospital stay and any other surgical interventions that might follow. It is important to remember that even very young children feel pain with the same intensity as adults

The knowledge of the extent of the surgical procedure and the anticipated level of pain is essential for good perioperative pain management. It is necessary to consider it carefully and plan analgesia accordingly to meet the basic premise: a good balance of preoperative analgesia (i.e. premedication), intraoperative, and postoperative analgesia. With the right combination of drugs at these stages and proper timing of their administration, postoperative analgesia may be performed in a significantly safer and more efficient way. In an optimal situation, premedication, anaesthesia, and postoperative analgesia should be performed by the same physician. An integral part of preoperative preparation is an interview with the parents and with the child (in a sensitive way, tailored to the child's age). They are assured that postoperative pain is common, that its intensity decreases with time and may fluctuate during the day and night, and most importantly, that the treatment of perioperative pain is possible and will be given full attention. Intraoperative analgesia depends on the selected method of general anaesthesia. It is essential to make sure that sufficient analgesia is provided for the period after recovery from anaesthesia, for the transfer of the patient to the recovery room and for the initial phase of the patient's stay. Preventing a period without analgesia is very important and often underestimated. It can be bridged by starting a continuous administration of analgesics already during the last phase of the surgical procedure, or by a careful administration of a "rescue" bolus dose of an analgesic. In addition to the pharmacological treatment of pain, it is very important to optimize environmental factors in the postoperative period. These negative effects include lack of privacy and constant noise on the postoperative ward, insensitive and unnecessary handling of the patient and intense light. In certain situations, the presence of agitated parents at the bedside after the child arrives from the operating room may be questionable. In the postoperative period, it is very important to distinguish an inadequately treated postoperative pain from distress and annoyance of the bedridden child. Both present as restlessness, crying, tachycardia, hypertension, avoidance of contact, and eating disorder. Lack of proper recognition may lead to an unnecessary increase in the dose of analgesics instead of using sedatives to supplement analgesia.

Recommendations for various types of surgical procedures in children

The following section offers recommendations for postoperative pain management in children. In each group of surgical procedures, the most suitable type of analgesia is presented, and several alternative options are provided.

16.5.1. Minor surgical procedures

(Hernia repair, orchidopexy, appendectomy, minor orthopaedic procedures, dental surgery, etc.)

Preoperatively: premedication with a marked sedative component – midazolam 0.2 mg/kg PO

Intraoperatively: general anaesthesia as usual (usually inhalational), after the induction of anaesthesia: sufentanil 0.1 mcg/kg and paracetamol 7.5–15 mg/kg IV or metamizol 10–15 mg/kg IV or nalbuphine 0.15 mg/kg

Postoperatively: paracetamol 15–20 mg/kg PR 4 times daily or ibuprofen 4–10 mg/kg PR 4 times daily

Alternative options

Preoperatively: premedication with a marked analgesic component – morphine 0.2 mg/kg IM (in children weighing more than 5 kg)

Intraoperatively: general anaesthesia combined with an epidural blockade – levobupivacaine up to a max. dose of 2 mg/kg caudally, or ketamine 1 mg/kg IV.

Postoperatively: epidural blockade, metamizol can be added in a dose of 10–15 mg/kg IV, paracetamol 7.5–15 mg/kg IV, tramadol 1–2 mg/kg PR, PO 4 times daily (max. daily dose: 8 mg/kg or 400 mg)8.7.2

16.5.2. Intermediate surgical procedures

(Pyloroplasty, pyeloplasty, paediatric urology, thoracoscopy, laparoscopy, orthopaedic correction, tonsillectomy, plastic surgery, etc.)

Preoperatively: premedication as usual, either midazolam 0.2–0.3 mg/kg PO or morphine 0.2 mg/kg IM. Given the need for strong intraoperative analgesia and a longer duration of the surgical procedure, an analgesic component of premedication is not necessary for postoperative analgesia

Intraoperatively: balanced anaesthesia, analgesia: sufentanil 0.2–0.5 mcg/kg, or a continuous administration of 0.3–1 mcg/kg/h, or fentanyl 0.5–1 mcg/kg/h

Postoperatively: metamizol 10–15 mg/kg IV 3 times daily, or paracetamol 7.5–15 mg/kg IV 4 times daily, or tramadol 1–2 mg/kg IV 4 times daily, or nalbuphine 0.1–0.2 mg/kg up to 4 times daily. If this is not sufficient, then continuous administration of morphine 15–30 mcg/kg/h (5–10 mcg/kg/h in newborns)

Alternative options

Intraoperatively: combined anaesthesia with an epidural catheter placed at an appropriate level, a bolus dose of bupivacaine, or levobupivacaine at a maximum dose of 2 mg/kg. During the procedure, start a continuous administration of levobupivacaine, or bupivacaine 0.2 mg/kg/h in children weighing less than 10 kg, or 0.3 mg/kg/h in children weighing more than 10 kg.

