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# *Paediatric anaesthesia – review paper*

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## Abstract

"Children are not little adults," Jean Jacques Rousseau used to say. A child's body differs in many aspects from an adult's body. When performing anaesthesia on children, infants and newborns, especially those born prematurely, one must bear in mind significant anatomical-physiological, pharmacokinetic-pharmacodynamic, as well as psychological-emotional differences. The differences in treating a sick child are more important when the child is younger. Difficulties in hospitalising such patients appear already at the stage of collecting the interview. Newborns and infants are specific examples of patients because the history, in this case, is never directly obtained from the injured party. Therefore, treating a sick child differs significantly from that used in adults. The review paper aims to address the most critical anaesthetic aspects in working with paediatric patients. *Anestezjologia i Ratownictwo 2025; 19: 323-337. doi:10.53139/AIR.20251930*

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## Anatomical differences

To better understand the differences in individual age groups, the following terminology is used: newborn – a child up to 4 weeks of age; infant – a child under 1-year-old; child – this term refers to children between 1 year old and the beginning of puberty; teenager-children from puberty.

## Respiratory tract

The larynx, trachea and bronchi of a newborn and infant show many differences compared to the respiratory tract of adults. The respiratory part of the nose in newborns is small. The horizontal nasal passages and nostrils are narrow. The mucous membrane is very richly vascularised. All these conditions mean that breathing difficulties may occur in the youngest children in the event of a slight mucous membrane swelling [1]. Babies physiologically breathe through their noses for the first six months of life. During this time, they do not show the ability to breathe through an open mouth. Therefore, nasal obstruction resulting in excessive mucous secretion may lead to the consumption of so much energy that respiratory failure may result. Underdevelopment and disproportion of the facial part of the skull are primarily responsible for nasal obstruction in newborns and infants. Only school-age children gain nose proportions comparable to adults. In addition, disturbances in nasal patency may result from anatomical anomalies, including choanal obstruction, or from an inserted endotracheal tube, gastric tube or plasters, which may cause blockage of the nasal openings [1].

The nasal part of the newborn's throat is distinguished by its small size and narrow shape. The throat's mucous membrane and the tongue's back have absorbent tissue arranged in clusters, creating Waldeyer's throat ring. It has a protective function and constitutes a barrier to pathogens, preventing them from penetrating further sections of the respiratory system. It consists of the pharyngeal tonsils, trumpet tonsils, palatine tonsils, lingual tonsils, individual lymph nodes, and lateral bands of lymphatic tissue. The pharyngeal tonsil develops the fastest and may become hypertrophied and a mechanical obstacle to breathing through the nose. It disappears with age, but there are sometimes cases of patients with its remnants. Early childhood is also the time of baby teething. A one-year-old child should have eight teeth, and a three-year-old should have all baby teeth [1].

The head of a newborn, infant or small child is larger than the rest of the body. Differences in proportions also occur in other body parts but are most visible in the head and neck. Looking at the newborn, we can see that the head is placed directly on the shoulders, and the neck is very short. A prominent and protruding occiput is responsible for bending the head to the trunk when the child is lying on its back, which may obstruct the soft tissues in the larynx. We could estimate the size of the infant's face as small and wide. Its shape is determined by the incomplete development of the jaw [1]. The nose is small and slightly turned up. However, the ears are large and protruding. Clinically, anatomically meaningful seems to be the infant's large tongue, which can easily lead to airway obstruction [1-3]. In addition, the floor of the mouth is sensitive to pressure, and there is a risk of inadvertently obstructing at this level. The short neck of an infant causes all the structures inside to be higher and may also facilitate the transmission of infection to the lower respiratory tract [2].

The larynx is the organ connecting the throat and trachea. The upper anterior border is limited at the level of the base of the tongue by the hyoid bone. It is essential here that the hyoid bone is movable, crescent-shaped, and the first bone in the human body to ossify. The larynx divides into three areas depending on the location of the vocal cords: the supraglottic area, which includes the epiglottis, arytenoids, epiglottal folds, and false vocal folds; then we distinguish the glottis area, which consists of the vocal folds and the area located directly below; and the subglottic region, which includes the area beginning 1 cm below the vocal folds and ending at the tracheal opening partially corresponding to the cricoid cartilage. In childhood, the cephalad position of the larynx is marked. It is also more forward compared to the adult anatomy. Newborns and children up to two years old have cricoid cartilage located at the level of the fourth cervical vertebra. At age 6, it is at the level of the fifth cervical vertebra, and finally, it is located at the level of the sixth cervical vertebra in adulthood. Due to their location, visualisation of the vocal cords during direct laryngoscopy is problematic in infants and small children. Moreover, in younger children, the laryngoscopic view is hampered by the epiglottis, which appears to be larger and longer than in older children. Its shape is compared to the Greek omega [2].

Additionally, the epiglottis in younger children lies more horizontally than in adults. Due to the larynx's higher position, the epiglottis tip almost reaches the soft palate. The previously mentioned anatomical conditions allow the infant to breathe and suck simultaneously without choking due to the occasional pressure of the tongue on the soft palate. Moreover, these anatomical features, combined with immature coordination between respiratory effort and motor and sensory input from the oropharyngeal cavity, help explain why infants between two and six months of age breathe almost exclusively through the nose. This is when babies improve their ability to breathe through the mouth, apart from when the baby cries, by disconnecting the soft palate from the tongue in the gradually enlarging mouth. Reflex constriction of the larynx is its defence mechanism against foreign bodies and food penetration into the lower respiratory tract. This reflex is not developed in premature babies. Therefore, they are more likely to aspirate various fluids and develop lung inflammation. The frequent occurrence of inflammatory laryngeal oedema can be explained by a narrow lumen, a gap between the vocal cords, and rich vascularisation of the lymphatic tissue. Excessive reflexes and nervous excitability may cause uncontrolled laryngeal spasms. Speech development is possible thanks to the exhalation of air flowing through the larynx, which causes the vocal cords to vibrate. A higher voice pitch in children is explained by the presence of short vocal cords. Their gradual lengthening over the years leads to a change in the tone of the voice [3].

The trachea in children is much shorter, narrower, and bent backwards [3]. The larynx is located above the trachea. Its proximity gives the impression that the cervical trachea in children comprises a more significant number of tracheal rings than in adults. There are 10 countable rings above the sternal notch in newborns, eight countable rings in adolescents, and six or fewer in adults. Compared to the trachea of an adult, in infancy, the trachea constitutes approximately 50%, 36% and 15% of the length, diameter and cross-sectional area. The growth pattern of the trachea is still a matter of dispute [4]. In 1986, Griscom et al. analysed approximately 130 children regarding the trachea's length, diameter and cross-sectional area. The study participants were children under six years old, and the necessary measurements were made using computed tomography. The study aimed to describe how length, diameter and cross-sectional area change over time from birth to adolescence. The research results indicated a doubling of the length of the trachea at the end of puberty [2].

