SPECIAL ARTICLE

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# The consensus statement of the Section of Paediatric Anaesthesiology and Intensive Therapy of the Polish Society of Anaesthesiology and Intensive Therapy on anaesthesia in children under 3 years of age

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Anaesthesia in a small child up to 3 years of age is a challenge for every anaesthesiologist. The specificity of this group of patients, especially newborns and infants, results primarily from differences in physiology, anatomy, and immaturity of individual organs, which results in different pharmacokinetics and pharmacodynamics of drugs used in anesthesiology. This is the reason for the significantly higher incidence of critical events during anaesthesia in children compared to the adult population [1–4].

According to data from the Anaesthesia PRactice in Children Observational Trial (APRICOT) published in 2018, the incidence of critical events, both respiratory and cardiovascular, in children undergoing anaesthesia in Europe was 5.3%. The data was collected from 261 hospitals in 31 European countries and covered a group of over 30,000 children undergoing anaesthesia in these centres. Critical respiratory events dominated, but the incidence of cardiovascular adverse events in this study also reached a significant percentage of 1.9% [1].

The younger the child, the greater the likelihood of such events occurring. This was confirmed by the results of another multicentre European study, The NEonate-Children sTtudy of Anaesthesia pRactice IN Europe (NECTARINE), which analysed these events in the population of the youngest children, under 3 months of age. In this group of patients, as many as 35.3% of critical events requiring anaesthesiologist's intervention were recorded [2].

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Risk factors for adverse/critical events included:
- child's age (< 3 years),
- comorbidities,
- current physical condition.

These three indicators had a statistically significant impact on the incidence of complications.

In turn, a factor that reduced the risk of complications, especially in the most seriously ill children – and which received special attention – was the experience of the anaesthesiologist administering anaesthesia to the child. Each year of additional work experience with children reduced the risk of both critical respiratory and circulatory events by 1% [1].

The safety of children undergoing anaesthesia is therefore based on the knowledge and experience of those responsible for anaesthesia, both the anaesthesiologist and the anaesthesiology nurse, along with an appropriately equipped operating room, an anaesthesia station and a post-anaesthesia monitoring room.

The Paediatric Section of the Polish Society of Anaesthesiology and Intensive Therapy (PTAiIT) closely monitors the dynamic changes taking place in the medical services market over the last two decades – the growing number of service providers, the expanding range of anaesthesiology services, the increasing percentage of one-person companies offering anaesthesiology services, the changes introduced in the training and enforcement of knowledge, skills and competence of anaesthesiology and intensive therapy specialists, and the often asymmetric diversity of teams in terms of knowledge, skills, and experience.

In the interest of the safety of children undergoing anaesthesia and striving to ensure the highest possible quality and uniform standard of anaesthesia services, the Expert Panel of the Paediatric Section of the PTAiIT has prepared the consensus statement on anaesthesia for children up to 3 years of age.

The Charter of the Rights of the Child and the Convention on the Rights of the Child of 20 November 1989, as well as the Helsinki Declaration on Patient Safety in Anaesthesiology (DeHaBePA) signed by the PTAiIT on 13 June 2010, guarantee this safety [5, 6].

We believe that the Consensus will generate interest and recognition among specialists and doctors in training, and will encourage anaesthesiologists to deepen their knowledge and acquire practical skills in units providing training in paediatric anaesthesiology and intensive care.

## ANATOMICAL AND PHYSIOLOGICAL DIFFERENCES IN A YOUNG CHILD

The anatomical and physiological differences of a child, especially a neonate, mean that anaesthesia of a paediatric patient requires special qualifications and experience, and for anaesthesiologists who do not work with children on a daily basis, it is a real challenge. They cause slightly different reactions of children to anaesthesia than observed in adults and – as mentioned – constitute risk factors for the development of both respiratory and cardiovascular complications.

Adaptation to postnatal life is a period of enormous transformations in the human body, and any medical intervention during this time creates a significant risk of disturbing the fragile systemic homeostasis. Elective surgeries – other than those resulting from the need to correct congenital defects – should not be performed on children before they reach 46–48 weeks of age, counting from conception [7].

### Respiratory system

The structure of the respiratory tract in the neonatal period differs from that described in older children and adults. It is adapted to the degree of maturity of the lung tissues and the different respiratory mechanics at this stage of life.

The respiratory tract of a neonate is characterized by:
- narrow and long nostrils,
- a relatively large tongue positioned posteriorly,
- high position of the larynx,
- narrow, long, and hanging epiglottis (makes intubation difficult),
- acute angle formed by the glottis and the base of the tongue (for this reason, it is generally easier to perform endotracheal intubation of a neonate using a straight laryngoscope blade),
- position of the vocal cords at the level of the fourth cervical vertebra (C4),
- so-called physiological subglottic stenosis, which is the narrowest point of the larynx – at the level of the cricoid cartilage just below the vocal cords, caused by the oblique position of the cricothyroid membrane in relation to the posterior wall of the larynx,
- short and narrow trachea (precise assessment of the depth to which the ETT is inserted is necessary),
- mucous membrane of the upper respiratory tract is loosely attached to the underlying tissue (this promotes the accumulation of transudate under its surface, secreted as a result of inflammatory reaction and also trauma related to intubation, leading to the rapid development of oedema),
- short distance between the physiological subglottic stenosis – the cricoid cartilage and the tracheal bifurcation (easy movement of the ETT into one of the main bronchi),

**TABLE 1.** Values of selected respiratory parameters in individual age groups

| Parameter | Infant | Child | Adult |
|---|---|---|---|
| Compliance | 1.5–2 mL cm $H_2O^{-1}$ kg$^{-1}$ | 2.5–3 mL cm $H_2O^{-1}$ kg$^{-1}$ | 100 mL cm $H_2O^{-1}$ |
| Airway resistance | 20–40 cm $H_2O$ L$^{-1}$ s$^{-1}$ | 20–40 cm $H_2O$ L$^{-1}$ s$^{-1}$ | 1–2 cm $H_2O$ L$^{-1}$ s$^{-1}$ |
| Tidal volume | 4–8 mL kg$^{-1}$ | 4–8 mL kg$^{-1}$ | 6–8 mL kg$^{-1}$ |
| Respiratory rate per minute | 20–60 | 20–30 | 12–20 |

- smaller diameter of the lumen of the bronchi and bronchioles (greater probability of their obstruction),
- lack of rib ossification (less stability of the chest, its high compliance),
- soft structure of the cartilage tissue of the larynx and trachea (which contributes to their collapse). A child's respiratory system during the adaptation period is highly immature. The primary respiratory muscle – the diaphragm – and the elastic rib cage prevent deep breathing.

Functional residual capacity (FRC) depends on the inefficient function of the surface factor in the lung epithelium – surfactant (static factor), and on the maintenance of constant positive airway pressure by physiological subglottic narrowing, short expiratory time and glottis that does not open completely (active factors). Tracheal intubation in neonates eliminates the effect of active factors, which is why it is necessary to provide the intubated neonate and infant with constant positive end-expiratory pressure (PEEP) [7–10].

It should also be borne in mind that inability to deepen breathing makes infants expand their lungs during active exhalation, crying and groaning; therefore, after removal of the endotracheal tube (ETT), it is important to quickly regain consciousness and protective reflexes, including crying.

The regulation of respiration depends largely on the chemosensitive surface neurons of the *medulla oblongata;* however impulses from the carotid bodies are not well received in the respiratory neurons of the pons and *medulla oblongata*. It should also be noted that it is effectively suppressed by relatively low concentrations of halogenated inhalation agents (at a concentration > 0.1 MAC). The respiratory drive is therefore determined primarily by the pH of the cerebrospinal fluid, in which changes are inversely proportional to $PaCO_2$ and occur relatively slowly. When oxygen consumption is much faster than in an adult compared to its content in the FRC, hypoxia occurs very easily [7–12].

Table 1 presents selected respiratory parameters in individual patient groups.

## Cardiovascular system

The high demand for oxygen means that a baby requires a relatively higher cardiac output in the first months of life. A neonate's cardiac output is three times greater than that of an adult.

**TABLE 2.** Values of selected cardiovascular parameters in individual age groups of children

| Age | Heart rate (min$^{-1}$) | Systolic blood pressure (mmHg) |
|---|---|---|
| Neonate | 120–160 | 60–75 |
| 1–6 months | 110–140 | 65–85 |
| 6–12 months | 100–140 | 70–90 |
| 1–2 years | 90–130 | 75–95 |
| 3–5 years | 80–120 | 80–100 |
| 6–8 years | 75–115 | 85–105 |
| 9–12 years | 70–110 | 90–115 |
| 13–16 years | 60–110 | 95–120 |
| > 16 years | 60–100 | 100–125 |

The cardiovascular system in children is characterized by the inability of the heart to increase stroke volume according to the Frank-Starling law and, consequently, poor fluid tolerance, low-resistance systemic circulation and a high-resistance pulmonary bed. Blood pressure in this period of life depends on the heart rate (HR) and filling of the vascular bed; depression of the myocardium by anaesthetic agents or the resulting dilation of the peripheral blood bed are poorly tolerated and difficult to reverse.

Compared to the mature heart, the neonatal heart has poorer diastolic compliance. However, it is very sensitive to ionized calcium concentration [8–10, 13].

The dominance of the parasympathetic nervous system causes the child to have a tendency to reflex bradycardia, for example during laryngospasm. Bradycardia leads to decreased cardiac output and hypotension, with a weak response to catecholamines resulting from the low density of $\alpha$-adrenergic receptors in peripheral vessels.

Table 2 presents selected parameters of the cardiovascular system in individual paediatric age groups.

## Urinary system

The urinary system in children differs from that of adults:

- glomerular filtration rate (GFR) – is lower due to low filtration pressure, high renal vascular resistance, and small filtration surface,

- immature mechanism of urine concentration (and poorer dilution) and regulation of sodium concentration. Immaturity of the urinary system causes reduced tolerance to overhydration and delayed elimination of drugs excreted by the kidneys – careful fluid balance and appropriate drug dosing are necessary [8, 9, 13].

### Other differences

Other differences in children up to 3 years of age include:

- liver immaturity – significant for drug metabolism,
- lower glycogen reserves – resulting in a tendency to hypoglycaemia,
- immature immune system – promoting infections; a special sanitary regime and appropriate perioperative antibiotic prophylaxis are necessary,
- disproportion between body mass and surface area – predisposing to hypothermia; ensuring thermal comfort is necessary,
- immature skin – promoting large, imperceptible water loss,
- low albumin concentration in neonates – increasing the active (free) fraction of drugs [8, 9, 13].

## NEUROTOXICITY OF GENERAL ANAESTHETICS

For over two decades, there has been an ongoing discussion among anaesthesiologists (especially those who deal with paediatric anaesthesia on a daily basis) about the potentially neurotoxic effects of anaesthetics on the immature, developing central nervous system (CNS) of young children. The basis for these considerations were the results of preclinical studies published by Jevtovic-Todorovic *et al.* [14], regarding the influence on cognitive functions of drugs used in general anaesthesia administered to rodents in the neonatal period. The results of studies conducted and published by this and other teams on the influence of ketamine, benzodiazepines, barbiturates, propofol, and finally inhalation anaesthetics, including isoflurane, on the immature brain of representatives of various animal species, including primates, in the vast majority of cases proved their strong neurodegenerative effect, mainly in the mechanism of significant intensification of apoptosis [15–17].

The medical literature on laboratory tests provides ample evidence supporting the thesis of the neurotoxic and neurodegenerative effects of anaesthetics on the immature brain. The problem is that these findings are not sufficiently reflected in clinical trials. Available cohort studies do not allow for definitive conclusions. Some of the results confirm that a single exposure to anaesthetics during the period of the greatest risk of their potential neurotoxic effects on the maturing CNS of a child should not cause permanent cognitive or behavioural disorders. However, repeated exposure (during several consecutive surgical procedures) significantly increases the likelihood of such disorders [18–21].