Postoperatively: continue with the continuous administration into the epidural catheter. If this is not sufficient, you can add metamizol 10–15 mg/kg IV, paracetamol 7.5–15 mg/kg IV, or tramadol 1–2 mg/kg IV, the dose may be repeated (see above)

16.5.3. Major surgical procedures

(thoracotomy, extensive surgical revision of the abdominal cavity, scoliosis surgery, major orthopaedic surgery, neurosurgical remodelling, corrective dental surgery, etc.)

Preoperatively: the same as with intermediate surgical procedures

Intraoperatively: balanced anaesthesia, the same as with intermediate surgical procedures. Before the end of surgery, it is possible to start a continuous administration of morphine 15–30 mcg/kg/h (5–10 mcg/kg/h in new-borns), or sufentanil 0.2–0.3 mcg/kg/h and thereby avoid a period without proper analgesia when transferring the patient to a postoperative ward.

Postoperatively: continuous administration of morphine 15–30 mcg/kg/h (5–10 mcg/kg/h in newborns), or sufentanil 0.2–0.3 mcg/kg/h. If continuous opioid analgesia is not sufficient, it is possible to add metamizol 10–15 mg/kg IV 3 times daily, or paracetamol 7.5–15 mg/kg IV 4 times daily.

Alternative options: The same as with intermediate surgical procedures.

16.6. Postoperative pain management in ambulatory surgery

Ambulatory surgical procedures offer many benefits to patients, and their number continues to rise. Proper selection of high-quality postoperative analgesia is of particular importance in outpatients, since strong postoperative pain, as well as adverse effects of the therapy, such as severe postoperative vomiting, are along with surgical complications among the most common reasons for unplanned hospitalization. Patients should be given instructions on postoperative pain management in advance, preferably in writing, and they should be provided with the necessary medication beforehand. The instructions should involve not only dose, but also the expected level of pain, possible side effects, and contact information for a physician in case of questions or issues that may arise after discharge. In general, any type of premedication may be used. In practical terms, it is advisable to avoid long-acting sedatives and medication that potentiates nausea and vomiting. Some authors recommend routine administration of antiemetics as part of premedication. The anaesthesiologist should ensure that the patient does not feel pain after recovery from anaesthesia, especially if only inhalational anaesthesia or short-acting opioids (remifentanil) were used. A great advantage is that it is possible to use a peripheral nerve blockade with a long-acting local anaesthetic, but it is necessary to use a lower concentration to reduce the motor blockade (recovery of motor function is a necessary condition for discharge). Neuroaxial blockades should be used only in fully informed patients familiar with the symptoms of potential complications associated with these techniques. Low doses are used to ensure rapid regression of the blockade – therefore, they are of little significance in postoperative analgesia. Spinal administration of opioids should be avoided. Widely recommended measures include wound infiltration with a long-acting local anaesthetic performed by the surgeon at the end of the procedure. A prerequisite for postoperative pain management in the home environment is the administration of oral medication only. The patient leaves the health care facility with an established and fully functional analgesic regimen and is familiar with the rescue procedure to be followed in case of failure of the established regimen (weak opioid at the upper limit of the recommended dose range as a supplement to regular doses of a non-opioid analgesic together with a nonsteroidal anti-inflammatory drug – NSAID). Intense postoperative pain is one of the reasons for unplanned hospitalization after ambulatory surgery. It is generally recommended to use multimodal analgesia including a combination of locoregional techniques and systemic analgesics, as well as suitable non-pharmacological methods. Patient education about the appropriate method of positioning, rehabilitation, physical factors, etc. is common with sports injuries, while in ambulatory surgery it is often neglected. In primary systemic therapy, the commonly recommended doses and combinations of non-opioid analgesics (1 g of paracetamol PO every 6 hours), NSAIDs (e.g. diclofenac 75 mg every 8–12 hours), and weak opioids may be used. An alternative option to nonselective COX inhibitors is to use coxibs. The necessity of using strong opioids implies hospitalization in many countries.