Furthermore, the mean transverse diameter is wider than the mean anteroposterior diameter in children up to six years of age. These diameters later increase and become almost identical, causing the cross-section of the trachea to become more rounded. By 18, the anteroposterior diameters usually become slightly larger [2].

The bronchial tree begins in the trachea. It is an asymmetric and dichotomous system of bronchi and bronchioles. As we move along subsequent generations of the airway conduction system, we can see the progressive reduction of cartilage in their walls [4]. Therefore, smaller bronchioles with a diameter ≤ 1 mm do not have cartilage in their walls and are called terminal bronchioles. They form the last generation of the respiratory conduction system. The respiratory system remains potentially immature until the age of 5-8. It reaches maturity when the number of alveoli is or exceeds 300 million. It is worth noting that a newborn baby has only 20 million alveoli. When the number of alveoli reaches the same number as in adults, the unfavourable ratio of gas exchange surface area to the size of the entire body changes. A small cross-section and high resistance characterise the respiratory tract of infants and high chest and low lung compliance. As the infant gains muscle mass, the chest walls become stabilised, preventing them from being quickly deformed and, at the same time, leading to a decrease in the compliance of the chest walls while increasing the compliance of the lungs [5].

The circulatory system, like the respiratory system, is essential to an anesthesiologist when anesthetising children. Its great importance results from the risk of cardio-depression resulting from the use of certain drugs during anaesthesia. Newborns and infants usually have a relatively high heart rate of 100-160 beats/minute, with good tolerance of tachycardia up to 200 beats/minute. The presence of bradycardia in an infant is a bothersome symptom because it is most often a symptom of severe hypoxia [5-7]. In such a situation, oxygen therapy and atropine treatment are necessary. A proper parameter in assessing heart function is its output, which is proportional to the child's age, although, at rest, it is almost 2-3 times greater than in adults [5].

The kidneys do not mature until the baby's first year of life. However, complete liver function is achieved by the end of the third year of life. The stage of development of these organs affects the metabolism of drugs used during anaesthesia, especially in newborns and infants [5].

Another equally important organ for an anesthesiologist is the brain and the central and peripheral nervous system. Their development can be divided in children into two stages. The first occurs in the 15th-20th week of pregnancy, during which advanced proliferation of nerve cells occurs. During the second trial, which lasts 25th week-2 at age, glial cell growth, dendrite proliferation, myelination, and synaptogenesis occur. Unlike small children, newborns have the blood-brain barrier with the highest permeability [5]. On the one hand, anaesthesiologists can benefit from this fact because it allows them to quickly achieve an anaesthetic state after administering anaesthetics. However, on the other hand, it is hazardous because the mechanism of action of drugs may be unpredictable. The level of oxygen metabolism is of fundamental importance for brain activity, which in turn depends on cerebral blood flow, which is subject to autoregulation mechanisms very similar to those in adults. However, in the case of children, there is no precise data on the values of systemic and intracranial pressures [6].

It should be remembered that each child's development is individual. Therefore, when undertaking any treatment involving children, the treatment should be very carefully assessed and adapted, not only pharmacologically but non-pharmacologically, to each child's individual needs [6].

## Differences in pharmacological aspects

The prominent problem anaesthesiologists face is the limited number of documented indications, according to the FDA (Food and Drug Administration). It is estimated that as many as 50-70% of drugs are used outside the indications specified in the summary of product characteristics. Many factors determine the absorption and bioavailability of drugs in paediatric patients. These include the pH of gastric juice, the rate of gastric emptying and intestinal peristalsis, enzymatic activity (in the liver, the walls of the digestive

Table I. Anatomical differences between newborns/children and adults

| System | Newborn/Child | Adult | Clinical Implication |
|---|---|---|---|
| Respiratory System | - Smaller nasal passages, narrow nostrils, and highly vascularized mucosa → increased risk of airway obstruction with minimal swelling<br>- Obligate nasal breathing for the first six months of life<br>- Large tongue, short neck, and underdeveloped jaw → risk of airway obstruction<br>- High laryngeal position (C3-C4) and omega-shaped epiglottis, positioned more horizontally<br>- Shorter, more compliant trachea with a narrower diameter<br>- Higher resistance in airways and reduced lung compliance | - Larger airways and nasal passages<br>- Ability to switch easily between nasal and oral breathing<br>- More proportionate tongue and jaw size<br>- Lower laryngeal position (C5-C6)<br>- Longer, more rigid trachea with wider diameter<br>- More stable chest wall mechanics | - Increased risk of respiratory distress with nasal congestion<br>- Higher risk of airway obstruction due to tongue size and short neck<br>- Difficult direct laryngoscopy due to high laryngeal position and long epiglottis<br>- Rapid oxygen desaturation due to smaller functional residual capacity and higher oxygen consumption |
| Circulatory System | - Transition from fetal circulation still ongoing<br>- Higher resting heart rate (100-160 bpm)<br>- Cardiac output dependent on heart rate rather than stroke volume<br>- Reduced response to catecholamines<br>- Higher metabolic oxygen demand | - Fully developed circulatory system<br>- Lower resting heart rate (60-100 bpm)<br>- Cardiac output regulated by both heart rate and stroke volume<br>- More effective sympathetic response to stress | - Bradycardia leads to rapid cardiac output reduction<br>- Limited ability to compensate for volume loss<br>- Risk of cardiovascular depression with anesthetics |
| Nervous System | - Immature myelination and synaptic connections<br>- Increased permeability of the blood-brain barrier → increased sensitivity to anesthetic agents<br>- High cerebral oxygen consumption<br>- Poor autonomic regulation | - Fully developed nervous system<br>- Stable blood-brain barrier<br>- Lower cerebral oxygen demand<br>- Mature autonomic regulation | - Increased sensitivity to anesthetics and risk of central nervous system depression<br>- Greater susceptibility to hypoxia and hypoglycemia<br>- Potentially unpredictable drug responses |
| Renal System | - Immature glomerular filtration, tubular function, and concentrating ability<br>- Higher total body water content<br>- Increased risk of dehydration and electrolyte imbalances | - Fully developed renal function<br>- More stable fluid and electrolyte balance | - Prolonged drug elimination for renally excreted anesthetics<br>- Increased fluid requirements with a risk of volume overload |
| Hematologic System | - Higher fetal hemoglobin (HbF) concentration, leading to increased oxygen affinity but reduced tissue oxygen release<br>- Physiologic anemia in infancy<br>- Lower glycogen stores → risk of hypoglycemia | - Predominantly adult hemoglobin (HbA)<br>- Stable erythropoiesis<br>- More stable blood glucose levels | - Increased risk of hypoxia due to decreased oxygen delivery to tissues<br>- Need for glucose monitoring to prevent hypoglycemia |
| Hepatic System | - Immature hepatic enzyme activity → slower metabolism of drugs<br>- Reduced protein synthesis (e.g., albumin)<br>- Increased risk of hyperbilirubinemia | - Fully developed hepatic function<br>- Stable protein synthesis and drug metabolism | - Prolonged drug metabolism and elimination<br>- Increased free drug concentration for highly protein-bound anesthetics |
| Termoregulation | - Larger body surface area relative to mass<br>- Limited ability to generate heat (non-shivering thermogenesis via brown fat)<br>- Rapid heat loss due to thinner skin and increased evaporation | - More efficient thermoregulation<br>- Effective shivering and vasoconstriction mechanisms | - High risk of hypothermia during surgery<br>- Need for active warming measures (e.g., heated blankets, warm IV fluids) |