The results of a multicentre, prospective, randomized study (with the working title GAS study – general anaesthesia and awake-regional anaesthesia in infancy), which compared the influence of two methods of anaesthesia: general and regional (spinal) in infants operated on in the first 3 months of life due to inguinal hernia on the IQ of these children measured with a special test at the age of 5, showed that the obtained results did not differ significantly between the two groups of study subjects. This allowed for the conclusion that a single exposure of a child to general anaesthetics during surgery lasting up to one hour does not affect their behavioural and cognitive functions assessed both at the age of 2 and 5 [22].

Due to the lack of clear results of clinical trials and alarming laboratory test results, the Paediatric Section of the PTAiIT, similarly to the US Food and Drug Administration (FDA) and the European Society for Paediatric Anaesthesiology (ESPA), maintains its position formulated for the first time in 2012 and recommends extreme caution in qualifying the youngest children, under 3 years of age, for elective procedures (which can be performed without harm to the patient's health at a later age) under general anaesthesia [13, 23–26].

## EQUIPMENT IN THE OPERATING ROOM, ANAESTHESIA STATION, ANAESTHESIA TABLE, AND POST-ANAESTHESIA CARE ROOM

The age and body mass of the child undergoing anaesthesia influence the preparation process and determine the type of equipment that must be provided in the operating room, the anaesthesia station, and the post-anaesthesia care room.

Children should not stay in rooms intended for adult patients. A hospital where children are treated, anaesthetized, and operated on must have separate rooms designated just for them. The interior design of the rooms should meet the age-specific emotional and aesthetic needs of patients. In a hospital where procedures are performed for adult and paediatric patients, the procedure plan should additionally include the principle of time or space allocation of procedures for these groups of patients [12].

### Operating room

The operating room environment must allow for temperature regulation within a range of 19–24°C, typically within ±2°C of the planned temperature. It is important to remember that the operating room temperature should be adjusted to the patient's age and the type of surgery being performed. A higher room temperature (preferably 23–24°C) is required when a neonate is anaesthetized [12]. The neutral temperature, i.e., the temperature at which the metabolic rate and so-called oxygen consumption are minimal, in an incubator for a full-term neonate is approximately 33°C, and for a premature infant – approximately 36°C. Devices that help maintain normothermia in a baby undergoing surgery include:

- operating incubator with heating lamp system,
- heating mattress,
- a device that heats the environment around the child using warm air,
- headgear that protects against heat loss through the head,
- thermal insulation foils,
- infusion fluid warming systems,
- humidifier and breathing mixture heater.

The baby's thermal comfort can also be ensured by:

- avoiding heat loss through conduction,
- minimizing contact with cold elements of the equipment,
- reducing heat loss through evaporation by minimizing the body surfaces subjected to washing or disinfection,
- preventing heat loss through convection – limiting the movement of cool air around the patient,
- performing procedures in a planned, targeted manner and without unnecessary delay.

It is also important to remember that neonates, especially premature babies, have sensitive skin that can be easily burned. Therefore, any direct warming methods without temperature control are prohibited [8, 10, 12, 27].

## Anaesthesia station

The equipment of the anaesthesia station should be in accordance with the applicable Regulation of the Minister of Health of 16 December 2016 (as amended) on the organizational standard of health care in the field of anaesthesiology and intensive care [27].

Due to the body mass and age of the patient undergoing anaesthesia, the station must include elements that are specific for anaesthesia in a young child.

Anaesthesia machine equipped with:

- a ventilator enabling ventilation of the child's lungs with parameters adapted to its body mass and age, i.e. low compliance, with regulation of small tidal volumes (from 10 mL), high respiratory rate (up to 80 min$^{-1}$), various inspiratory pressures (10–60 mmHg),
- respiratory gas heater and humidifier,
- circular system with an appropriately small diameter of the respiratory tract,
- anaesthetic vaporizers,
- suction unit,
- high airway pressure alarm,
- respiratory system disconnection alarm,
- device for continuous measurement of respiratory rate,
- device for continuous measurement of tidal volume.

Monitoring systems for the following parameters adapted to the patient's age and body mass [27, 28]:

- HR,
- ECG (neonatal electrodes must be available),
- arterial oxygen saturation (the pulse oximeter must be equipped with bands or clips designed to measure saturation in neonates and infants),
- non-invasive blood pressure measurement (set of neonatal and infant cuffs),
- invasive blood pressure measurement,
- analysis of the composition of the breathing mixture,
- monitoring of anaesthetic gases,
- central and peripheral body temperature,
- measurement of neuromuscular blockade.

Additionally, it is worth ensuring the possibility of monitoring cerebral oximetry using near-infrared spectroscopy (NIRS).

Anaesthesia table equipped with:

- central venous access catheters (3–4.5 F diameter; smaller sizes recommended for premature babies),
- peripheral venous access catheters (0.6–1.0 mm in diameter),
- arterial catheters (22 G and 20 G),
- suction catheters – 6 F, 8 F and 10 F (the catheter diameter should be 1/3 of the ETT diameter),
- ETTs measuring 2–5 mm (without a cuff or with a low-pressure cuff),
- setons,
- oropharyngeal tubes (from 000, 00, 0, to larger ones for bigger children),
- transparent face masks (from size ≥ 0),
- laryngeal mask airway (sizes: 1, 1.5 and 2, adjusted to the child's body mass),
- laryngoscope/video laryngoscope with a small straight and/or curved intubation blade – sizes from: 000, 00, 0, 1 (for the smallest patients, a laryngoscope with lateral oxygen access is recommended),
- fiber optic guide and/or bronchofiberoscope,
- self-inflating bags adjusted in volume to the patient's age and body mass,
- gastric tubes,
- guides for ETTs adapted to their size, long and flexible (bougie type),

- Magill forceps (small and medium),
- stethoscope,
- oesophageal stethoscope (optional),
- equipment for rapid fluid transfusion,
- equipment for regulated fluid transfusions,
- catheters for urinary bladder catheterization (6–10 F),
- a set for difficult intubation, including a video laryngoscope, bronchofiberoscope, fiber optic guide, and bougie guides,
- a QuickTrach device for emergency cricothyrotomy for children over infancy,
- syringe infusion pumps – at least 3 pieces,
- a defibrillator with the ability to perform cardioversion and electrostimulation – at least one per set of interconnected anaesthesia stations or a separate operating room.

Various phone applications (e.g. PediHelp, Anesthesiologist) with dose conversion based on age and body mass or printed anaesthetic procedure diagrams with the dosage of individual drugs may be helpful.

In the case of regional anaesthesia:

- needles and/or sets for performing central regional anaesthesia with appropriately sized catheters,
- needles for regional and peripheral anaesthesia with sizes adapted to specific groups of paediatric patients (preferably with markings visible on ultrasound),
- elastomer pumps (with a fixed, preferably adjustable, flow for regional anaesthesia), or syringe pumps for continuous infusion (specially protected against accidental administration of a larger dose of the drug), adapted to the age and body mass of the child,
- ultrasound machine,
- neurostimulator – optional,
- injection pressure gauge – optional,
- 20% fat emulsion.

### Post-anaesthesia care room

In the immediate postoperative period, the patient is placed in a post-anaesthesia care room:

- separate for children and located within the operating suite or in its close vicinity,
- with the recommended constant presence of a specialist in anaesthesiology and intensive care or at least constant contact with him,
- with direct supervision of the patient by nurse anaesthetists, who must be provided with technical means enabling constant contact with a specialist in anaesthesiology and intensive care,
- with the ratio of the number of nurse anaesthetists on each shift to the number of actually occupied post-anaesthesia supervision stations not less than 1 : 4 – 1 nurse for every 2 children is recommended.

According to the above-mentioned regulation of the Minister of Health, the post-anaesthesia supervision room should include [26]:

- resuscitation trolley and cricothyrotomy kit,
- defibrillator with cardioversion capability,
- ventilator with adjustable oxygen concentration ranging from 21% to 100%,
- electric suction devices (at least 1 in 3 monitoring stations).

Post-anaesthesia monitoring stations must be equipped with:

- source of oxygen, air and vacuum,
- blood pressure monitor,
- ECG monitor,
- pulse oximeter,
- thermometer.

In the post-anaesthesia care room, it is necessary to ensure the possibility of direct observation of the patient or using cameras equipped with auto-start functions, allowing, in particular, facial observation.

This type of room should also be equipped with a bedside ultrasound machine, which is currently considered a standard tool when performing invasive procedures: vascular cannulation or regional anaesthesia. It is also used to identify possible complications and assess individual organs (e.g. lungs, abdominal cavity, and others).

It is also recommended to equip the post-anaesthesia monitoring room with a device for measuring critical parameters, as well as a set of equipment for restoring airway patency in case of an emergency. The components of such a set are described in the position paper of the Paediatric Section of the PTAiIT entitled: "Management of unexpectedly difficult airways in children – position paper of the Paediatric Section of Anaesthesiology and Intensive Therapy, Section of Instrumental Airway Management of the Polish Society of Anaesthesiology and Intensive Therapy and the Polish Society of Neonatology" [29].

## ANAESTHESIOLOGY TEAM

According to §11 of the Regulation of the Minister of Health of 16 December 2016 (as amended), "anaesthesia of a neonate or an infant may be performed by a specialist in anaesthesiology and intensive care or an anaesthesiologist with the written consent of the physician in charge of the anaesthesiology and intensive care department, an anaesthesiology department, a paediatric anaesthesiology and intensive care department or a paediatric anaesthesiology department, as well as by a physician undergoing specialization under the direct supervision of an anaesthesiology and intensive care specialist" [28].

According to anaesthesiology and intensive care specialists from the Paediatric Section of the PTAiIT, children under 3 years of age should be anaesthetized by a specialist in anaesthesiology and intensive care specialist with knowledge and experience in the management of patients in this age group. This is consistent with the opinion of the ESPA and confirmed by available research (APRICOT) [1].

The anaesthesiologist must be accompanied by an anaesthetic nurse with knowledge and experience in the care of children under 3 years of age.

## PREPARING CHILDREN FOR ANAESTHESIA

In accordance with the aforementioned regulation of the Minister of Health [28], a specialist in anaesthesiology and intensive care or an anaesthesiologist or a physician in the process of specialization is obliged to take patient's medical history and perform physical examination of the child at least 24 hours before the elective surgery in order to qualify the patient for anaesthesia. According to the latest regulations, it is advisable to establish an anaesthesiology clinic at the hospital, which would provide convenient and comfortable conditions for obtaining medical history and performing physical examinations, preferably in a special room adapted to different age groups of children. Such a room allows for privacy while taking medical history or examining a patient.

The main goal during anaesthesiology qualification is to select the anaesthetic method that will optimally ensure the patient's safety during anaesthesia, which is in line with DeHaBePA signed by the PTAiIT on 13 June 2010 [6]. To ensure safe anaesthesia, it is necessary to review the patient's current records, containing information about their health, as well as other documents, especially those relating to previous hospitalizations, procedures and anaesthesia, or comorbidities.

During an anaesthesiology consultation, special attention should be paid to the following issues:

- current diagnosis and elective type of procedure,
- current course of the disease (which is an indication for surgical treatment or diagnostic testing),
- perinatal history,
- infectious diseases.

A history of infectious diseases within the 2 weeks preceding anaesthesia excludes the possibility of performing the procedure as elective due to the increased risk of intra- and postoperative complications. It should be remembered that after an infection, bronchial hypersensitivity may persist for up to 6 weeks, and in the case of children, it may also increase the risk of respiratory complications, which in certain cases may be an indication for postponing the procedure for at least 2 weeks after the acute symptoms have subsided.