17. Anaesthesia related complications

J. Málek

17.1. Risk of death

Mortality directly attributable to anaesthesia is low (1 in 30 000 to 1 in 185 000 anaesthetics), but anaesthesia can contribute to overall mortality after surgery, mainly because of decompensation of previous concomitant disease. Probability of death 30 days after surgery is 1 :1 77 – 1 : 200 (0.56%) in scheduled surgeries and 1 : 34 – 1 : 40 (2.94%) in emergency surgeries.

17.2. Malignant hyperthermia

Malignant hyperthermia (MH) is a life-threatening clinical syndrome of hypermetabolism involving the skeletal muscle. It is triggered in susceptible individuals primarily by the volatile inhalational anaesthetic agents and the muscle relaxant succinylcholine, though other drugs have also been implicated as potential triggers. Malignant hyperthermia is an inherited disorder that is found both in humans with incidence of 1:15 000 in children and 1:50 000 in adults (according to other resources it is has an incidence 1:260 000 cases of general anaesthesia and an incidence of 1:60 000 when suxamethonium is used.

In persons susceptible to MH, the ryanodine receptor in skeletal muscle is abnormal, and this abnormality interferes with regulation of calcium in the muscle. An abnormal ryanodine receptor that controls calcium release causes a build-up of calcium in skeletal muscle, resulting in a massive metabolic reaction. This hypermetabolism causes increased carbon dioxide production, metabolic and respiratory acidosis, accelerated oxygen consumption, heat production, activation of the sympathetic nervous system, hyperkalaemia, disseminated intravascular coagulation (DIC), and multiple organ dysfunction and failure. Early clinical signs of MH include an increase in end-tidal carbon dioxide (even with increasing minute ventilation), tachycardia, muscle rigidity, tachypnoea, and hyperkalaemia. Later signs include fever, myoglobinuria, and multiple organ failure.

The drug of choice for treatment of malignant hyperthermia is dantrium (Dantrolene). Indications for treatment of malignant hyperthermia (MH) with dantrolene include signs of hypermetabolism, a rapid rise in carbon dioxide in the face of an increase in the minute ventilation, tachycardia, muscle and or jaw rigidity (after succinylcholine), and fever (a late sign). A fulminant, rapidly progressive MH reaction requires early diagnosis and early rapid administration of dantrolene, discontinuance of triggering agents, and assistance from extra personnel. The surgeon should be notified immediately and should stop the procedure as soon as possible.

Cooling and early treatment of hyperkalaemia are desirable. Calcium-channel blockers should be avoided if dantrolene is used, because they may cause hyperkalaemia. The recommendation is that 36 dantrolene vials (containing 20 mg/vial) should be immediately available wherever general anaesthesia is administered. It is helpful to place an MH treatment poster in the operating room.

Once the initial reaction is controlled, continued monitoring in the intensive care unit (ICU) for 24-48 hours is recommended, along with administration of dantrolene (1 mg/kg every 4-6 hours, or an equivalent amount given as a continuous infusion). Myoglobinuria should be watched for and treated with fluids and diuretics if it occurs. The creatine kinase level will peak about 8-10 hours after the event and should be followed until it returns to near normal.

Safe drugs

benzodiazepines, opioids, barbiturates, atropine, glycopyrrolate, LA, etomidate, propofol, nitrous oxide, vecuronium, atrakurium

Contraindicated drugs

phenothiazines, suxamethonium, volatile anaesthetics (all), Ca channels blockers, alpha-sympathomimetics, digoxine, calcium