tract, and the kidneys), the throughput of the mucous membrane, the bacterial flora and the ability to produce bile. Younger children have a higher pH in the stomach and more intense intestinal peristalsis. High pH causes impaired absorption of weak acids. In contrast, drugs that have the properties of weak bases are absorbed to an excellent extent, which is also due to the accelerated motility of the gastrointestinal tract. The above-mentioned substances cause more significant absorption of, among others, phenobarbital in older children [6].

The main organ responsible for drug metabolism is the liver. The patient's age does not determine the degree of hepatic metabolism but depends on the type of enzymes that participate in metabolic processes. For example, the activity of cytochrome P-450 (CYP) enzymes and their isoenzymes, CYP3A4, CYP1A2 and CYP2C9, is much higher in children than in adults, which necessitates increasing the doses of drugs that are metabolised in this way. CYP2C19, CYP2D6, N-acetyl-transferase, and UDP-glucosyltransferase enzyme activity is similar in children and adults. Therefore, we can use the dosage schedule in paediatric patients as in adults. The activity of hepatic enzymatic pathways also depends on genetic conditions, specifically genetic polymorphism, which determines different gene expressions and, consequently, different clinical effects [6].

The concentration of free drugs in plasma depends on the degree of drug binding to proteins and the volume of distribution [6-8]. The concentration of plasma proteins, apart from pathological conditions such as liver and kidney failure and malabsorption syndromes, does not change significantly between the ages of 2 and 18. As the body matures, two factors change that affect the distribution of drugs. These include the content and distribution of water and fat tissue and the composition of plasma proteins, which change in pathological conditions and are primarily concerned with albumins. Their deficiency increases the free fraction of drugs that bind to albumin, which makes these drugs work more strongly. This applies, for example, to midazolam. The total body water content in full-term newborns (expressed as a percentage of the values observed in adults) decreases from 75% to 55% in 12-year-olds. This relationship increases the distribution of hydrophilic drugs in paediatric patients compared to adults. The distribution is also influenced by the body fat content. This, in turn, increases between the ages of 5 and 10. In boys, from the age of 10 until about the age of 17, the adipose tissue content decreases, while in girls, it increases during puberty. As the content of adipose tissue increases, the volume of distribution of lipophilic drugs also increases. When inhaled anaesthetic drugs are used, the child's age also has a significant impact on the minimum alveolar concentration [7].

## Pre-operative fasting

Preoperative fasting in children is a key element of preparation for anaesthesia, aimed at reducing the risk of aspiration of gastric contents during the procedure. Current recommendations for the duration of fasting are presented in table II [8].

Table II. New guidelines for preoperative fasting (so-called 6-4-3-1 rule)

| Type of solid/liquid consumed | Fasting time |
|---|---|
| Solid foods and cow milk | 6h |
| Formula milk | 4h |
| Breast milk | 3h |
| Clear liquids (water, tea, juices without pulp) | 1h |

It should also be emphasised that shortening the preoperative fasting time for clear fluids does not increase the risk of aspiration. It may help reduce the child's discomfort and the risk of hypoglycemia. Evidence-based recommendations, particularly those concerning preoperative fasting, should be consistently followed in clinical practice. Therefore, current evidence-based recommendations- particularly those concerning clear fluids- should be consistently and strictly followed in clinical practice, rather than adjusted individually without medical justification. Ensuring adherence to these guidelines enhances both patient safety and comfort.

## Premedication

Before performing anaesthesia, the anesthesiologist must conduct an anaesthetic consultation [8]. It is essential to ensure the mental comfort of the paediatric patient. It can be obtained by examining the presence of parents in a room equipped with toys, books and other distractors that will allow the child to focus on things that are not the subject of the doctor's visit [8]. The doctor's approach to the minor is essential. The anesthesiologist should gain the child's trust through positive conversation, interest in him, patience and willingness to answer questions. During such a visit, it is crucial to collect a complete medical history and thoroughly examine the patient; for this purpose, a special questionnaire is prepared, which helps obtain all the necessary information regarding the perinatal period, congenital disabilities, comorbidities, diseases or genetic defects occurring in the family, as well as previous anaesthesia and surgery and current disease [8-10]. If the interview or physical examination raises doubts, the child should be referred for additional tests or specialists in other fields should be consulted [8].

Premedication aims to calm the child down and achieve cooperation, eliminate anxiety and stress, and reduce vegetative reflexes. The short-acting benzodiazepine-midazolam is very popular [8]. It is often administered 30-60 minutes before anaesthesia in syrup for younger paediatric patients and tablets for older paediatric patients. Midazolam is a specific drug with high pharmacodynamic variability. Midazolam can be administered in various ways. It is often administered orally at 0.25-0,5mg/kg body weight (usually 0.5 mg/kg body weight max. 7,5 mg). Most often, the effect is achieved after 15-30 minutes of administration, and the duration of action is 30-90 minutes. Intravenous administration is also possible. The dose in this case is 0.05 mg-0.1 mg/kg body weight (max. 2-5 mg per dose). Intravenous administration provides rapid action (1-5 minutes). It is used for premedicationand procedural sedation. The dose can be repeated every 2-3 minutes. Therefore the dose of this drug is titrated in the youngest patients, which is the safest method. The dose is titrated for intravenous administration by gradually increasing every few minutes, assessing the sedative effect. There are other administration methods, such as intranasal, buccal, and rectal, but they are less commonly used than previously mentioned. Only lipophilic substances can pass through the blood-brain barrier, so consider the proportions of lipophilic and hydrophilic substances included in the syrup. In recent years, significant agitation of minor patients after benzodiazepines has been reported. Therefore, drugs from the group of α-2 receptor agonists are becoming more and more popular. In this group, the most important are dexmedetomidine and clonidine, which allow the child to calm down, eliminate vegetative symptoms, and reduce pain without causing disturbances in the respiratory and circulatory systems. All three previously mentioned, midazolam, dexmedetomidine and clonidine, can be administered intranasally. This is particularly important in endoscopic gastrointestinal tract procedures and in situations where oral drug administration is not possible. Atropine is not recommended for newborns and infants. However, a syringe with a solution of this drug is always prepared before starting anaesthesia due to the risk of vagal reflex that may occur during intubation [9].