Infection-related criteria for disqualification from elective anaesthesia include: acute inflammation of the upper and/or lower respiratory tract (red throat, runny nose, productive cough, increased body temperature (> 37.8°C), auscultatory changes over the lungs), antibiotic therapy (related to respiratory tract infection) up to 2 weeks after the end of treatment, infectious diseases.

Selected infectious diseases and the period during which a patient cannot receive elective anaesthesia are presented below:

- chickenpox up to 21 days after contact – the disease is considered resolved when the last rash dries up,
- mumps up to 24 days after contact – the disease is considered resolved 10 days after the skin lesions appear,
- measles up to 12 days after contact – the disease is considered resolved 5 days after the skin lesions appear,
- rubella up to 21 days after contact – the disease is considered resolved 7 days after the skin lesions appear,
- whooping cough up to 20 days after contact – the disease is considered resolved 21 days after the first symptoms appear,

In the case of respiratory syncytial virus (RSV) infection, the time from the end of the disease must be 4–6 weeks.

## COMORBIDITIES

Systemic diseases that can significantly impact planned anaesthesia include neuromuscular diseases (e.g., muscular dystrophies), malignant hyperthermia during a previous anaesthesia or a family history of malignant hyperthermia, congenital coagulation disorders, congenital heart defects, and defects and diseases of other organs and systems. Children with asthma are always at risk of perioperative complications, which may be related, for example, to bronchospasm. To ensure safe anaesthesia in this group of patients, their condition must be optimized.

The following situations are important for the safety of anaesthesia:

- allergies/sensitivities – attention should be paid to allergies and sensitivities, especially allergies to medications, in particular those used during anaesthesia. It is necessary to take into account latex allergy and allergens causing cross-reactions with latex, such as kiwi or chocolate in the group of children after multiple surgeries (> 5), children with congenital urinary tract disorders and those after surgery for myelomeningocele; children with atopic dermatitis also belong to this group;
- vaccinations – in the case of live vaccines (tuberculosis, mumps, rubella, measles, chickenpox, rotaviruses), the patient should not undergo scheduled anaesthesia within 2 weeks of vaccination, while in the case of other vaccines – within 2 days

of vaccination; this is due to the risk of adverse events following immunization (AEFI) and the difficulty in differential diagnosis with postoperative adverse events;
- family history – hereditary diseases in the family, previous surgeries, and possible deaths related to surgical treatment are important. Special attention should be paid to the presence of malignant hyperthermia, as mentioned above, in the family or in the patient after previous anaesthetic procedures. This requires the use of enhanced precautions (the patient should be operated on first on a given day) and modification of the method of anaesthesia to ensure safety for the patient.

## ADDITIONAL TESTS

Before administering anaesthesia and the surgery, the anaesthesiologist must review the results of laboratory and imaging tests, the scope of which depends on the type and extent of the surgery.

Generally, in children with a score of I or II according to the American Society of Anesthesiologists (ASA) classification system, qualified for day surgery procedures and not at high risk of bleeding, only a complete blood count is recommended (although the necessity of this test is questioned in some European countries).

In a child with an ASA score of at least III or if the procedure involves the loss of a large volume of blood, the following are necessary:
- blood typing,
- serum electrolyte test,
- coagulation tests,
- determination of certain biochemical parameters, such as serum urea, creatinine, and glucose, alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activity, as well as assessment of acid-base balance.

The performance of other tests [electrocardiography – ECG, echocardiography – ECHO, X-ray, computed tomography – CT, magnetic resonance imaging – MRI] should depend on comorbidities, the patient's general condition, and the type and scope of surgery.

In children in good general condition and free from comorbidities (including oncological diseases), it is possible to accept tests performed 3 months before anaesthesia, provided that the child's condition has not changed significantly since the tests were performed and the results of these tests were normal.

Deviations from the norm in laboratory tests that disqualify from elective surgery include:
- anaemia: haemoglobin < 8 g dL$^{-1}$, haematocrit < 28% in neonates haemoglobin < 10 g dL$^{-1}$ (excluding oncological patients). Anaemia is a significant factor contributing to an increased risk of perioperative complications, therefore reference values should be achieved. If a child is diagnosed with anaemia, it is recommended to postpone the elective procedure and start the diagnostic process and treatment to correct the deficiencies before surgery [30];
- electrolyte dysregulation: potassium, sodium, calcium – exceeding the reference values for a given age group. Reference values for individual age groups are presented below:
– potassium in children up to 4 weeks: 3.6–6.1 mmol L$^{-1}$; 2–12 months : 3.6–5.8 mmol L$^{-1}$; 1–18 years: 3.1–5.1 mmol L$^{-1}$;
– sodium in children up to 4 weeks: 132–147 mmol L$^{-1}$; 2–12 months: 129–143 mmol L$^{-1}$; 1–18 years: 132–145 mmol L$^{-1}$;
– calcium (total) in children 0–10 days: 1.90–2.60 mmol L$^{-1}$; 11 days to 24 months: 2.25–2.75 mmol L$^{-1}$; 2–12 years: 2.20–2.7 mmol L$^{-1}$; over 12 years: 2.20–2.65 mmol L$^{-1}$;
- thrombocytopenia – a patient scheduled for elective surgery should generally have a normal platelet count (within the normal range for age). In patients with symptoms and comorbidities that may compromise coagulation, risk factors such as the presence of bleeding, the type of surgical procedure and associated bleeding risk, and other abnormalities in coagulation tests should be assessed. Platelet transfusion should be administered prior to invasive surgical procedures if the platelet count is < 20 G L$^{-1}$. If the platelet count is 20–50 G L$^{-1}$, the above risk factors and the risk/benefit ratio of transfusion should first be considered.

According to the latest recommendations, in the absence of active bleeding, the platelet count should not be lower than: 50 G L$^{-1}$ before a planned major surgery, 20 G L$^{-1}$ before central venous catheter insertion, and 50 G L$^{-1}$ before liver biopsy. A platelet count below 80 G L$^{-1}$ is an indication for preoperative diagnosis.

It is recommended to implement compensatory treatment if the values of prothrombin time (PT), international normalized ratio (INR) and activated partial thromboplastin time (aPTT) exceed at least twice the reference values (for individual age groups) [31, 32]:
- PT – 80–120%;
- INR – 0–5 days: 0.53–1.62; 6 days – 3 months: 0.53–1.26; over 3 months: 0.85–1.25;
- aPTT – 0–1 day: 31.5–54.5 s; 2–5 days 25.5–59.0 s; 6–30 days: 25.5–55.5 s; 1–3 months: 24.0–50.0 s; 4–6 months: 27.0–43.0 s; over 6 months: 25.9–36.6 s

**NOTE!** In premature infants and small for gestational age (SGA) infants, the upper normal limit of aPTT may reach 95 and 77 s, respectively.

## MEDICATION

The anaesthesiologist must be familiar with the medications taken by the patient and make modifications to the pharmacotherapy if a given medication may affect the patient's safety. It is important to note that there are few medications that should be discontinued before or on the day of surgery. Among those that definitely should not be discontinued are antiepileptic medications. The examples given below use principles analogous to those used in the 2022 guidelines for anaesthesia in adults according to the European Society of Cardiology (ESC) – cardiovascular risk assessment and management in patients undergoing non-cardiac surgery [33].

### Angiotensin-converting enzyme inhibitors

Data on the use of drugs from this group in the preoperative period are inconclusive, but the results of most studies suggest that continued use of drugs from this group is associated with a higher risk of hypotension and its complications, such as stroke or myocardial ischaemia, and other organ complications, such as kidney damage. It was found that omitting angiotensin receptor blockers (ARBs)/ angiotensin-converting enzyme inhibitors (ACEIs) on the morning of surgery was associated with a lower incidence of intraoperative hypotension and did not increase the incidence of death or serious adverse cardiovascular events. If these medications were discontinued preoperatively, therapy should be resumed as soon as possible in the postoperative period.

### Calcium channel blockers

Similar recommendations as in the case of ACEI/ ARB apply to calcium channel blockers. In this group, the fibrinolytic system shows reduced activity due to lower concentrations of tissue plasminogen activator (tPA) and plasminogen activator inhibitor-1 (PAI-1). The maturation process of this system occurs during childhood. However, it reaches full maturity, similar to that of adults, only in adolescence. It is recommended to discontinue the medication on the day of surgery to avoid hypotension during the intraoperative and postoperative periods.

### Anticoagulants

Most recommendations for paediatric patients are based on guidelines for the adult population, but changes in the coagulation system in the paediatric population should be taken into account, as they significantly influence the dynamics and age-related differences. In neonates and infants, the activity of the coagulation system is reduced by about 50% due to lower concentrations of factors II, VII, IX, X, XI and XII, as well as proteins C and S, alpha-antitrypsin and alpha-macroglobulin.

#### *Low molecular weight heparin*

In the case of prophylaxis with low-molecular-weight heparin (LMWH), the drug should be discontinued one day before surgery, regardless of the level of perioperative thrombosis risk (low, medium, high), and LMWH should be resumed 6–12 hours after surgery.

#### *Acetylsalicylic acid*

In patients who can safely discontinue acetylsalicylic acid (ASA), administration should be discontinued 7–10 days before the procedure.

#### *Clopidogrel*

Clopidogrel should be discontinued 5 days before elective surgery [33].

#### *Warfarin*

Warfarin should be discontinued 4 days before elective surgery.

Low risk of thrombosis – no other medications are required preoperatively; LMWH should be started 6–12 hours after surgery, provided the risk of postoperative bleeding is assessed.

Moderate risk of thrombosis – LMWH should be started preoperatively on days 3–1 before surgery; LMWH should be started 6–12 hours after surgery, provided the risk of postoperative bleeding is assessed.

High risk of thrombosis – LMWH should be started in the preoperative period on days 3–1 before surgery; LMWH should be started 6–12 hours after surgery provided the risk of postoperative bleeding is assessed.

#### *Endoxaban, apixaban, rivaroxaban – direct oral anticoagulant inhibitors (DOAC)*

Low, medium, high risk of thrombosis and minor surgery: the drug should be discontinued 24 hours before surgery if creatinine clearance is > 50 mL min$^{-1}$; the drug should be discontinued 48 hours before surgery if creatinine clearance is 30–50 mL min$^{-1}$.

Low, medium, high risk of thrombosis and major surgery: 30–50 mL min$^{-1}$ – the drug should be discontinued 48 hours before surgery if creatinine clearance is 30–50 mL min$^{-1}$.

Postoperatively, DOAC may be resumed after 6–8 hours if no bleeding is observed; in the case of increased risk of postoperative bleeding, LMWH is administered 6–12 hours after surgery; in patients at high risk of thrombosis, the administration of unfractionated heparin (UFH) may be considered.

*Dabigatran (DOAC)*

Low, medium, high risk of thrombosis and minor surgery – the drug should be discontinued:

- 24 hours before surgery if creatinine clearance is > 80 mL $min^{-1}$,
- 36 hours before surgery if creatinine clearance is in the range of 50–80 mL $min^{-1}$,
- 48 hours before surgery if creatinine clearance is in the range of 30–50 mL $min^{-1}$.

Low, medium, high risk of thrombosis and major surgery – the drug should be discontinued:

- 72 hours before surgery if creatinine clearance is > 80 mL $min^{-1}$,
- 72 hours before surgery if creatinine clearance is in the range of 50–80 mL $min^{-1}$,
- 96 hours before surgery if creatinine clearance is in the range of 30–50 mL $min^{-1}$.

Postoperatively, DOAC administration should be resumed 6–8 hours after surgery if no bleeding is observed; in the case of an increased risk of postoperative bleeding, LMWH administration should occur 6–12 hours after surgery; in patients at high risk of thrombosis, UFH administration may be considered.

Detailed rules of perioperative management depend on the type of procedure and the preparation used, as well as the risk of thrombosis [33].

### Herbal preparations

Ginger: worsening platelet aggregation by inhibiting thromboxane synthase.