Better to avoid

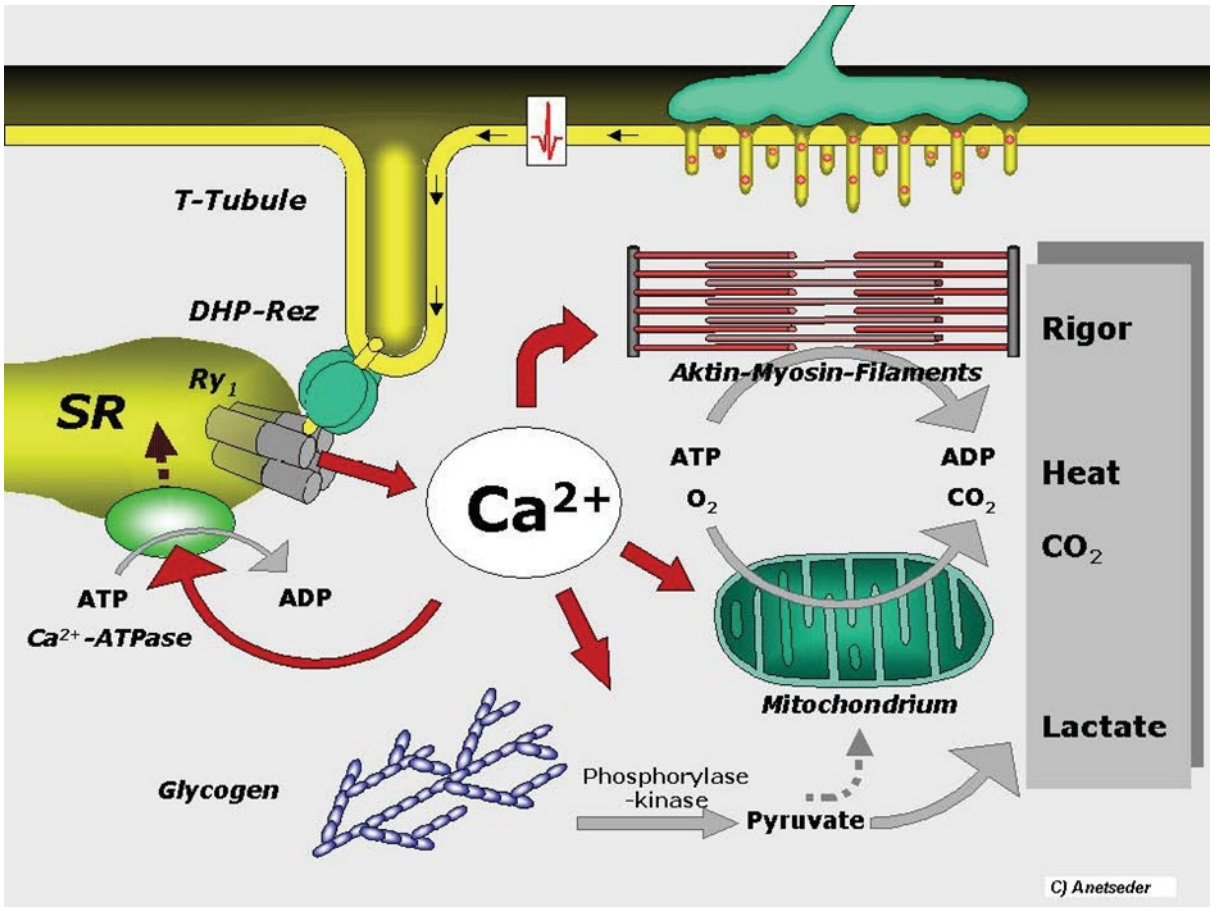
d-tubocurarin, galamine, pancuronium

No information

ketamine, methylxantins, neostigmine

The patient and the family members will need to be educated about MH and should be referred to a testing centre for a caffeine halothane contracture test.

Source: *https://emedicine.medscape.com/article/2231150-questions-and-answers*



Picture 17: Metabolism of calcium in a muscle. Source: www.biozentrum.uni-wuerzburg.de

17.3. Complications of locoregional anaesthesia

Toxic reaction appears because of high plasmatic level of LA, because of inadvertent intravascular administration or exceeding maximal dose. Signs are changing of behaviour, motoric restlessness, muscle twitches, convulsion, unconsciousness, arrhythmias, collapse and cardiac arrest. Therapy consists of 100% oxygen, small midazolam dose (1 – 5 mg), thiopental, intubation and muscle relaxation and mechanical ventilation. In case of cardiac arrest resuscitation is performed, catecholamines and Intralipid 20% 1 ml/kg IV are administered

Allergic reaction to LA is rare. It can manifest as hypotension, shock, cardiac arrest, bronchospasm, angio-oedema, erythema and skin reaction. Therapy consists of securing airways, oxygen, adrenaline 0.5 mg IM or repeated 50 ug IV till effect, infusion of crystalloids, hydrocortisone 100 – 300 mg IV.

17.3.1. Common complications of locoregional anaesthesia

Hypotension is frequent and is a sign of effective neuroaxial blockade. It is caused by sympathetic block and usually responds well to infusion and small dose of ephedrine.

Pruritus (itching) is caused by spinal or epidural opioids. Treatment is small dose of naloxone, if necessary.

Urine retention is caused by both opioids and LA. Urinary catheterisation is the solution.

Major complications of continuous epidural blockade are rare, but devastating. In case of expansion in spinal canal, decompression laminectomy must be performed within 8 hours since symptoms. The neurological deficit is paraplegia usually irreversible.