## Anaesthesia in children – practical aspects and current recommendations

Induction of general anaesthesia can be achieved by inhalation, intravenously, or- less commonly- via alternative routes such as rectal or intranasal administration. The safest way, especially for inexperienced doctors, is intravenous route, however due to problems with iv access and/or patient's reluctance to injections some paediatric centers prefer inhalational induction in the majority of cases. In clinical practice, the choice of induction technique depends not only on the child's age and cooperation, but also on institutional preferences and the experience of the anaesthesia team. Understanding the practical implications of both intravenous and inhalational approaches, along with their indications, contraindications and current guidelines, is essential for ensuring safety and efficacy in paediatric anaesthesia.

Contraindications to the use of inhalation induction are patients with a high risk of regurgitation, risk of malignant hyperthermia and the child's fear of the mask. There are three methods of inhalation induction. The first involves gradually increasing the inhalation agent, the second uses normal tidal volumes, and the third uses high concentrations of the anaesthetic from the beginning. Only sevoflurane is safe for induction of anaesthesia by inhalation. The others may negatively affect the respiratory system and even lead to respiratory depression. Current approach to oxygenation before inhalation induction in healthy children (without risk of hypoxia): several deep breaths (4-8 breaths in 30-60 seconds) of 100% oxygen before induction are sufficient. As for longer oxygenation, it does not provide significant benefits and may cause discomfort. In children at risk of hypoxia (e.g. premature babies, children with lung diseases, obesity), oxygenation for 1-2 minutes is indicated to extend the time of safe apnea. CPAP or manoeuvres increasing FRC (functional residual capacity) are also used. After that sevoflurane is used at a concentration of 5-6%. 6% of sevoflurane in patients breathing independently and 5% during assisted ventilation is not recommended. 1.5 times the minimum alveolar concentration should not be exceeded to maintain anaesthesia due to the risk of convulsions and abnormal EEG (electroencephalography) recordings, which may be accompanied by a sudden increase in blood pressure and pulse rate in the anaesthetisedchild. Sevoflurane inhalation may be started immediately with oxygen withoutpreoxygenation if the patient is not at high risk of desaturation. Prolonged administration of 100% oxygen may lead to absorptive atelectasis and paradoxically increase the risk of desaturation after induction. Themost popularof all inhalation anaesthetics in the paediatric patient group is sevoflurane [10]. It enables gentle and safe insertion of a laryngeal mask or endotracheal tube (at sufficiently deep level of anaesthesia). It is worth mentioning that intubation in paediatric patients is mandatory for procedures lasting more than an hour, performed in the side or stomach position, and for procedures involving the head and neck, and it is always done in premature infants [11].

Maintenance of anaesthesia is typically achieved using a mixture of oxygen and air or oxygen and nitrous oxide, with an inspired oxygen fraction (FiO2) tailored to the child's needs. While children have a higher oxygen demand than adults, excessive oxygen concentrations (e.g., 100% O2) are generally avoided to prevent oxygen toxicity and absorption atelectasis. A FiO2 of 30-50% is often sufficient to ensure adequate oxygenation [11]. The administration of 100% oxygen for a prolonged period can lead to several serious complications, especially in children more sensitive to changes in lung ventilation and perfusion. One of the most serious complications is absorption atelectasis. Nitrogen (N2) acts as a "support gas". It is not absorbed and stabilises the alveoli. Administration of 100% oxygen causes alveoli to flush nitrogen out. Oxygen is rapidly absorbed into the blood, leading to alveolar collapse and atelectasis [12]. This is not the only complication of long-term oxygenation with 100% oxygen. In addition to absorption atelectasis, oxidative stress and tissue damage may also occur. Excess oxygen promotes the formation of reactive oxygen species (ROS), damaging cell membranes, DNA and proteins. In turn, damage to the epithelium of the lung alveoli leads to inflammation and the development of pulmonary oedema [11-14]. In addition, the respiratory centre may also be inhibited, especially in children with chronic hypercapnia (e.g. in neuromuscular diseases). Usually, in a healthy organism, ventilation is controlled mainly by pCO2. However, in patients with chronic hypercapnia (e.g. children with bronchopulmonary dysplasia), the respiratory centre switches to oxygen-dependent regulation (hypoxic respiratory drive). Sudden administration of high FiO2 eliminates the stimulus to breathe, and then apnea and hypercapnia occur. Excess oxygen may also increase the risk of hypoxia in some organs. Hyperoxia leads to cerebral and coronary vasoconstriction. In patients at risk of ischemia (e.g., neonatal asphyxia), this may impair tissue perfusion. This may impair tissue perfusion [15]. It may increase oxidative stress, leading to cellular damage. Data on sevoflurane's cardioprotective or neuroprotective effects are limited in this age group. Further studies are needed to evaluate its benefits fully. Desflurane is the drug of choice in children with renal or hepatic impairment because it is not metabolised. It also has the shortest wake-up time among other anaesthetics [11]. There are cases of excessive psychomotor stimulation after its use. Inhalation anaesthesia should be administered together with an opioid analgesic and, if necessary, a muscle relaxant [12].