Garlic, Ginkgo biloba, St. John's wort: inhibition of platelet activity and potentiation of the anticoagulant effect of warfarin.

Ginseng: synergistic effect with anaesthetics.

### Sodium-glucose co-transporter 2 (SGLT2) inhibitors – so-called flozins

They should be discontinued 3–4 days before the elective procedure.

### Previous blood product transfusions and their possible complications

The anaesthetist needs to gather information on the subject.

## ADDITIONAL TESTS AND CONSULTATIONS BEFORE SURGERY

After reviewing the information in the questionnaire and the patient's medical history, the anaesthesiologist may decide whether additional tests and/or specialist consultations are necessary.

During the visit, the anaesthesiologist is also required to conduct a physical examination, the scope of which depends on the anamnesis obtained from the parents or, in the case of older patients, also from them. Particular attention should be paid to the assessment of the nose, mouth and anatomical abnormalities; auscultation of the chest (heart, lungs) should be performed and any difficulties with intubation should be assessed [34].

## PREMEDICATION

The final element of preparing a child for anaesthesia is planning premedication before the procedure, which largely depends not only on the patient's age but also on their psychoemotional state. The aim of this action is to reduce anxiety and calm the patient, as well as to provide pain relief if the child reports such complaints or if analgesia is planned in advance.

Table 3 presents the drugs most commonly used in premedication along with their dosage and possible route of administration.

In recent years, there has been a trend to avoid the use of benzodiazepines during premedication due to the unintended reverse effect, leading to irritation and agitation in children, as well as a higher risk of neurotoxicity, especially in infants and young children up to 4 years of age, during the maturation of the CNS. $\alpha_2$-receptor agonists, through their physiological action, stimulate sedation and sleep in a mechanism similar to the natural one by inhibiting receptors in the *locus oeruleus* in the brain. The modification of this procedure in recent years has been influenced by the increase in the number of diagnoses of disorders such as attention deficit hyperactivity disorder (ADHD), attention deficit disorder (ADD), autism spectrum disorder, Asperger syndrome, and others in children and adolescents. Non-pharmacological

**TABLE 3.** Pharmacological premedication

| Drug | Route of administration | | | |
|---|---|---|---|---|
| | Oral | Intranasal | Intravenous | Intrarectal |
| Midazolam | 0.3–0.5 mg $kg^{-1}$ (max.15 mg) | 0.2 mg $kg^{-1,*}$ | 0.1 mg $kg^{-1}$ | 0.5 mg $kg^{-1,***}$ |
| Dexmedetomidine | 1–4 µg $kg^{-1,**}$ | 1 µg $kg^{-1}$ | – | – |
| Clonidine | 4–5 µg $kg^{-1}$ | 2 µg $kg^{-1}$ | – | – |
| Ketamine | 10 mg $kg^{-1}$ | 1–3 mg $kg^{-1}$ | 0.1–0.5 mg $kg^{-1}$ | 5 mg $kg^{-1}$ |

*pH of the midazolam solution is approx. 4.0, burning sensation in the nasal cavity. **pH of the dexmedetomidine solution is close to physiological, i.e., approx. 7.0 .*** Intrarectal administration is not routinely indicated.

methods using distractors are increasingly recommended. They include mirror techniques, virtual animation, systemic desensitization, behavioural training, virtual reality glasses (VR), etc., which, through preoperative preparation and/or distraction and reduction of intraoperative anxiety, allow for the reduction or even avoidance of drug administration.

## CONSENT TO ANAESTHESIA

The anaesthesiology visit ends with obtaining written informed consent for anaesthesia, after presenting the type of anaesthesia (general/regional/procedural sedation and analgesia) and answering questions about the procedure. Consent is given by parents or legal guardians; in the absence of such, consent is given by the family court.

## FASTING TIME

The current rules for food withdrawal in the paediatric population prior to elective anaesthesia include the following restrictions [35]. The following should be discontinued:

- 6 hours before anaesthesia – solid foods,
- 4 hours before anaesthesia – formula milk,
- 3 hours before anaesthesia – breast milk,
- 1 hour before anaesthesia – clear fluids (water, tea, clear apple juice).

## ANAESTHESIA IN A CHILD WITH A FULL STOMACH

Anaesthesia in a child with a full stomach increases the risk of complications due to the risk of aspiration of food into the respiratory tract. Conditions associated with the risk of aspiration and a full stomach are presented in Table 4.

Currently, it is recommended, whenever possible, to perform ultrasound assessment of gastric contents [36].

When inducing anaesthesia in a young child with a full stomach, intravenous access should always be established before induction, and if unsuccessful, intraosseous access should be performed. Alternatively, in a neonate in the first few hours of life, umbilical vein access can be established. The presence of intravascular or intraosseous access allows for the induction of anaesthesia by a controlled rapid induction method, i.e. with ventilation before intubation. Ventilation before intubation is necessary because the younger the child, the higher the metabolism and therefore the oxygen demand, and at the same time the smaller FRC volume, which makes it difficult to "store" oxygen, so if the child is not oxygenated very quickly, desaturation occurs. Traditional rapid sequence induction (RSI), i.e., passive preoxygenation, followed by rapid administration of a sedative and

**TABLE 4.** Conditions associated with aspiration risk and a full stomach

| |
|---|
| Full stomach (trauma, bleeding tonsils, intestinal obstruction, preoperative nausea/vomiting, hypertrophic pyloric stenosis) |
| Delayed gastric emptying (acute abdomen, paralytic ileus, gastroesophageal reflux, abdominal/retroperitoneal tumour) |
| Congenital defects of the gastrointestinal tract |
| Child in shock with haemodynamic instability |
| Acute pain (post-traumatic, acute appendicitis) |
| Upper respiratory tract reflex disorders (neurological diseases) |

succinylcholine (suxamethonium) (the fastest and shortest-acting muscle relaxant), followed by intubation without mask ventilation, is contraindicated in the youngest children. Apnoea, even after prior oxygenation, is tolerated for a very short time, and intubation may be more difficult than in older children. Ventilation with low pressures and tidal volumes through a face mask with the option of positive inhalation pressure (PIP) of up to 15 mmHg and the fraction of inspired oxygen ($FiO_2$) of 0.8, has been shown not to increase the risk of aspiration and significantly improves patient safety. In this age group, continued oxygenation during intubation is recommended, as is possible with some video laryngoscopes, or via a cannula placed in the nasopharynx.

To visualize the larynx, a laryngoscope and a spatula (straight vs. curved) should be used, choosing those tools with which the anaesthesiologist has the most experience. If the anaesthesiologist is proficient in using a video laryngoscope and it is available in the appropriate size, it is recommended that it be used as the equipment of choice.

The anaesthetic of choice in a haemodynamically stable patient is propofol (in neonates it is used off-label, thiopental can be used on-label), and in neonates and children in shock and/or hypovolemia – ketamine.

An opioid, typically fentanyl, is also commonly used. However, it should be noted that its administration may result in vomiting. Rocuronium is most often used to provide muscle relaxation, necessary for efficient and non-traumatic intubation. Its advantage – apart from the rapid onset of action, comparable to that of succinylcholine – is the possibility of immediate reversal of the effect using sugammadex. Due to their longer duration of action in neonates, atracurium or cisatracurium, whose metabolism is not dependent on renal and hepatic function, are often used in this age group.

Cricoid cartilage compression is not recommended; this maneuver (Sellick maneuver) has not been proven to be effective in preventing regurgitation, but it often causes problems with ventilation or intubation.

There is no clear indication of when a gastric tube should be inserted, or whether, if one is already in place, it should be left during induction or removed. Therefore, the decision in this matter depends on the anaesthesiologist's experience. In all cases, induction in a young child on a full stomach should be performed by an experienced anaesthesiologist or at least he/she should be present in the room, ready to assist immediately. The choice of ETT depends on the anaesthesiologist's experience and available equipment. In the past, uncuffed ETTs were used in the youngest children, even in patients with a full stomach – if the tube was properly selected, this did not increase the risk of aspiration. Currently available ETTs with a microcuff (low-pressure cuff) enable intubation of even full-term neonates with this type of tube. Using cuffed tubes reduces the need for reintubation, which increases the safety of anaesthesia in children with a full stomach. It should be remembered to choose a tube half a size smaller than the size without the cuff. It is advisable to use a guide to avoid tube manipulation and reduce intubation time [37, 38].

## OPERATION PLAN

The order of operations performed in the operating room and procedures requiring anaesthesia performed outside the operating room should take into account the age of the patients undergoing surgery. The smaller the child, the sooner they should be anaesthetized and operated on to reduce the risk of dehydration and possible hypoglycaemia. If the procedure is delayed, the child should be given a clear fluid or an IV drip (10 mL $kg^{-1}$ of a balanced solution). When planning a surgical procedure, consideration should be given to the possibility of transferring the child to a paediatric intensive care unit (PICU) in the immediate postoperative period. This applies particularly to neonates and children undergoing surgery in critical condition.

## METHODS OF INDUCTION OF ANAESTHESIA

There are the following methods of induction of anaesthesia:

- inhalation,
- intravenous,
- intrarectal,
- intranasal.

### Inhalation induction

Inhalation induction is considered a method that allows for the anaesthesia of children with a high level of needle phobia or in whom establishing vascular access is very difficult.

Two methods of inhalation induction are proposed. The first of them involves gradual increasing the concentration of the inhalation agent, while the second involves using high concentrations of the anaesthetic from the start. The second method allows for rapid induction of anaesthesia, which is particularly important in the case of uncooperative patients, but is associated with a much higher risk of undesirable effects. The only anaesthetic currently used for inhalation induction is sevoflurane, at a concentration not exceeding 5 vol.%. The exception is difficult intubation performed under inhalation anaesthesia, when higher concentrations of sevoflurane can be used – up to 6 vol%, and even, according to some sources, up to 7–8 vol%. Maintaining full airway patency is essential for the safety and effectiveness of this induction method.

In neonates and premature infants, due to the difficulties associated with maintaining a patent airway during mask ventilation, routine intubation is recommended or, if the type of procedure allows, the insertion of a laryngeal mask airway. Intubation is mandatory for procedures lasting longer than one hour, performed in the lateral or prone position, and for procedures involving the head and neck.

Inhalation agents can be used both for induction and maintenance of anaesthesia. Alternatively, an inhalation agent can be used as the sole anaesthetic throughout the entire anaesthetic period. This method is called volatile induction and maintenance of anaesthesia (VIMA). Inhalation induction is contraindicated in children with hypovolemia, circulatory failure, and right-to-left shunting because myocardial depression and vasodilation may lead to profound hypoperfusion and circulatory arrest in these patients. Higher concentrations of sevoflurane are often accompanied by bradycardia, especially in children with Down syndrome [8, 9, 13, 39–41].

### Intravenous induction

Intravenous induction is possible in children of all ages but requires prior vascular access, which can be difficult and painful in the youngest children. Pain associated with venipuncture can be alleviated by applying a cream/gel containing a local anaesthetic.

In children, it is beneficial to have intravenous access established outside the operating room prior to the procedure. This reduces unnecessary stress in the operating room for both the child and the staff, and streamlines workflow. If the primary ward is unable to place a cannula into the child's vein, induction of anaesthesia can be performed using an alternative method (inhalation, intranasal, or rectal). Intravenous access should always be established after the child is placed under anaesthesia.

The following agents are used for intravenous administration:

- propofol – in all age groups above 1 month of age, off-label in children under 1 month of age,
- thiopental – in all age groups (currently rare),
- ketamine – in all age groups – recommended for patients in serious condition, with unstable circulation, in shock, and in children with heart defects (except for coarctation of the aorta and stenosis of the coronary vessels),
- etomidate – in children over 6 months of age – with cardiomyopathy and/or left ventricular ejection fraction (LVEF) < 40%,
- midazolam – in all age groups.