Complication of continuous epidural blockade

	Epidural abscess	Epidural haematoma	Syndrome a. spinalis ant.
Age	any	50 % >50 years	old
History	immunosuppression	anticoagulants	arteriosclerosis/hypotension
Onset	days	sudden	sudden
Common signs	fever, signs of infection, back pain	Sharp back pain or eradiation to lower extremity	no
Sensitive signs	no, or paraesthesia	weak and late	weak and late
Motoric signs	weakness or spastic paresis	weakness (frequently as the first sign)	weak paresis
Segmental reflexes	Sometimes increased, later absent	absent	absent
MRI/CT/myelogram	compression	compression	no
CSF	inflammation markers	no	no
Blood	inflammation markers	haemocoagulation	no

18. Ambulatory (outpatient) anaesthesia

(source: Jeong Han Lee Anaesthesia for ambulatory surgery. Korean J Anaesthesiol. 2017 Aug; 70(4): 398–406.)

Definition

Ambulatory anaesthesia is used for surgical procedures where the patient does not need to stay overnight in the hospital. Ambulatory surgery occurs in a variety of settings. Some centres are within a hospital or in a freestanding satellite facility, which is either part of or independent of a hospital. Physicians' offices may also serve as locations for these procedures. The same anaesthetics that are used in the operating room setting are used in the ambulatory setting, including general, regional and local anaesthetics. Sedation anaesthetics are also given in the ambulatory setting. Patient is dismissed the same day, usually 2 – 6 h. after end of anaesthesia. The priority is patient´s safety and consent of the patient, the anaesthetist and the surgeon.

Equipment

Anaesthetic team, equipment and drugs must comply with the standards of safe anaesthesia, which are the same as in a hospital setting.

Preparation of patients

Preoperative assessment of patients for ambulatory surgery is again standard. Most patients are eligible for ambulatory surgery unless there is a specific reason for an overnight stay. Recently, patient choice has become an important factor because of the complexity of ambulatory surgical procedures and the increased incidence of comorbidities. Preoperative assessment and optimization according to medical comorbidities are associated with improved perioperative results. For a successful ambulatory surgery, it is necessary that both the patient and the procedure are appropriate for ambulatory anaesthesia. The advantages of ambulatory surgery disappear in cases in which an emergency occurs or an unplanned hospital admission is required.

Patient selection for ambulatory surgery depends on several factors, including surgical, social, medical, and anaesthetic factors (source https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5548941/) and Association of Anaesthetists of Great Britain and Ireland; British Association of Day Surgery. Day case and short stay surgery.

Surgical considerations

- Ambulatory surgery should not carry a significant risk of major complications (e.g., haemorrhage, cardiovascular instability).
- When opening the abdominal or thoracic cavities, minimally invasive surgical techniques should be used.
- Postoperative pain should be controlled with oral analgesia and regional or local anaesthetic techniques.
- Patients should be able to resume normal functions (e.g., oral drinking) as soon as possible.
- Patients should be mobile to at least some extent before discharge.
- Long-term professional care or observation after surgery is not required.
- The anticipated degree of surgical trauma is more important than the surgical duration.
- The surgeon should have sufficient experience with the procedure and a low complication rate record.

Social considerations

- Patients must understand the procedure and postoperative care requirements and consent to the ambulatory surgery.
- When a patient is discharged to home, he/she should be accompanied by a responsible adult who can take care of them in the 24 h after surgery.
- It is essential for patients and caregivers to have easy access to a telephone after discharge.
- Patients should not drive for at least 24 h after anaesthesia or sedation.
- It is also important to be within 1 h of emergency medical services and to minimize pain.
- The patient's home environment should be suitable for postoperative care.

Medical considerations

- Patient selection is based on the patient's functional status at the time of assessment and is not necessarily restricted by age, body mass index (BMI), or American Society of Anaesthesiologists status. While a high BMI is not an absolute contraindication, obese patients may have other medical problems, such as obstructive sleep apnoea (OSA). In the case of obese patients, the preoperative assessment must be sufficiently thorough to identify patients with obesity-related diseases and to exclude those with severe coexisting diseases that may be better managed in a hospital setting.
- Patients with chronic but stable illnesses prefer to be at home, as this interferes less with their daily lives.
- Patients with unstable medical condition, such as unstable angina or poorly controlled diabetes, are not appropriate for ambulatory surgery.