Intravenous induction of anaesthesia is preceded by thorough local anaesthesia of the skin using Emla cream, which contains 2.5%lidocaine and 2.5%prilocaine or another drug that will help us anaesthetise the planned injection sites [12]. Propofol is most frequently used in the induction of intravenous anaesthesia, at a dose depending on age, higher in younger patients [12-15]. Administration of a lipid solution of propofol is quite an unpleasant experience for children because its administration may cause pain at the injection site, especially if smaller veins are used. That is why, if possible, it is preferred to choose a large vein in the elbow bend. Optionallylidocaine, a small dose of an opioid, or ketamine can be additionally administered. Propofol has many advantages. Its use allows for smooth application of the laryngeal mask airway. It is a drug that has the fastest hypnotic effect, but its limitations are a narrow safety margin, cardio-depressant effect and deepening sedation or anaesthesia accompanied by respiratory depression, which requires respiratory support in more than half of young patients. Thiopental was also used in paediatric anaesthesia, but its use is currently limited due to the availability of newer agents with a better safety profile.Ketamine is also an important drug used for iv induction. It belongs to the group of lipophilic drugs; therefore, it quickly penetrates the blood-brain barrier [12]. Unless administered too quickly, it does not depress the circulatory and respiratory systems, on the contrary, by sympathetic stimulation its use can lead rto the increase in heart rate, blood pressure and bronchial dilation. It provides an anaesthetic and an analgesic effect. This drug is beneficial in children who are in a serious condition, such as shock or respiratory failure, during short and painful procedures, as well as for premedication before conducting anaesthesia [13]. Ketamine may be administered not only intravenously, but also intramuscularly or orally, which makes it especially useful in children with difficult venous access. Although it shares certain clinical effects with $\alpha_2$-agonists, such as sedation and analgesia, it does not act via $\alpha_2$-adrenergic receptors; its primary mechanism of action is NMDA receptor antagonism. One of its potential adverse effects is emergence agitation or hallucinations, particularly in older children. However, this is less common in younger patients and can be mitigated by the co-administration of benzodiazepines. Due to its combined anaesthetic and analgesic properties, haemodynamic stability, and airway reflex preservation, ketamine remains a valuable agent for induction of anaesthesia, especially in some situations like haemodynamic instability or short, but painful procedures. [16]. Atropine in children can only be used in cases of reflex bradycardia. The routes of atropine administration are very diverse, and it can be administered intravenously, orally, intranasally and rectally. The following opioid painkillers may be administered during surgery: fentanyl, alfentanil, sufentanil and remifentanil. Fentanyl and its analogue alfentanil have no age restrictions. It is not recommended for epidural use in children under 1 year old [13]. Even though remifentanil is registered with the FDA from the neonatal period, in Poland, it is registered from 6 months. It also has favourable PK/PD (pharmacokinetic and pharmacodynamic properties) in newborns and infants. Its serum concentration is reduced by 50% after just 3-4 minutes, thus reducing the risk of postoperative respiratory depression. However, it is necessary to give the patient painkillers very early(preemptive analgesia),so that the child does not wake up due to pain. Administration of myorelaxants allows to achieve optimal conditions for intubation as well as to ensureproper muscle relaxation during surgery [14].

When choosing analgesia methods, we should consider the child's age, previous pain experiences, type of surgery, expected intensity and duration of pain. Drugs should be administered at regular intervals, according to their pharmacokinetics characteristic for individual age groups, or by continuous infusion, which ensures a constant concentration of analgesics in the blood and a practical analgesic effect. A prudent method of administering analgesics is required in children, equivalent to eliminating the intramuscular route (the intramuscular route is generally contraindicated in children). The route of administration of analgesics should be comfortable for the patient and should take into account their swallowing capabilities and the presence of an intravenous catheter. The most commonly used routes of administration of analgesics are intravenous and oral. Suppose we decide to use the intravenous route. In that case, we can use the following methods: the first one involves repeated single doses of analgesics at regular intervals, the second option is a continuous infusion, including the widely used PCA (Patient Controlled Analgesia) option or the third most preferred in paediatric intensive care units (ICUs) method NCA (Nurse Controlled Analgesia). In the recommendations for postoperative analgesiaalso, continuous subcutaneous supply of analgesics (e.g. morphine) is mentioned. This recommendation particularly applies to palliative patientsin out of hospital setting. Transdermal patches can also be used [17]. In the youngest, if both oral or intravenous routes are unavailable, the rectal route can be used in such a situation. It should be avoided in immunosuppressed patients because it can lead to the formation of perianal abscesses. Alternative routes of administration are intranasal or transmucosal (buccal, sublingual).

Rectal induction is used in case of problemswiththe inhalation or intravenous method. An example of such a situation may be the occurrence of autism or cerebral palsy in a child. Nasal induction is used during premedication or procedural sedation. There are increasing reports that this route is an effective and safe method of anaesthesia [18].

## Maintenance of anaesthesia

Anaesthesia is maintained by continuation by inhalation or intravenously, supplemented with analgesics and muscle relaxants, depending on the patient's condition, type of surgery, available equipment and the choice and experience of the anesthesiologist [19].

## Analgesia

Intraoperative analgesia should always be planned individually, combining systemic and regional techniques where appropriate.

The most common route of analgesic drug administration in the perioperative period is intravenous, but oral, and less commonly rectal (as unpleasant to the children and the least predictable), can be used as well [20-22]. In pain therapy, it is vital to both achieve an analgesic effect and monitor the patient's safety while using analgesics. This is the so-called holistic, or in other words, a comprehensive approach to a patient's therapy, for whom improving the comfort of life and wellbeing through painkillers should be as crucial as excluding complications related to analgesia.Doctors, in cooperation with pharmacists, develop pain treatment regimens of various intensities by analysing the interaction of drugs and medicinal substances [22]. For this purpose, multimodal analgesia is used, a combination of several medicinal substances. The administration of an analgesic should be adjusted to the patient's comfort, considering their current abilities, e.g. in terms of swallowing and the presence of an intravenous line. This is the most common route of drug administration immediately after surgery in paediatric patients [23].

Regional anaesthesia techniques are highly recommended in paediatric surgery whenever not contraindicated. According to recent Polish expert guidance, these techniques- including epidural, spinal, or peripheral nerve blocks- should be considered standard practice in most operations, unless specific contraindications exist (e.g. ENT or neurosurgery) [24]. Regional approaches are associated with effective intraoperative analgesia, reduced systemic opioid use, enhanced postoperative comfort, and shorter recovery times. Observational data (APRICOT) show that despite strong recommendations, regional techniques are underutilized in children, with usage rates around only 31% across Europe, and below 5% in some centres, including in Poland [22]. Establishment of "Paediatric Plan A" blocks by the Regional Anaesthesia-United Kingdom (RAUK) highlights seven essential regional techniques that every anaesthesiologist should master to ensure high-standard care [24].

Local infiltration of the surgical wound with local anaesthetic is also very effective [23]. The preferred time to perform it is before the skin incision is made or at the end of the procedure [25].

## Anaesthetic agents – intravenous and inhalational

General anaesthesia in children may be maintained using either total intravenous anaesthesia (TIVA) or a combined approach with inhalational agents and intravenous drugs.