Propofol is most often used for induction in children at a dose of 2–5 mg kg b.w.$^{-1}$. To reduce the pain associated with injection, it may be preceded by the administration of fentanyl at a dose of 1–2 µg kg b.w.$^{-1}$ or lidocaine at a dose of 1–2 µg kg b.w. 0.5% propofol solutions are also available, which usually do not cause pain or significantly reduce its intensity during injection.

Table 5 lists intravenous anaesthetics used in children.

The induction of anaesthesia should be smooth – without fluctuations in blood pressure or heart rate, regardless of the use of intravenous or inhaled agents. The induction should include the following steps:

- oxygenation of the patient with a mixture of oxygen and air under the control of blood saturation ($SpO_2$),
- administration of an induction dose of an analgesic (with prior intravenous access; in other cases after obtaining it),
- induction of anaesthesia with an intravenous drug or sedation with an inhalation agent,
- muscle relaxation – optional,
- intubation or insertion of a laryngeal mask airway. Before administering a hypnotic agent, if intubation is planned, it is advisable to administer fentanyl (1–2 µg kg b.w.$^{-1}$) or sufentanil (0.25 µg kg b.w.$^{-1}$). Strong opioids, such as fentanyl, should be administered by titration to avoid chest muscle stiffness that may occur when the drug is administered too quickly, which may impair proper ventilation of the child [8, 9, 13, 38–40].

**TABLE 5.** Intravenous anaesthetics used in children

| Name | Ketamine | Thiopental | Propofol | Etomidate* | Dexmedetomidine |
|---|---|---|---|---|---|
| Derivative | Phencyclidine | Thiobarbiturate | Alkylphenol | Carboxylated imidazole | Cyclic organic derivative of imidazole and 1,2-xylene |
| Receptors | NMDA cholinergic muscarinic, indirect opioid MOR, KOR, DOR | (+) GABA-A Inhibition of neuronal activity | (+) GABA-A glycine, (–) 5-HT nicotinic | Stimulation of GABA receptors | $Alpha_2$ |
| Clinical effects | Analgesic effect, stimulation of the sympathetic nervous system | Hypnotic and anticonvulsant effects | Hypnotic and anticonvulsant effects | Little effect on circulation, muscle tremor | Hypnotic, anxiolytic effect Inhibition of the sympathetic nervous system |
| Central nervous system | Nervous system – ICP ↑, CBF ↑, $CMRO_2$ ↑, IOP ↑ | Nervous system – CBF ↓, ICP ↓, IOP ↓, $CMRO_2$ ↓ | Nervous system – ICP ↓, CPP ↓, $CMRO_2$ ↓ | Nervous system – IOP ↓, CBF ↓, ICP ↓, $CMRO_2$ ↓ | Nervous system – IOP ↓, CBF ↓, ICP ↓, $CMRO_2$ ↓ |
| Cardiovascular effects | Cardiovascular system – HR ↑, cardiac output ↑, BP ↑, CVP ↑, | Depressant effect on the cardiovascular system – BP ↓, CVP ↓, negative inotropic effect, decreased cardiac output, HR ↓, risk of arrhythmia ↑, | Depressant effect on the cardiovascular system – BP ↓, CVP ↓, cardiac output ↓, no impact on HR | Cardiovascular system – MAP ↓, HR ↓ | Cardiovascular system – MAP ↓, HR ↓ |
| Other effects | Respiratory system – bronchodilation, no respiratory depression | Respiratory system – RF ↓, TV ↓ | Respiratory system – TV ↓, RF ↑, | Respiratory system – TV ↓, RF ↓ | Respiratory system – TV ↓, RF ↓ |
| Posology | 1–2 mg kg$^{-1}$ intravenous 2–4 mg kg$^{-1}$ intramuscular | 3–5 mg kg$^{-1}$ | 2–5 mg kg$^{-1}$ | 0,3 mg kg$^{-1}$ | 0,7 µg kg$^{-1}$ |

↓ – decrease, ↑ – increase, BP – blood pressure, CBF – cerebral blood flow, $CMRO_2$ – cerebral metabolic rate for oxygen, CPP – cerebral perfusion pressure, CVP – central venous pressure, DOR – δ-opioid receptor, GABA – gamma-aminobutyric acid, HR – heart rate, ICP – intracranial pressure, IOP – intraocular pressure, KOR – κ-opioid receptor, MAP – mean arterial pressure, MOR – µ-opioid receptor, NMDA – N-methyl-D-aspartate, RF – respiratory frequency, TV – tidal volume

*Note: adrenal suppression, if used in long infusions, seizure-like activity in electroencephalography, influence on QT prolongation, the weakest and dose-independent anticonvulsant effect.

**NOTE!** In an emergency situation where intravenous access is not possible, intraosseous access may be used.

### Rectal induction

In special cases where establishing intravenous access is very difficult or impossible in the child, rectal induction can be performed. This method most often achieves deep sedation, which can then be deepened to general anaesthesia using an inhalant. This method uses ketamine at a dose of 10 mg $kg^{-1}$ administered with midazolam at a dose of 0.5 mg $kg^{-1}$. After rectal administration of these drugs, the child usually falls asleep after 15–20 minutes.

### Intranasal induction

This type of induction involves administering an anaesthetic and/or analgesic into the nose using a special applicator in the form of a mist that is easily absorbed by the nasal mucosa. It may be used in situations where a child's severe anxiety combined with needle phobia prevents intravenous access, and the child exhibits an equally high degree of anxiety about placing a mask on its face. Midazolam, ketamine, sufentanil, fentanyl, and dexmedetomidine can be administered via this route. As with rectal induction, this method more often achieves sedation than actually putting the child into deep sleep. However, as with the previously discussed method, it is much easier to further deepen anaesthesia, i.e., achieve actual induction by using, for example, sevoflurane. For this reason, this method is more often considered a form of premedication rather than a type of induction [8, 9, 40].

In young children, vagal stimulation and reflex bradycardia may frequently occur during manipulations associated with induction of anaesthesia. However, routine administration of atropine to neonates and infants during induction of anaesthesia is not recommended.

A syringe with a properly prepared solution of this drug should always be ready before the start of anaesthesia in the case it is necessary to use it urgently.

## ENDOTRACHEAL INTUBATION

Before performing endotracheal intubation, it is necessary to determine that the child is unconscious and adequately oxygenated. When oxygenating neonates and premature infants, 100% oxygen should be administered with caution due to its toxic effects in this group of patients.

It is believed that endotracheal intubation in children should be performed, whenever possible, after administration of a nondepolarizing agent. Modern nondepolarizing agents act rapidly with minimal risk of electrolyte and circulatory disturbances.

Succinylcholine should only be used in exceptional situations, such as when a patient is anaesthetized on a full stomach or when difficult intubation is anticipated.

This medication should not be used in boys under two years of age due to the risk of asymptomatic muscular dystrophy, such as Duchenne muscular dystrophy (DMD). Particular sensitivity to succinylcholine, manifested by the development of defibrillation-resistant ventricular fibrillation, occurs in these children much earlier than the first symptoms of this disease.

It is also possible to intubate a child without muscle relaxation, but always under deep sedation and with sufficient analgesia.

Over the past decade or so, new devices have been introduced into widespread use, allowing the development of methods that increase the effectiveness and safety of intubation in both normal and problematic airways. The Pediatric Difficult Intubation Registry (PeDIR) has also been established and its reports are available [42–44].

Many scientific papers, prospective studies, and guidelines of scientific societies regarding the improvement of the quality of management in the case of difficult airways have also been published [45–48].

## ASSESSMENT OF INTUBATION DIFFICULTY

Before administering anaesthesia, it is essential to examine the child and assess the degree of difficulty maintaining a patent airway. Neonates and infants constitute a vulnerable group, with an increased risk of complications and a lower degree of predictability of problematic airways. The rate of difficult intubation in this group is 5.8%, compared with 0.88% in the overall paediatric population; 9% of these children also experience difficulties with face mask ventilation [1, 2, 49, 50].

The Colorado Pediatric Airway Score (COPURway Score) incorporates medical history, bedside testing, and anthropometric measurements and suggests appropriate intubation equipment. It combines elements of the Mallampati and Cormack Lehane scales [51] (Table 6A, B).

## CONTINUOUS OXYGENATION DURING APNOEA

Traditional pre-oxygenation using a face mask is difficult to perform in children due to the lack of cooperation and anxiety. The term "preoxygenation" means the continuous supply of oxygen during induction of anaesthesia and intubation, both in the period of active breathing and apnoea, until the airway is effectively secured. This procedure reduces the risk of desaturation and extends the time of "safe apnoea", defined as the time of maintaining saturation above 90% [48, 52, 53]. Continuous oxygenation

**TABLE 6A.** Pediatric Colorado Airway Score (COPURway Score)

| | Observation | Assessment | Score |
|---|---|---|---|
| 1. C | Chin – observe the child's profile | 1. Normal size<br>2. Small, moderately hypoplastic<br>3. Clearly recessive<br>4. Extremely hypoplastic | 1<br>2<br>3<br>4 |
| 2. O | Degree of mouth opening – distance between the front teeth<br>In neonates and infants – 3 baby fingers is the equivalent of 40 mm in an older child | 1. 40 mm (in neonates and infants – 3 baby fingers)<br>2. 20–40 mm<br>3. 10–20 mm<br>4. < 10 mm | 1<br>2<br>3<br>4 |
| 3. P | Previous intubations, OSA | 1. Previous intubations uneventful<br>2. No previous intubation, no OSA symptoms<br>3. Difficult previous intubations or OSA symptoms<br>4. Difficult intubation – extreme or failed; emergency tracheotomy; inability to sleep on back | 1<br>2<br>3<br>4 |
| 4. U | Uvula – observe the palate with the mouth open and the tongue sticking out | 1. Visible tip of uvula<br>2. Uvula is partially visible<br>3. Uvula is hidden, soft palate is visible<br>4. Soft palate is not visible at all | 1<br>2<br>3<br>4 |
| 5. R | Neck mobility – observe the line from the ear to the eye socket, estimate the range of motion from above and below | 1. > 120°<br>2. 60–120°<br>3. 30–60°<br>4. < 30° | 1<br>2<br>3<br>4 |
| 6 | Modifiers – add 1 point for: | 1. Protruding front teeth<br>2. Huge tongue, macroglossia<br>3. Extreme obesity<br>4. Mucopolysaccharidoses | 1<br>1<br>1<br>2 |

OSA – obstructive sleep apnea

**TABLE 6 B.** Pediatric Colorado Airway Score (COPURway Score)

| Score | Assessment of intubation difficulty | View of the glottis in DL |
|---|---|---|
| 5–7 | Easy intubation | 1 |
| 8–10 | Problematic intubation, pressure on the thyroid cartilage may help | 2 |
| 12 | Difficult intubation, fiberscope may be considered | 3 |
| 14 | Difficult intubation, use a fiberscope or other advanced methods | 3 |
| 16 | Very difficult intubation, use advanced methods, prepare for tracheotomy | 4 |
| 16+ | Artificial airway is necessary to maintain life | – |

DL – direct laryngoscopy

**TABLE 7.** Oxygenation techniques during apnoea

| Machine | Technique | Oxygen flow ($FiO_2$ 1.0) |
|---|---|---|
| Nasopharyngeal tube | Connection to the respiratory system | 6 L min$^{-1}$ with the exhalation valve open |
| Low-flow nasal cannulas | Connection to a separate oxygen source | 0.2–1.0 L kg$^{-1}$ min$^{-1}$ |
| High-flow nasal cannulas | Connection to a high-flow therapy device such as Optilow/Airvo | 2.0 L kg$^{-1}$ min$^{-1}$, max. 20 L min$^{-1}$ |
| Oxygen supply integrated with the laryngoscope blade | Video laryngoscope or laryngoscope with continuous oxygen supply (C-MAC, Oxyscop, Truview) | 2–6 L min$^{-1}$ |

$FiO_2$ – fraction of inspired oxygen

during apnoea contributes to higher first-attempt intubation success and reduces the number of intubation attempts by extending the time available for the procedure [46, 47]. This technique is particularly important in patients in whom face mask ventilation should be avoided after induction of anaesthesia and in patients at increased risk of hypoxemia.