Anaesthetic considerations

- Anaesthetic history (suxamethonium apnoea, malignant hyperthermia and other related complications, are usually contraindications
- PONV is the most common complication of anaesthesia and the risk varies greatly according to the anaesthesia method. In preoperative evaluations, it is useful to evaluate the risk of PONV using the four Apfel risk factors (female gender, history of PONV and/or motion sickness, non-smoking status, and postoperative use of opioids) [24]. This makes it possible to classify patients into risk groups for better planning of anaesthesia.
- Airway assessment should be done. Certain patient groups, such as those with OSA and obesity, may be at higher risk for anaesthesia-related complications

Special considerations

- Age alone should not be used to determine the appropriateness of ambulatory surgery. Preoperative assessment should be done to determine whether there are any exclusion criterion for ambulatory surgery.
- Obstructive sleep apnoea

18.1. Intraoperative Anaesthetic Management

No single anaesthetic or method is appropriate for all ambulatory anaesthesia cases. Thus, the patient's preference, age and physical condition, the surgeon's requirements, the duration of effect of the selected medication, and the degree of postoperative nursing care required are considered in determining the most effective and convenient anaesthetic method and medication. The choice of anaesthetic method for ambulatory surgery should also take into account the safety, quality, efficacy, medicine, and equipment of the different methods. Furthermore, in general, the anaesthetic agents that are chosen are those with a rapid onset of action and fast recovery time, and that do not cause problems with respect to intraoperative control of consciousness and pain relief, and have no other side effects. The choice of anaesthetic method depends on the type of surgery and the patient's status. Anaesthesia for ambulatory surgery includes general and regional anaesthesia, local anaesthesia, monitored anaesthesia care (MAC), or a combination of these methods.

General anaesthesia is the most common choice, because it is safe, economical, easy to recover from, and familiar to most anaesthesiologists. The use of new anaesthetics, such as propofol, sevoflurane, and desflurane, allows for easier titration, early awakening, and a reduction in the time required to meet postanaesthesia care unit (PACU) discharge criteria [

The major types of regional anaesthesia include peripheral nerve blockade (with or without a continuous peripheral nerve catheter) and neuroaxial blockade. Regional anaesthesia can avoid the side effects often caused by general anaesthesia, such as nausea, vomiting, dizziness, residual muscle relaxation, and aspiration pneumonia. Additionally, analgesic effects can onset from the early postoperative period. However, regional anaesthesia requires more time to take effect, and in cases in which the anaesthesia is unsuccessful or incomplete, general anaesthesia is used.

Postoperative pain management

Postoperative pain management, which is an integral facet of successful ambulatory anaesthesia, includes regional nerve block and analgesic administration. The infiltration of local anaesthetics or nerve block at the surgical site at the conclusion of the operation may reduce the dose of anaesthetics and analgesics required thereafter. Thus, the recovery time is shortened, and anxiety or excitement in the recovery room due to pain can be alleviated. Multimodal or balanced analgesia therapy, or the use of more than one pain relief method, can increase analgesic effects while simultaneously reducing the side effects associated with certain medications. The perioperative use of multimodal analgesia therapies with both narcotic and non-narcotic analgesics can increase the speed of a patient's quick recovery and improve satisfaction rates.

Postoperative nausea and vomiting

While the frequency of nausea and vomiting varies, approximately 30–50% of patients report such symptoms. Even if other problems associated with surgery and anaesthesia are alleviated, in cases of severe nausea or vomiting, patient discharge may still be delayed and unexpected hospitalization may be necessary. Despite the development of various new anti-emetics, the incidence of nausea and vomiting due to patient, surgery, and anaesthesia-related risk factors remains high, at around 30%. Treatment of PONV requires the administration of antiemetic drugs of a different pharmacological class than the initial prophylactic drugs, and low-dose 5-hydroxytryptamine receptor antagonists are recommended unless prophylaxis is indicated.