The choice between these techniques depends on the duration and type of surgery, patient characteristics, available equipment, and anaesthesiologist experience. Inhalational anaesthesia using sevoflurane remains the most common technique in paediatrics due to its favourable profile-non-irritating, rapid onset and offset [26]. In selected cases, desflurane may be used, particularly when rapid awakening is desirable, although psychomotor agitation has been reported. TIVA with propofol is an alternative, especially in older children or when avoidance of inhalational agents is indicated. Anaesthetic maintenance is usually accompanied by opioids and, if necessary, neuromuscular blocking agents [27].

## Neuromuscular blockade

Muscle relaxants are often used during maintenance of anaesthesia to improve surgical conditions and facilitate intubation.

During maintenance of anaesthesia, muscle relaxants are also commonly used. For short procedures, mivacurium should be considered. Its half-life in children is 5-10 minutes. The short time of action makes this drug controllable. Mivacurium, like all benzylisoquinoliniums, may cause histamine release, which in children will manifest as skin redness and erythema, while the clinical significance of the hemodynamic effects is limited. It is also worth adding that mivacurium is contraindicated in children with asthma. When neuromuscular blockade is necessary, mivacurium is particularly useful in short procedures, lasting less than 10 minutes in the operating room or the paediatric Intensive Care Unit. For longer procedures lasting between 30 and 60 minutes, the administration of atracurium, cis-atracurium, vecuronium (currently unavailable), or rocuronium is preferred [28]. In some paediatric cases, the reversal of residual block is indicated, which persists after vecuronium in 64% and after rocuronium in 34%, which allows for reducing the risk of postoperative apneas, aspiration of gastric contents and the risk of hypoxia [28]. Sugammadex is a cyclodextrin that forms a complex with the rocuronium or vecuronium molecule in plasma, neutralising its action and allowing rapid recovery of muscle function. Unfortunately, it does not act on all the muscle relaxants (it does not reverse atracurium, cis-atracurium, and suxamethonium). Succinylcholine is the only drug in paediatric anaesthesia that has a depolarising effect and is characterised by a postsynaptic grip site. The duration of action of this drug is shorter in paediatric patients than in adults. It happens that after the administration of succinylcholine in children up to 6 years of age, the concentration of myoglobin and creatine kinase in the plasma may increase. Muscle tremor and myalgia also occasionally appear. For these reasons, if we decide to administer this drug to younger children, there is the possibility of using it in an undiagnosed child who suffers from a disease of the neuromuscular system, which may cause rhabdomyolysis, hyperkalemia or metabolic acidosis. It is also contraindicated in patients with a history of malignant hyperthermia, recent major burns, spinal cord injuries, or immobilisation. For this reason, this drug is used in scarce situations, such as rapidly bleeding tonsils [29].

## Fluid therapy

Intraoperative fluid therapy in children should be tailored to age, weight, clinical condition, and metabolic needs.

During surgery, children should be given multi-electrolyte, balanced isotonic fluids, additionally containing glucose, but it all depends on the age and condition of the patient. Newborns and premature babies have a higher risk of hypoglycemia due to limited glycogen stores and immature metabolism. In their case, fluids containing 5-10% glucose are often recommended, but administered in a controlled manner to prevent hyperglycemia. Current recommendations indicate that full-term newborns should receive isotonic fluids, e.g. balanced electrolyte 5% glucose. Premature newborns often require fluids containing 5-10% glucose at maintenance rate or slightly less to prevent hypoglycemia. Intraoperative fluid losses are replaced with balanced isotonic fluids without glucose. It means that neonates often require 2 simultaneous infusions of fluids. Infants have a better-developed ability to regulate blood glucose, so balanced fluid with 1% glucose or glucose-free isotonic fluids are appropriate. However, in prolonged surgeries it is essential to control glucose levels and adjust fluid therapy to individual needs [19]. According to Polish guidelines, newborns under 3 years of age generally do not require glucose intraoperatively unless specific conditions indicate otherwise [30].

Children over one year usually do not require glucose in infusion fluids unless they have specific metabolic needs, for example children with carbohydrate metabolism disorders, malnourished, or on parenteral nutrition preoperatively [20].

## Awakening

Currently the drugs and gases used in anaesthesia are easily controllable, therefore awakening is usually a result of their discontinuation and reversal of their action is rarely needed.

Waking up primarily involves restoring the cough reflex and efficient independent breathing. Hypothermia, hypovolemia and hypoglycemiashould

Table III. Doses of drugs used for anaesthesia in paediatric patients divided into age groups

| Drug | Neonates (0-28 days) | Infants (1-12 months) | Children (1-12 years) | Adolescents (12-18 years) | Route |
|---|---|---|---|---|---|
| Propofol | 2-3 mg/kg | 2.5-4 mg/kg | 2-3 mg/kg | 1.5-2.5 mg/kg | iv |
| Thiopental | 3-4 mg/kg | 4-6 mg/kg | 3-5 mg/kg | 3-5 mg/kg | iv |
| Ketamine | 1-2 mg/kg | 1.5-2 mg/kg | 1-2 mg/kg | 1-2 mg/kg | iv |
| Fentanyl | 2-3 ug/kg | 1-5 ug/kg | 1-5 ug/kg | 1-2 ug/kg | iv |
| Midazolam | 0.05-0.1 mg/kg | 0.1 mg/kg | 1 mg (fractionated doses) | po 1-2 mg | iv |
| Rocuronium | 0.4-0.6 mg/kg | 0.6-1 mg/kg | 0.6-1 mg/kg | 0.6-1 mg/kg | iv |
| Succinylcholine | 2-(3) mg/kg | 2 mg/kg | 2 mg/kg | 1-2 mg/kg | iv |

Table IV. Selected drugs administered to paediatric patients in Postanaesthesia Care Units and Intensive Care Units, divided into age groups with specified doses