The techniques used during apnoeic oxygenation are presented in Table 7 [48, 53].

## DEVICES THAT INCREASE THE EFFECTIVENESS AND SAFETY OF INTUBATION

Devices that increase the effectiveness and safety of intubation include:

- video laryngoscopes with a standard Macintosh or Miller blade (can also be used for direct laryngoscopy), e.g. C-MAC,
- video laryngoscopes with a wide-angle field of view, such as the GlideScope,
- bronchofiberoscope,
- video laryngoscope for hybrid intubation equipped with an intubation fiberscope,
- standard laryngoscopes with integrated oxygen supply,
- supraglottic devices, mainly laryngeal mask airway (LMA),
- nasopharyngeal airway (NPA), oropharyngeal airway (OPA), face masks, ETTs.

## NEW INTUBATION STRATEGIES

The use of a video laryngoscope with an age-appropriate standard blade (Macintosh or Miller) is recommended as the first-line method for tracheal intubation in neonates and infants, including lateral decubitus intubation [46, 48].

Repeated intubation attempts using the same device should be avoided as this increases the number of complications [45, 46].

According to some authors, videolaryngoscopy with high-flow oxygen supplementation should be the standard of care for tracheal intubation in neonates, infants, and children [54].

An equally effective method is intubation using a bronchofiberoscope, which remains the "gold standard" for patients with limited mouth opening and symptoms of cervical spine instability [55]. However, it is necessary to be well trained and gain experience in using this method, as it may take too much time.

## HYBRID TECHNIQUES

Combining techniques takes advantage of the strengths of the devices, particularly video laryngoscopy and fiberoscopy. Hybrid techniques require the collaboration of two physicians – one responsible for visualizing the larynx using the video laryngoscope, and the other who inserts the fiberscope into the airway. This approach allows visualization throughout the intubation period [56].

In the case of difficult airways, another hybrid technique can also be used, which involves securing ventilation with a laryngeal mask during the initial period and then inserting an ETT through the mask channel using a bronchofiberscope [45, 47].

## LARYNGEAL MASK AIRWAYS

Among many supraglottic devices, LMAs have found a permanent place in paediatric anaesthesiology as an alternative device for intubation. They provide sufficient protection for the airway during planned anaesthesia for appropriately selected procedures, and also serve as an intermediate link facilitating intubation in the case of problematic airways. They should not be routinely used when a child is given anaesthesia on a full stomach.

Masks such as i-gel or LMA supreme have an additional channel enabling the insertion of a gastric tube and evacuation of gastric contents.

Tables 8–11 list the types and sizes of airway management devices used in paediatric patients. Table 12 lists the nondepolarizing muscle relaxants used in paediatric anaesthesia.

## MAINTENANCE OF GENERAL ANAESTHESIA

During the maintenance phase of anaesthesia, opioids and inhalation anaesthetics in an oxygen-air mixture are most often used. Currently, most anaesthesiologists avoid the use of nitrous oxide due to its penetration into free spaces, which significantly complicates the use of endoscopic surgical techniques – laparoscopy and thoracoscopy, as well as its significantly negative impact on the environment. Global recommendations also indicate avoiding desflurane as a gas that strongly irritates the respiratory tract and significantly contributes to the greenhouse effect – some countries are gradually phasing out the use of desflurane [57].

In justified cases, total intravenous anaesthesia (TIVA) can be performed using propofol (most often), thiopental or ketamine (the latter in haemodynamically unstable children) [58].

During operations requiring muscle relaxation, the administration of muscle relaxants should require monitoring of neuromuscular conduction. The dose of the muscle relaxant to maintain anaesthesia should be selected individually, taking into account the expected duration of the procedure, interactions with drugs administered before and during anaesthesia, and the condition of the child (based on the characteristics of the medicinal product). Inhalation anaesthetics potentiate the effects of muscle relaxants. Available intravenous prepara-

**TABLE 8.** Endotracheal tubes (ETT)

| Child's age | Body mass [kg] | ETT (ID) without cuff [mm] | ETT (ID) with cuff [mm] | ETT depth [cm] from mouth level | Laryngoscope – blade size |
|---|---|---|---|---|---|
| Neonate | < 1 | 2.0–2.5 | – | 7 | Miller 0 |
| Neonate | 1–2 | 2.5–3.0 | – | 8 | Miller 0 |
| Neonate | 2–3 | 3.0 | 3.0 | 9 | Miller 0/1 |
| Neonate | > 3 | 3.5 | 3.0 | 10 | Miller 1 |
| 1–6 months | 4–6 | 3.5–4.0 | 3.0 | 11 | Miller 1 |
| 6–12 months | 6–10 | 3.5–4.0 | 3.5 | 12 | Miller1/MAC1 |
| 1–2 years | 10–12 | 4.0 | 3.5–4.0 | 13 | MAC1 |
| 2–4 years | 12–16 | 4.5 | 4.5 | 14 | MAC1/MAC2 |

ID – internal diameter

**TABLE 9.** Diameter and depth of endotracheal tube (ETT) insertion depending on age

| | |
|---|---|
| ETT internal diameter without cuff | (Child's age/4) + 4 mm |
| ETT internal diameter with cuff | (Child's age/4) + 3 mm |
| Depth of ETT inserted through the mouth | (Child's age/2) + 12 cm |
| Depth of ETT inserted through the nose | (Child's age/2) + 15 cm |

**TABLE 10.** I-gel laryngeal mask airway (LMA)

| i-gel size | Colour | Body mass [kg] | Maximum size of the nasogastric tube | Maximum size of the endotracheal tube |
|---|---|---|---|---|
| 1 | Pink | 2–5 | No channel | 3 |
| 1.5 | Blue | 5–12 | 10 | 4 |
| 2 | Grey | 10–25 | 12 | 5 |
| 2.5 | White | 25–35 | 12 | 5 |
| 3 | Yellow | 30–60 | 12 | 6 |

**TABLE 11.** Nasopharyngeal airway (NPA) and oropharyngeal airway (OPA)

| Age | NPA size | Suction catheter size | OPA size | Age group |
|---|---|---|---|---|
| < 1 month | 3 | 6 | 000–40 mm | Neonates |
| 1–6 months | 3.5 | 8 | 00–50 mm | Infants |
| 6–18 months | 4 | 8 | 0–60 mm | Young children |
| 18 months – 3 years | 4.5 | 8 | 1–70 mm | Older children |

**TABLE 12.** Non-depolarizing muscle relaxants used in paediatric anaesthesia

| Indications | Drug | Dose for intubation [mg kg b.w.$^{-1}$] | Maintenance dose [mg kg b.w.$^{-1}$] | Duration of drug effect [min] |
|---|---|---|---|---|
| Basal | Rocuronium | 0.5 | 0.2 | 30–40 |
| Kidney/liver failure | Atracurium | 0.6 | 0.2 | 15–35 |
| Neonates | Atracurium | 0.4 | 0.15 | 15–35 |
| Anaesthesia up to 15 min | Mivacurium | 0.25 | 0.1 | 13–23 |
| Anaesthesia > 20 min | Vecuronium | 0.15 | 0.05 | 20–40 |
| Rapid intubation, anaesthesia > 30 min | Rocuronium | 0.6–1.2 | 0.2 | 30–40 |

tions of nondepolarizing muscle relaxants include rocuronium, vecuronium, atracurium, cisatracurium, and mivacurium. The duration of action and recovery is shorter than in adults.

It is permissible to use low-flow anaesthesia (LFA) techniques, but when using this technique, it is important to maintain the oxygen concentration in the end-tidal mixture above 25% [59].

## MONITORING

During anaesthesia, the patient's vital parameters must be monitored in accordance with the Regulation of the Minister of Health of 16 December 2016 (as amended) on the organizational standard of health care in the field of anaesthesiology and intensive care [28].

## OXYGEN THERAPY AND MECHANICAL VENTILATION

### Use of oxygen during anaesthesia

Oxygen is an essential component of cellular metabolic processes, therefore an adequate supply of oxygen is essential during anaesthesia. For many years, high concentrations of oxygen in the breathing mixture were used in clinical practice due to the fear of hypoxia, but there is now increasing evidence that hyperoxia is also harmful, especially in extreme age groups. In children, excessive oxygen concentration in tissues causes increased vascular resistance, which leads to narrowing of cerebral vessels and causes a decrease in cerebral blood flow (CBF), also contributing to the formation of atelectasis foci in the lungs. In premature infants, hyperoxia poses a significant risk of retinopathy of prematurity (ROP) and predisposes to the development of bronchopulmonary dysplasia; therefore, increasing attention is now paid to avoiding excessive exposure to oxygen [60, 61]. Thus, it is recommended to carefully titrate the oxygen supply during general anaesthesia so that the saturation is within the optimal range for the patient:

- premature infant – 88–94%,
- full-term infant – 92–96%,
- older child – over 95%.

It's important to remember about the limitations of pulse oximetry. Measurement results can be significantly distorted by conditions such as anaemia, hypothermia, shock, or high foetal haemoglobin (HbF) levels.

During routine general anaesthesia, unless specifically indicated, an oxygen concentration of 80% should not be exceeded during induction and recovery from anaesthesia, as higher oxygen concentrations rapidly induce airway closure and alveolar collapse, which leads to the formation of atelectasis. They also cause cerebral vasoconstriction and decreased blood flow. During the maintenance phase of general anaesthesia, an FiO2 concentration of 25–35% appears to be sufficient [60].

It should be remembered that in the immediate postoperative period, passive oxygen therapy may mask the symptoms of hypoventilation or airway obstruction and delay an adequate response, which is an additional reason to avoid routine administration of oxygen in the recovery room in healthy children with saturation above 95% [62].

### Mechanical ventilation of the lungs

During general anaesthesia, the use of positive pressure ventilation is an essential element of anaesthesia to ensure proper gas exchange. For many years, anaesthesiologists primarily used pressure-controlled ventilation (PCV) in children, usually due to equipment limitations. Ventilators at the time were imprecise in administering small tidal volumes, and PCV ensured maximum safety for paediatric patients. Currently, modern anaesthesia machines incorporate ventilators modelled on those used in intensive care units. These allow for pressure- or volume-controlled ventilation (VCV) modes, even in young children, pressure support when the patient is breathing spontaneously, and hybrid modes (PCV-VG: pressure controlled ventilation-volume guarantee, PRVC: pressure-regulated volume control) that provide synchronized mandatory minute ventilation in addition to pressure support. All of these modes are potentially useful for paediatric surgical patients, but it is important to understand the advantages and limitations of each when selecting ventilation and ventilator settings. In children breathing spontaneously through an LMA, pressure support ventilation (PSV) is extremely useful, significantly reducing respiratory effort.

The use of PIP always causes significant changes in the physiology of the respiratory system, such as increased airway resistance, decreased FRC, the appearance of atelectasis foci, disturbance of the ventilation-perfusion ratio or surfactant damage [13]. Currently, experts agree that the best ventilation strategy during general anaesthesia is lung-sparing ventilation, conducted in a way that prevents the negative consequences of ventilation replacement and minimizes the risk of ventilator-induced lung injury. It should be carried out in such a way that the blood gas parameters are within the reference range – both hypo- and hyperoxia, but also hypo- and hypercapnia should be avoided [63].

### Tidal volume

It is currently widely accepted that the normal tidal volume (TV) in children should be 6–8 mL per kg of ideal body weight (IBW). In healthy neonates, the average tidal volume is 4–6 mL $kg^{-1}$, and minute ventilation is 0.2–0.3 L $min\ kg^{-1}$ [64].