Recovery

The process of recovery from anaesthesia can be divided into three stages: early, middle, and late. Early recovery refers to the period between awakening from anaesthesia and restoration of protective reflexes and motor capacity. Up to this point, the patient remains in the postanaesthesia care unit (PACU), where vital signs and oxygen saturation are monitored. If necessary, oxygen, analgesics, and anti-emetics can be administered. Patients in the middle recovery phase stay in step-down units and are nursed in resting chairs. They are considered ready for discharge when they are capable of walking, drinking, and urinating. Transfer decisions from the PACU to the step-down unit commonly follow evaluations done using the modified Aldrete scoring system or White's fast-track criteria. When a simple operation is performed using short-acting anaesthetics, such as propofol, sevoflurane, or desflurane, there are many cases in which the patient recovers consciousness, regular breathing, and stable vital signs in the operating room. The more recently introduced 'WAKE' score includes not only the modified Aldrete score (maximum score = 10), but also "zero tolerance" criteria to assess post-operative pain, PONV, tremors, itching, and orthostatic symptoms (dizziness, hypotension). The late recovery period refers to the period prior to a patient being able to return to work and daily life, after all functions have recovered fully post discharge. For a safe discharge, the patient must have stable vital signs and show restoration of full orientation. Furthermore, the patient must be able to walk without dizziness and have little to no pain, nausea, vomiting, or surgical-site bleeding. When the patient has completed the second recovery phase, the Post Anaesthesia Discharge Scoring System may be used to decide whether or not they can be discharged from the hospital. In US and Canadian hospitals, as well as in the Czech Republic to return home, all outpatients who receive sedative or analgesic medications must have be escorted by a responsible adult. A responsible adult escort must be provided with printed instructions, including detailed information regarding precautions, guidelines, and the medical personnel to contact in case of an emergency.

19. Monitored anaesthesia care

J. Šturma

Monitored anaesthesia care (MoAC) is a method in which patients are anaesthetized by intravenous injection of analgesic and sedative drugs. Rather than being used alone, MoAC is often used in conjunction with local infiltration anaesthesia and peripheral nerve block. MoAC can increase patient satisfaction and shorten recovery times compared with general anaesthesia or neuroaxial block. Recently, propofol, low-dose ketamine, and dexmedetomidine have been used increasingly because they can reduce the incidence of respiratory depression caused by sedative-analgesic use. Because respiratory depression is caused by excessive sedation, special attention must be paid to this possibility by the staff performing ambulatory surgery.

Sometimes, there is a confusion between MoAC and moderate sedation, so a new definition was published by American Society of Anaesthesiologists.

During moderate sedation, a physician supervises or personally administers sedative and/or analgesic medications that can allay patient anxiety and limit pain during a diagnostic or therapeutic procedure. During moderate sedation, the responsible physician typically assumes the dual role of performing the procedure and supervising the sedation. Such drug-induced depression of a patient's level of consciousness to a "moderate" level of sedation, as defined in the Joint Commission (TJC) standards, is intended to facilitate the successful performance of the diagnostic or therapeutic procedure while providing patient comfort and cooperation. Physicians providing moderate sedation must be qualified to recognize "deep" sedation, manage its consequences and adjust the level of sedation to a "moderate" or lesser level. The continual appraisal of the effects of sedative or analgesic medications on the level of consciousness and on cardiac and respiratory function is an integral element of this service.

The American Society of Anaesthesiologists has new defined Monitored Anaesthesia Care (see Position on Monitored Anaesthesia Care, updated on October 17, 2018). MoAC can be distinguished from

Moderate Sedation in several ways. An essential component of MAC is the periprocedural anaesthesia assessment and understanding of the patient's coexisting medical conditions and management of the patient's actual or anticipated physiological derangements during a diagnostic or therapeutic procedure. While Monitored Anaesthesia Care may include the administration of sedatives and/or analgesics often used for Moderate Sedation, the qualified anaesthesia provider of MAC is focused exclusively and continuously on the patient for any attendant airway, hemodynamic and physiologic derangements. Further, the provider of MAC must be prepared and qualified to convert to general anaesthesia. The proceduralist providing moderate sedation may have their attention diverted to their primary focus, the procedure. Additionally, a provider's ability to intervene to rescue a patient's airway from any sedation-induced compromise is a prerequisite to the qualifications to provide Monitored Anaesthesia Care. By contrast, Moderate Sedation is not expected to induce depths of sedation that would impair the patient's respiratory function or ability to maintain the integrity of his or her airway. These components of Monitored Anaesthesia Care are unique aspects of an anaesthesia service that are not part of Moderate Sedation. The administration of sedatives, hypnotics, analgesics, as well as anaesthetic drugs commonly used for the induction and maintenance of general anaesthesia is often, but not always, a part of Monitored Anaesthesia Care. In some patients who may require only minimal sedation, MAC is often indicated because even small doses of these medications could precipitate adverse physiologic responses that would necessitate acute clinical interventions and resuscitation.

Classification of various types of sedation and general anaesthesia

Minimal sedation (previously known as anxiolysis) –a minimally depressed level of consciousness, produced by a pharmacological method, that retains the patient's ability to independently and continuously maintain an airway and respond normally to tactile stimulation and verbal command. Although cognitive function and coordination may be modestly impaired, ventilatory and cardiovascular functions are unaffected.