| Drug | Neonates (0-28 days) | Infants (1-12 months) | Children (1-12 years) | Adolescents (12-18 years) | Route | Comments |
|---|---|---|---|---|---|---|
| Paracetamol | 7.5-10 mg/kg every 6-8h | 10-15 mg/kg every 6h | 15 mg/kg every 6h | 15 mg/kg every 6h (max 1 g/dose) | iv/po/pr | Max 60 mg/kg/day/ max 4g iv |
| Ibuprofen (approved for IV use in children >6 years old, approved for rectal/oral use in children >3 months old) | Not recommended | 5-10 mg/kg every 8h | 5-10 mg/kg every 8h | 200-400 mg every 8h | iv/po | Max 30 mg/kg/day |
| Metamizole | Not recommended | 10-15 mg/kg every 6-8h | 10-15 mg/kg every 6-8h | 10-15 mg/kg every 6-8h (max 1 g/dose) | iv/po | Use restricted in some countries; monitor for agranulocytosis |
| Morphine | 5-30 mcg/kg/h | 10-50 mcg/kg/h | 10-50 mcg/kg/h | 10-50 mcg/kg/min | iv | Adjust dose for renal impairment |
| Morphine | 0.05-0.1 mg/kg every 4-6h | 0.1 mg/kg co 4h | 0.1 mg/kg every 4h | 0.1 mg/kg every 4h | iv | Slow injection 10-20 min |
| Fentanyl | 1-5 ug/kg/h | 1-5 ug/kg/h | 1-5 ug/kg/h | 1-5 ug/kg/h | iv | Used in continuous infusion |
| Ketamine | 1-2 mg/kg loading dose, then 5-20 ug/kg/min infusion | 1-2 mg/kg loading dose, then 5-20 ug/kg/min infusion | 1-2 mg/kg loading dose, then 5-20 ug/kg/min | 1-2 mg/kg bolus, then 5-20 ug/kg/min | iv | Used mostly as mean to deepen sedation eg. succioning of the airways or for procedural analgesia and sedation, rarely as an infusion |
| Dexmedetomidine | 0.1-1.5 ug/kg/h infusion | 0.2-2 ug/kg/h infusion | 0.2-2 ug/kg/h infusion | 0.2-2 ug/kg/h infusion | iv | Used in ICU sedation/analgesia. Beware of bradycardia |
| Remifentanyl | 0.05-0.5 ug/kg/min | 0.05-1 ug/kg/min | 0.05-1 ug/kg/min | 0.05-1 ug/kg/min | iv | Ultra-short acting opioid |
| Tramadol | Not recommended | Not recommended | 1-1.5 mg/kg every 6h | 50-100 mg every 6h | iv/po | Only hospitalised children |

** maximal opioid doses are approximated as the upper limit is usually titrated to effect
Strong opioids like fentanil, sufentanil, remifentanil as well as high doses of morphine infusions are given to patients who are mechanically ventilated.

be prevented, as they interfere with the proper course of waking up the patient. They may enhance postoperative apneas, laryngeal or bronchospasm, and prolonged metabolism of anaesthetic drugs, including muscle relaxants [29]. The necessary steps to be taken include adequate warming of the child, , oxygen therapy and, if needed, reversal of the neuromuscular block. The decision to reverse muscle relaxation should be based on neuromuscular monitoring and clinical assessment, as its routine use is not always required. It is important to choose an appropriate moment of extubation of the patient's trachea. There are generally two technics-either when a patient is fully awaken or in a patient asleep, but breathing spontaneously. Extubation should be avoided during agitation phase or when a patient is only coughing, but respiratory drive is still suppressed.

## Postoperative management

Postoperative period is challenging especially in the youngest patient, as anxiety is common and its causes are often not evident. They can include eg. pain, thirst, hunger, full urinary bladder in case of urinary retention, uncomfortable position, separation from the parents. Anxiety can also result from metabolic (eg. hypoglycemia) or electrolyte (eg hyponatremia) abnormalities. Therefore it is vital to recognize and treat the cause of the patient's anxiety. If other causes have been excluded, postoperative delirium, most common after sevoflurane anaesthesia, should be taken into consideration.

As pain is the main reason of postoperative discomfort, this should be always taken into consideration in the first place. In order to address this issue adequately, it is obligatory to regularly assess the intensity of pain in children. There are appropriate pain scales that can be used even in the youngest babies, whereas in older children the same pain assessment scales are avalable than those used in adults. Pain should be assessed frequently – at least every 3 hours, and additionally whenever a child's clinical condition changes or a new intervention is introduced. Paediatric anaesthesiologists should follow the principle that the child must not feel pain after waking up. The paintreatment should be implemented before surgery – the so-called advanced preemptive analgesia [29].

It is important to know the pharmacology of painkillers in different age groups. If regional anaesthesia is initiated during general anaesthesia – particularly using continuous techniques – it can significantly reduce the need for systemic analgesics in the postoperative period. The most important principle for pain relief in children is multimodal analgesia, which is achieved by combining drugs and techniques aimed at the mechanisms of generation, transduction, and perception of the nociceptive stimulus. As a result of the synergistic action of various drugs, it is possible to achieve adequate analgesia while minimising the risk of adverse effects. Recommendations indicate the critical role that opioids play in the treatment of severe and moderate pain. Drugs are most often administered intravenously [31].

Postoperative pain relief in children should follow a stepwise, multimodal approach, as recommended by the 2022 Polish national guidelines on acute pain management in paediatrics (PTAiIT). The selection and sequence of medications are determined by pain intensity, patient age, and comorbidities.

Paracetamol is the first-line analgesic and is recommended for use in children of all ages. It should be administered regularly (rather than on-demand) to ensure effective baseline analgesia, as highlighted in the 2022 Polish guidelines for acute pain management in children.

Metamizol is commonly added to paracetamol in moderate or severe pain. It may be administered orally or intravenously, and it shows synergistic effects with NSAIDs and opioids. It is widely used and considered safe in paediatric populations under appropriate monitoring.

Non-steroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen, naproxen, ketoprofen, diclofenac, and selective COX-2 inhibitors (e.g. celecoxib) are added next, typically in children over 3 months of age and only if there are no contraindications (e.g. renal failure, dehydration, coagulopathy). They are effective in all types of pain (mechanical, visceral, inflammatory). NSAIDs achieve their analgesic effect by inhibiting prostaglandin synthesis, inducible nitric oxide synthase, and substance P. Several NSAIDs should not be combined due to increased risk of adverse effects [27].

Morphine is the most commonly usedμ-receptor agonist. It is the so-called gold standard to which the effects of other opioids are compared. In children, as in adults, its pharmacokinetics are the same. However, their doses should be reduced for premature babies and newborns due to the immature liver and kidneys, as well as it must be remembered that these patients need to be monitored while receiving morphine (and other opioids) because of the risk of apnea [31]. Exceeding the recommended dose may result in the accumulation of the active metabolite of morphine, which may manifest itself in respiratory failure.

Sufentanil is an opioid with a potency 1000 times greater than morphine and a potency 10 times greater than fentanyl [32]. It is used postoperatively only in mechanically ventilated patients, in such a case continuous intravenous infusion is preferred for administration.

Oxycodone has a strong analgesic effect. It is an agonist of μ, κ, and δ receptors. It is available in both oral and intravenous forms. In Poland, it is registered in children over 12 years of age [32]. However, like many other analgesics in paediatric practice, it may be used off-label in younger children based on clinical judgment and local standards of care.

In paediatric analgesia, drugs with an agonist-antagonist mechanism also play a significant role. These drugs are characterised by a so-called ceiling effect, which means that increasing the doses of drugs does not cause the risk of respiratory failure.