### Respiratory rate

Ensuring the correct respiratory rate is crucial for achieving adequate minute ventilation. When determining the normal value, the patient's age should be taken into account (for a premature infant, the normal respiratory rate is 30–60/min, for a one-year-old, 20–40/min, and for a 10-year-old, 12–20/min), as well as anatomical differences (e.g., resulting from obesity, chest or lung abnormalities), and chronic diseases such as asthma or bronchopulmonary dysplasia. It is important to adjust the inspiratory time parameter to the required respiratory rate to ensure the patient experiences physiological inspiratory and expiratory phases.

### Positive end-expiratory pressure

The use of PEEP is now an integral part of lung-sparing ventilation strategies. It minimizes the risk of distal alveolar collapse and atelectasis, and reduces intrapulmonary shunting. However, there are no clear recommendations regarding the optimal PEEP value for ventilation of healthy children during anaesthesia. A PEEP level of 5–7 cm $H_2O$ is generally considered optimal in healthy patients [65, 66].

### Recruitment maneuvers

The purpose of recruitment maneuvers, which involve a transient increase in intrathoracic plateau pressure, is to aerate collapsed alveoli and prevent the formation of atelectasis. Although literature data on the use of recruitment maneuvers during general anaesthesia in children are limited it appears that in certain clinical situations associated with a high risk of developing atelectasis (e.g., after airway suctioning or during laparoscopic procedures), they may be beneficial and prevent the development of postoperative pulmonary complications. They are particularly indicated when a gradual decrease in saturation is sometimes observed. A correct recruitment maneuver is intended to prevent later complications.

In children with preserved spontaneous breathing during anaesthesia, it is worth considering the use of PSV, because positive inspiratory pressure compensates for the resistance of the artificial airways and reduces the respiratory effort [64]. New methods of respiratory support, such as high-flow nasal oxygen therapy, are promising, and although there are few reports on their use in paediatric anaesthesia, it seems that they will also find a place in anaesthesia practice in the operating room.

## PERIOPERATIVE FLUID THERAPY

It should be borne in mind that the youngest patients, especially neonates and infants, due to the immaturity of their kidneys, are less resistant to errors in fluid therapy – both in the case of fluid deficiency and excess. Fluid overload has been shown to be associated with potentially longer mechanical ventilation, heart failure, acute kidney injury, prolonged hospitalization, and increased mortality [67]. In neonates, a positive fluid balance additionally increases the risk of bronchopulmonary dysplasia (BPD), intracranial haemorrhage (ICH), necrotizing enterocolitis (NEC), and haemodynamically significant patent ductus arteriosus (PDA) [66]. In the youngest patients, the mechanisms regulating normal sodium concentration are also immature, and sodium disturbances may negatively impact the CNS and the child's further development. Similarly, abnormal glucose levels and hypo-, but also hyperglycaemia are observed more frequently [67]. For the reasons mentioned above, careful fluid therapy is particularly important in this age group.

## PREOPERATIVE FLUID THERAPY

Due to the fact that currently the preoperative fast should be very short (1 hour from clear fluids, 3 hours from breast milk, 4 hours from formula), even the youngest children should not have a fluid deficit in the case of anaesthesia for elective surgery [68]. Therefore, even such young patients usually do not require fluid therapy before transfer to the operating room. If the procedure takes significantly longer to begin, the child should be given clear fluid or receive an intravenous infusion (10 mL $kg^{-1}$ of isotonic balanced crystalloid).

Fluid depletion may occur during emergency procedures [67]. In such cases, efforts should be made to correct any fluid deficiencies before induction of anaesthesia, as this may reveal previously hidden hypovolemia. If this is not possible, administering a bolus/boluses of 10 mL $kg^{-1}$ of isotonic crystalloid, preferably balanced, should be considered before induction.

**TABLE 13.** Basic fluid requirements in children

| Body mass (kg) | mL $kg^{-1}$ $day^{-1}$ | Dose per hour |
|---|---|---|
| Up to 10 | 100 mL $kg^{-1}$ $day^{-1}$ | 4 mL $kg^{-1}$ $h^{-1}$ |
| 10–20 | 1000 mL + 50 mL $kg^{-1}$ between 10 and 20 kg | 40 mL + 2 mL $kg^{-1}$ $h^{-1}$ |
| > 20 | 1500 mL + 20 mL $kg^{-1}$ > 20 kg | 60 mL + 1 mL $kg^{-1}$ $h^{-1}$ |

**TABLE 14.** Basic fluid requirements in neonates

| Day of life | Fluid amount (mL $kg^{-1}$ $day^{-1}$) |
|---|---|
| 1 | 60 (preterm infants 80) |
| 2 | 80 |
| 3 | 100 |
| 4 | 120 |
| 5 | 120 |

## INTRAOPERATIVE FLUID THERAPY

The goal of intraoperative fluid therapy is to maintain adequate tissue perfusion during the procedure, taking into account baseline requirements, ongoing losses, and any pre-existing deficit. The approximate basic requirements of children are presented in Table 13, and of neonates (babies up to 28 days of age) – in Table 14. Similarly to older children, in the case of infants, it is recommended to use isotonic crystalloid solutions during anaesthesia (these are fluids containing sodium at a concentration of 130–155 mmol $L^{-1}$), preferably balanced, without glucose or containing 1% glucose [68, 69]. Balanced crystalloids contain physiological concentrations of chloride and organic anions, for example: acetate, lactate, gluconate, malate, which are a substrate for the systemic production of bicarbonates, thanks to which they have a buffering effect. Large volumes of NaCl-based fluids (e.g., 0.9% NaCl, Ringer's solution) have the opposite effect and can cause hyperchloremic metabolic acidosis. Even in the youngest patients, as a result of the hormonal response to the stress related to surgery, glucose levels usually increase during anaesthesia, even if glucose-free fluids are used. However, the youngest patients – neonates, especially those born prematurely and/or hypotrophic, full-term babies in the first days of life, as well as infants and children with additional health problems may require intraoperative glucose supply and/or frequent monitoring of its concentration (Table 1). The type of surgery and the anaesthesia are also important; the longer the surgery and the more effective the anaesthesia (e.g. regional anaesthesia effectively eliminating pain impulses), the higher the risk of hypoglycaemia.

In the case of neonates, the most commonly used technique involves two infusions, one of which administers 10% glucose at a rate of approximately 50% of the basal requirement, and the other one administers balanced isotonic crystalloid without glucose, the volume of which depends on the type of surgery and the losses observed. In children under 1 year of age, fluids must be transfused using an infusion pump.

The use of hypotonic solutions (e.g. 5% glucose, mixtures of 5% glucose with 0.9% NaCl: in volume ratios of 4 : 1, 2 : 1, 1 : 1) is strongly contraindicated due to the risk of developing acute hyponatremia and, consequently, cerebral oedema. This risk is due to potentially inappropriate secretion of antidiuretic hormone (ADH), which is a stress hormone. Therefore, the occurrence of acute hyponatremia is possible, although much less likely, even with properly conducted fluid therapy using isotonic crystalloids [68].

## POSTOPERATIVE FLUID THERAPY

It is recommended to resume oral fluid (and food) intake as soon as possible. From the anaesthesiologist's perspective, oral intake can be resumed if the child is awake. In the case of neonates and infants, the child can be breastfed after awakening. If this is impossible due to surgical reasons or the child's general condition, it is advisable to transfuse isotonic crystalloids, preferably balanced, with 4–5% glucose [67, 68]. Neonates who are unable to take food orally for a prolonged period may require parenteral nutrition, while fluid therapy typically involves 10% glucose with electrolytes – sodium, initially 2 mmol kg $day^{-1}$, potassium, initially 2 mmol kg $day^{-1}$, and calcium, initially 1 mmol kg $day^{-1}$. The composition of the fluid should be modified depending on the monitoring blood gases, electrolytes, glucose, lactic acid, fluid balance, and the child's body mass. The starting point for calculating the volume of fluids to be transfused should be the basic requirement (Tables 13 and 14). This volume, depending on the circumstances, should be increased if fluid loss progresses, the neonate is kept in an open incubator and/or is undergoing phototherapy, or more frequently reduced by 30–50%, especially after extensive surgery when an inappropriately high ADH concentration is expected.

## EMERGENCE

This is the period of anaesthesia that requires the most attention due to the high risk of complications. It should be emphasized that uncomplicated intubation/LMA insertion does not guarantee equally uneventful removal. Waking up a child from anaesthesia, especially after extubation or removal of the LMA, may be accompanied by adverse events resulting from irritation of the respiratory tract due to the entry of blood, secretions, or tissue fragments into the glottis or bronchial tree (particular attention is required for young ENT patients, often suffering from allergies or early childhood asthma). Coughing, abnormal respiratory movements, laryngospasm, and consequently, desaturation, may be observed. If these occur, a predetermined action plan is necessary, as if left untreated, they can cause hypoxia or even cardiac arrest. Extubation in the lateral position is recommended. Oxygenation for several minutes is also important, as in the induction of anaesthesia. This allows for "buying" time for effective intervention. The younger the child, the less time this will require, due to their greater oxygen requirements. Extubation after the child is fully awake is considered a safer method, but is more likely to be associated with agitation. Extubation during sleep prevents excessive agitation following anaesthesia but should only be performed by experienced anaesthesiologists.

Sometimes respiratory problems after extubation are due to residual neuromuscular blockade, therefore the importance of train-of-four (TOF) monitoring of neuromuscular conduction is emphasized. If a short time has passed since the last administration of a non-depolarizing drug, the patient has a TOF of less than 0.9 or clinical symptoms of residual blockade (jerky movements of skeletal muscles, weak cough reflex), the block should be reversed by administering neostigmine at a dose of 0.05 mg $kg^{-1}$ after prior administration of atropine or (ideally) sugammadex; however, it only eliminates steroid preparations from the body.

The condition of a patient in the post-anaesthesia care unit requires assessment and documentation. The Aldrete Scoring System can be used to assess the child's condition.

## POSTOPERATIVE NAUSEA AND VOMITING

It is worth mentioning that children are characterized by a relatively high tendency to nausea and/or vomiting, also in the perioperative period.

According to the ERAS (enhanced recovery after surgery) protocol, drinking fluids before anaesthesia, especially those containing carbohydrates and electrolytes, is one of the effective non-pharmacological methods for reducing the incidence of postoperative nausea and vomiting (PONV) in children. A similar effect is achieved by drinking fluids as early as possible after surgery, provided there are no surgical contraindications, even in the post-anaesthesia care unit.

The strategy for preventing PONV begins during the preoperative anaesthetic visit, when the risk factors for PONV should be identified. They can be divided into three groups, depending on the timing and risk of occurrence: preoperatively, intraoperatively, and postoperatively (Table 16). If a child has all four preoperative factors, the risk of PONV is estimated at up to 80%. In these patients, special attention should be paid to observing the fluid withdrawal period before anaesthesia and not extending the fasting period, but rather encouraging the child to take fluids in accordance with the principles described.

**TABLE 15.** Conditions/situations requiring intraoperative glucose administration and/or glycaemic control

| |
|---|
| Risk factors for intraoperative hypoglycemia |
| Neonates, especially those < 48 hours of age, and premature babies |
| Prolonged anaesthesia |
| Regional anaesthesia |
| Hypotrophy/low body mass index |
| Preoperative parenteral nutrition |
| Metabolic diseases |
| Type 1 diabetes |

Preoperative fluids are also supplemented by sufficient supply during the intraoperative period, and according to a liberal fluid policy, it may be as much as 30 mL $kg^{-1}$ in children at medium and high risk of PONV.