Moderate sedation –a drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.

Deep sedation – a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.

General anaesthesia – a drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired.

Because sedation and general anaesthesia are a continuum, it is not always possible to predict how an individual patient will respond. Hence, practitioners intending to produce a given level of sedation should be able to diagnose and manage the physiologic consequences (rescue) for patients whose level of sedation becomes deeper than initially intended.

20. Anaesthesia for emergency surgery

J. Šturma

When elective surgery is planned, preoperative examinations and precautions are performed in order to bring the patient to the best possible state of health for the surgery. When emergency surgery, the extent of surgery is often unknown; patient can be in suboptimal stay with increased risk of complications, which is 1.5 to 2 times higher compared with the same ASA classification patient scheduled for planned

surgery. Pre-anaesthesia time is sometimes very short and the patient's history poorly known. The most dangerous situations are hypovolaemia and risk of pulmonary aspiration.

Decreased intravascular volume

Underestimation the extent of hypovolaemia can result in serious complications during induction of GA or use of neuroaxial anaesthesia.

Hypovolaemia	**minimal**	**mild**	**middle**	**significant**
Loss of circulating volume (%)	10	20	30	>40
Loss ml (in adults)	500	1000	1200	>2000
Pulse	normal	100-120	120-140	>140
Blood pressure	normal	Orthostatic hypotension	systole <100	Systole <80
Urine output/hour	normal 1 ml/kg	20-30 ml	10 – 20 ml	0
Consciousness	normal	normal	restlessness	lost
Periphery	normal	cold, pale	decreased capillary return	decreased capillary return
CVP (cm H2O)	normal	-3	-5	-8

Teble: Estimation of circulating volume loss

Loss of extracellular volume are underestimated more frequently than loss of circulating volume and are more difficult to estimate.

% loss of body fluid	**ml fluid/70 kg**	**signs**
>4% (small)	>2500	thirst, dry tongue, decreased skin turgor
>6% (mild)	>4200	as above + orthostatic collapse, decreased venous filling, oliguria, nausea, decreased sweating, low CVP, lethargy, haemoconcentration
>8% (middle)	>5500	as above + hypotension, shallow pulse, cold periphery
10 -15% (significant)	7000-10500	shock, coma, death

Table: Estimation of extracellular fluid loss

If volume depletion cannot be corrected before surgery, intensive volume therapy must be done during surgery and sometimes catecholamine administration is necessary to support circulation. Optimal method of anaesthesia is peripheral nerve blockade and infiltration anaesthesia, which is in majority of cases impossible. Neuroaxial anaesthesia, thiopental and propofol are contraindicated. For inducing anaesthesia the drug of choice is ketamine.

Full stomach

Under normal situation, stomach is empty after 6 hours of ingestion of solid food and 2 hours after clear fluid. In some situation, this is not guaranteed: alcohol intake, pregnancy, pain, some drugs, ileus and others. The most important factors leading to complications from aspiration are increased gastric volume and low pH. One choice to decrease the risk is to use locoregional anaesthesia, next possibility is insertion of gastric tube and suctioning. Rarely is used drink with 0,3M natrium citrate to increase pH of gastric juice. Method of choice for GA is rapid sequence induction (RSI). Extremely rarely awake intubation in topical anaesthesia is used.

Rapid sequence induction

- Full monitoring with suction ready
- Trained assistant
- IV access
- Suck from gastric tube, if in place and remove it
- Pre-oxygenation for 3 minutes
- Appropriate dose of induction agent
- Apply cricoid pressure (Sellick manoeuvre) - see
- Suxamethonium 1 mg/kg, or rocuronium
- Laryngoscopy and intubation when patient relaxed
- Check position and inflate cuff of tracheal tube before releasing cricoid
- Secure tube

21. Advanced cardiac life support

J. Málek, J. Knor

See *https://www.lf3.cuni.cz/3LFEN-233.html*

22. Further reading

- Raymer K et al. Understanding Anesthesia. Available at *https://anesthesiology.queensu.ca/source/Anesthesiology/UnderstandingAnesthesia1_1_2.pdf*
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- European Society of Anaesthesiology (ESA) guidelines. Available at *https://www.esahq.org/guidelines/guidelines/published*
- American Society of Anesthesiologists standards and guidelines. Available at *https://www.asahq.org/standards-and-guidelines*
- European Resuscitation Council guidelines for resuscitation. Available at *https://cprguidelines.eu/*
- Free anaesthesia handbooks. Available at *https://www.pdfdrive.com/anaesthesia-books.html*

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