Unfortunately, increasing the doses of drugs does not increase the effectiveness of pain management. Therefore, these drugs are used in the treatment of postoperative pain of low and medium intensity. The most commonly used drug from this group is nalbuphine. Unfortunately, it has an antagonist effect on the μ receptor, which reduces the effectiveness of analgesia with rescue doses of full agonists [32].

Tramadol is a weak opioid that inhibits the reuptake of noradrenaline and increases the release of serotonin. Due to the high risk associated with the use of this drug, its use has been banned in the US, explaining the lack of sufficient studies to confirm its safety. It is approved for use in European children but only in hospitals. Tramadol interacts with other drugs, such as ondansetron or metoclopramide. Giving a child metoclopramide during tramadol treatment exposes them to the risk of seizures [32].

It is essential to emphasise that undertreated pain in children can lead to significant physiological stress responses, such as hypertension and hyperglycaemia, which may in turn increase the risk of postoperative complications. Poor pain control may also contribute to pulmonary complications such as atelectasis and pneumonia, especially when pain limits effective coughing and mobilisation.

In terms of the use of non-opioid drugs, we can say that they are a heterogeneous group of drugs that have analgesic and antipyretic effects, some of them also inflammatory. This group includes paracetamol, metamizole, non-steroidal anti-inflammatory drugs, and selective cyclooxygenase 2-COX-2 inhibitors (celecoxib) [32].

Gabapentinoids are primarily used in the treatment of chronic neuropathic pain in children and adolescents. Although there are some suggestions regarding their use in acute pain management as part of multimodal analgesia, such use remains off-label and is not supported by sufficient paediatric evidence. However, it is necessary to emphasise that such action is “off-label” [32]. These drugs are also used in multimodal analgesia in the perioperative period as part of premedication. Their action is to inhibit the occurrence of hyperalgesia and allodynia, exerting only a minor influence on the process of pain perception.

Corticosteroids can also be administered in the treatment of pain. Their anti-inflammatory effect is based on inhibiting the formation and release of proinflammatory cytokines. They stabilise the cell membranes of neurons in peripheral tissues and have an antinociceptive effect at the spinal level. The most frequently chosen corticosteroid is dexamethasone, especially for procedures in the head and neck area that last more than an hour. Dexamethasone at a dose of 0.1-0.5 mg/kg reduces pain intensity and also reduces the need for opioids in the postoperative period. It also has an antiemetic effect [32].

Postoperative nausea and vomiting (PONV) are among the most common complications following anaesthesia in children. Risk factors include a personal or family history of motion sickness, older age (especially school-aged children and adolescents), and specific surgical procedures such as strabismus, otolaryngological, or orchidopexy surgeries. Prophylactic treatment is recommended in children at high risk and typically includes dexamethasone, ondansetron, or their combination. When PONV occurs despite prophylaxis, treatment involves re-dosing antiemetics and ensuring adequate hydration. Another complication worth mentioning is stridor, most commonly post extubation. The most effective management consists of nebulized adrenaline, sometimes also corticosteroids are used.

## Postoperative fluid therapy

The goals of postoperative fluid therapy are to maintain normovolemia, compensate for intraoperative losses, ensure adequate hydration and electrolytes, and maintain normoglycemia. The recommended management is the administration of isotonic balanced solutions containg glucose. As there is only one such fluid commercially available- but it only contains 1% glucose (benelyte) so it is adequate for older children. In younger patients recommended fluid should be provided by hospital pharmacy if it is not possible, it should be prepared in sterile conditions by adding 40% glucose to isotonic fluid to obtain 4-5% glucose in ypunger children and infants and 10% glucose in neonates. As ADH secretion is induced by stress associated with surgical trauma and may be inadequately increased also in the postoperative period, the free water excess elimination can be impaired. Therefore hypotonic fluids (5%glucose, 5%glucose/0,9% NaCl 2:1/4:1) are contraindicated as they increase the risk of acute hyponatremia, the commonest electrolyte abnormality in hospitalized children. It can happen even if isotonic fluids are used. Inacreased levels of

ADH also decreases children's essential fluid requirement by 30-50% so fluid restrictionsare recommended if there are no ongoing fluid losses. The consequence of this phenomenon is the need to reduce the volume of calculated fluids by half based on the Holliday and Segar rule [25].

Table V. Daily fluid requirements according to the Holliday-Segar rule

| Child's body weight | Daily requirement | Per hour |
|---|---|---|
| 0-10 kg | 100 ml/kg | 4 ml/kg/h |
| 10-20 kg | 1000 ml +50 ml/kg > 10 kg | 2 ml/kg/h |
| >20 kg | 1500 ml + 20 ml/kg > 20 kg | 1 ml/kg/h |

In postoperative practice, 70-80% of the norm is often used, especially in the first 24 hours after surgery.

## Summary

When performed by an experienced paediatric anaesthesiologist in appropriate conditions, general anaesthesia in children is considered fundamentally safe, although not entirely risk-free. This has been confirmed by large multicentre studies such as APRICOT and NECTARINE, which have contributed significantly to our understanding of perioperative risks and outcomes in the paediatric population. Noteworthy, mortality related to anaesthesia in children is extremely rare, and the risk of death as a complication of anaesthesia is minimal. Nevertheless, safe anaesthetic management requires careful preparation, ongoing monitoring, and a multidisciplinary approach that includes effective fluid therapy, pain control, and prevention of postoperative nausea and vomiting. Modern paediatric anaesthesia, based on current recommendations and adapted to the individual needs of the child, can ensure not only physiological stability but also psychological comfort for both the patient and their caregivers.

Conflict of interest
None

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Table VI. Types of fluids

| Type of fluid | When to use | Composition | Comments |
|---|---|---|---|
| Balanced = Isotonic multi-electrolyte fluids (e.g. Ringer's lactate solution, Plasmalyte solution, Optilyte, Sterofundin) | The standard in hydration | Similar to plasma, (without glucose, without proteins) | Recommended instead of 0.9% NaCl in the majority of clinical situations |
| 0.9% NaCl | Sodium loss, vomiting, metabolic alkalosis | Only Na+ and Cl- | Risk of hyperchloremic acidosis |
| Balanced Fluids with added glucose 1-10% | Newborns, infants, children-standard fluid postoperatively (the younger the patient the higher glucose concentration needed) | Water, electrolytes, glucose | In Poland commercially available only Balanced fluid with 1% glucose (Benelyte) |
| Glucose 10%<br>2-3ml/kg iv bolus | Treatment of hypoglycemia | Lack of electrolytes | Never as the only hydration fluid |

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