In the process of qualifying for anaesthesia and surgery, appropriate procedures should be considered and then implemented. These include:

- avoiding general anaesthesia by using regional anaesthesia,
- use of propofol as the drug of choice in TIVA,
- avoiding nitrous oxide in operations lasting longer than 60 minutes,
- avoiding other inhalation anaesthetics,
- minimizing intra- and postoperative doses of opioids,
- proper fluid therapy,
- use of sugammadex instead of neostigmine to reverse neuromuscular blockade.

Prophylactic pharmacological treatment depending on the risk level of PONV is presented in Table 17.

**TABLE 16.** Risk factors for post-operative vomiting/post-operative nausea and vomiting (POV/PONV) in children

| Preoperative | Intraoperative | Postoperative |
|---|---|---|
| Age > 3 years | Strabismus surgery | Long-acting opioids (indications for the inclusion of multimodal analgesia to limit the supply of opioids) |
| History of motion sickness or POV/PONV during previous anaesthetic procedures | Adenotonsillotomy | |
| Family history of POV/PONV | Otoplasty | |
| Female, after puberty | Operations lasting ≥ 30 min | |
| | Inhalation anaesthetics | |
| | Cholinesterase inhibitors | |

**TABLE 17.** Prevention of nausea and/or vomiting in the postoperative period in children

| | Low risk | Medium risk | High risk |
|---|---|---|---|
| Number of risk factors | 0 | 1–2 | ≥ 3 |
| Prevention | No treatment or 5-$HT_3$ antagonist or dexamethasone | 5-$HT_3$ antagonist + dexamethasone | 5-$HT_3$ antagonist + dexamethasone + consider TIVA |

In the treatment of postoperative vomiting and nausea, simultaneous administration of ondansetron with dexamethasone is recommended.

Ondansetron is recommended for both prophylactic and therapeutic use as a single slow intravenous injection (≥ 30 s) at a dose of 0.05–0.1 mg $kg^{-1}$ (max. ≤ 4 mg) in patients from 1 month of age, although data for children under 2 years of age are limited. Similarly, dexamethasone may be administered in combination with ondansetron in patients at high risk of PONV at a dose of 0.1–0.15 mL $kg^{-1}$ intravenously (max. 5 mg).Other drugs, such as droperidol, tropisetron, dolasetron, granisetron and others, are not covered by the recommendations of the FDA or the European Medicines Agency (EMA) [70, 71].

## LARYNGOSPASM

Laryngospasm is caused by reflex contraction of the muscles that close the glottis. It is more common in children, especially the youngest ones [1, 72]. Since improper management of laryngospasm may lead to severe hypoxia and even death of the patient, every anaesthesiologist taking care of paediatric patients should know how to prevent, recognize and treat this potentially dangerous complication.

Laryngospasm most often occurs in the youngest patients (under 5 years of age), but can occur in all age groups. It most often appears during the recovery after anaesthesia, then during induction, and least frequently during maintenance [73]. The immediate trigger factor may be irritation of the laryngeal area, for example by blood, secretions or suctioning of the respiratory tract with a catheter, but it may also be a sudden pain stimulus from the operated area when the depth of anaesthesia is insufficient. Table 18 presents the risk factors for laryngospasm [1, 72, 73].

Laryngospasm most often manifests as a sudden inability to ventilate the lungs of a non-intubated patient, retraction of the zygomatic fossa, increased inspiratory effort, and paradoxical movements of the chest and abdomen (the patient attempts to inhale air, but this is impossible or very difficult with a closed glottis), as well as inspiratory stridor during partial spasm. Complete airway obstruction, particularly in a young child with a low oxygen reserve, can quickly lead to desaturation, bradycardia, and even cardiac arrest. The good news is that proper management virtually completely prevents permanent complications of laryngospasm. The key factors are:

- immediate cessation of the stimulation that caused laryngospasm,
- making sure the problem is not caused by blood/vomit in the throat,
- supply of oxygen under positive pressure through a tightly fitted face mask,
- deepening anaesthesia with an intravenous drug (inhalation is not possible!). Use a drug that is readily available, for example, propofol (but it is better not to administer ketamine) in titrated doses of 1 mg $kg^{-1}$; benzodiazepines, especially relanium, are also effective,

**TABLE 18.** Risk factors for laryngospasm

| Patient related | Anaesthesia related | Surgery related |
|---|---|---|
| Age < 5 years | Too shallow anaesthesia | ENT procedures (adenotonsillotomy!)/ airway shared with an anaesthesiologist |
| Current or past respiratory infection < 2 weeks | Respiratory irritation (e.g., desflurane) | Painful procedures with a face mask, e.g., perianal abscess |
| Respiratory hypersensitivity, asthma | Airway manipulations (e.g., suctioning, laryngoscopy without relaxation) | Neck surgery – thyroid, superior laryngeal nerve palsy, hypocalcemia |
| Passive smoking | Airway instrumentation (laryngeal mask airway!, endotracheal tube) | Oesophageal surgery |
| Gastroesophageal reflux | Inhalation anaesthesia only | Anogenital surgery |
| Obesity with sleep apnea | Inexperienced anaesthesiologist | – |
| Abnormal anatomy of the upper respiratory tract | – | – |

- in the absence of reaction (this happens extremely rarely), a muscle relaxant should be administered and the trachea intubated (in the absence/loss of intravenous access, succinylcholine should be injected, preferably sublingually 2 mg kg$^{-1}$, intraosseously 1 mg kg$^{-1}$, or intramuscularly 4 mg kg$^{-1}$) [72].

The assistance of a second anaesthesiologist should always be sought if the situation requires it, and in the case of inexperienced physicians (even if they are specialists) it should be mandatory [72].

It's also worth remembering that children who experience laryngospasm may develop pulmonary oedema, a result of the extreme negative pressure in the chest. Therefore, after controlling the critical situation, the child's chest should be carefully auscultated.

## POSTOPERATIVE PAIN MANAGEMENT

The International Association for the Study of Pain (IASP) defines pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage. Effective pain management, especially in situations of acute pain associated with surgery and painful diagnostic procedures, is not only crucial for improving the quality of life of patients, but it also constitutes the foundation for respecting a fundamental human right – the right to relief from suffering.

Acute pain affects approximately 5% of the population in all age groups. It is estimated that approximately 70% of paediatric patients undergoing surgery experience moderate to severe pain, which demonstrates the importance of effective analgesia in this group of patients.

The main goals of acute pain management in children include:

- ensuring effective analgesia – using modern pharmacological and non-pharmacological methods to minimize pain,
- achieving hemodynamic stability – bearing in mind that acute pain causes adverse body reactions, such as increased blood pressure, HR or increased secretion of stress hormones,
- reducing the risk of chronic pain – untreated or insufficiently treated pain not only affects the child's current physical and emotional state, but also causes permanent changes in the CNS and increases the risk of developing chronic pain in the future.

Effective perioperative pain management requires a carefully developed management plan that addresses the entire medical care process – before, during and after surgery. A key element of this plan is a thorough assessment of the patient's health status, taking into account both the underlying disease and any comorbidities. Safe and effective perioperative analgesia requires special emphasis on several key activities:

- assessment of the occurrence and severity of pain should be conducted and documented, including the types of medications used, principles for monitoring pain and adverse events, and guidelines for patients with special needs (e.g., neonates, premature infants),
- regular pain assessment in children should be conducted based on their age, communication skills, and health status. Regardless of the scale chosen, pain assessments be repeated at regular intervals, and the results of these assessments must be documented. The following pain scales are used for this purpose:

– visual analogue pain scales [e.g. numerical rating scale (NRS), visual analogue scale (VAS)] – in which the child assesses occurrence and intensity of pain (rarely used in children under 3 years of age),

– behavioural scales [e.g. Face, Legs, Activity, Cry, Consolability scale (FLACC), Cry, Requires increased oxygen administration, Increased vital signs, Expression, Sleepless [CRIES]) – used to assess facial expressions, crying, body movements, as well as changes in physiological parameters, used in infants and young children,

– in assessing pain, especially in the youngest patients, so-called pain monitors may be useful, operating on the basis of the assessment of HR variability or electrical conductivity of the skin;

- pain medication administration should be tailored to the individual needs of the child; the choice of analgesia method will depend on the child's age, previous pain responses, type of surgical procedure, and the expected intensity and duration of pain,
- proper management of postoperative analgesia in children must ensure correct assessment of pain intensity, knowledge of the pharmacology of analgesics used in different age groups, and the ability to perform regional anaesthesia in patients for whom it is possible,
- informing parents/legal guardians about planned pain management and how to report their child's pain symptoms is an important element of care. Including caregivers in the treatment process increases its effectiveness and allows for a more precise assessment of the child's feelings.

The basic principle of postoperative pain management in children is multimodal analgesia, which combines drugs and techniques targeting different elements of the nociceptive system to improve the effectiveness of therapy, reduce pain intensity, and limit side effects. Severe pain in children should be prevented by implementing preemptive or preventive analgesia. Preemptive analgesia refers to the administration of pain medication before a painful stimulus occurs, such as a surgical incision or other painful procedures. Its goal is to inhibit activation of the nervous system by painful stimuli. In practice, this means administering pain medications before induction of anaesthesia or using analgesia techniques during anaesthesia (e.g., peripheral nerve blocks, local anaesthetic infusion). Preventive analgesia, on the other hand, focuses on preventing persistent pain effects by reducing the activity of the pain system both during and after surgery. The aim of these actions is to block inflammatory and neuropathic processes and increased activity of pain receptors after surgery. All painful procedures, such as insertion of additional intravenous or arterial access or an epidural catheter, should be performed after the child has been induced into anaesthesia. If continuous local analgesia methods (e.g. epidural analgesia) are planned, the first dose of local anaesthetic should be administered before the start of the surgery, which increases the effectiveness of pain control. It is crucial that pain does not wake the child after surgery, which requires proper planning and implementation of effective analgesia methods. Maximum doses of analgesics should not be exceeded during treatment. The most common routes of analgesic administration in children are intravenous and oral. In young children, the rectal route may also be used. When choosing an intravenous route, the following methods can be used: repeated single doses of analgesics at regular intervals, continuous infusions, including a widely used modified patient-controlled analgesia (PCA) option for younger children, known as nurse-controlled analgesia (NCA), which is used in intensive care units. Routes of administration that cause pain, such as intramuscular injections, are unacceptable. It is important to remember about the possibilities of using non-pharmacological techniques, including: distraction (diverting attention) using elements of play, kangaroo care (skin-to-skin contact with a parent), which reduces the sensation of pain in neonates and infants, relaxation or stimulation techniques, such as acupuncture, acupressure or electrostimulation (TENS – transcutaneous electrical nerve stimulation).

One of the fundamental elements of modern acute pain management in children is regional anaesthesia. Unlike traditional systemic analgesia, regional blocks provide significantly more effective and long-lasting pain control. What is particularly important, this method allows for a significant reduction in the need for opioid analgesics, thus minimizing the risk of undesirable effects associated with their use. Unlike in adults, a regional block in children should be performed under deep sedation or general anaesthesia. This procedure not only increases patient comfort but also improves the precision and safety of the procedure. The role of modern technology in regional anaesthesia deserves special attention. The use of ultrasound imaging and/or a nerve stimulator significantly improves the quality and effectiveness of this type of analgesia. These tools enable precise location of anatomical structures, which results in greater safety and effectiveness of the procedure.

During the initial postoperative period, the child's condition should be closely monitored, including the level of consciousness and pain intensity. The obtained information allows for the decision to administer another dose of analgesic immediately after the effect of anaesthesia wears off. During this time, it is equally important to verify the extent and quality of regional anaesthesia which may influence the verification of therapeutic assumptions established before the procedure. Further pain management in the subsequent postoperative days

**TABLE 19.** Paracetamol dosage in neonates, infants, and children with detailed consideration of age differences

| Body mass (kg) | Route of administration | Dose | Interval between doses (hours) | Maximum daily dose |
|---|---|---|---|---|
| < 5 (neonates) | Intravenous | 7.5 mg kg$^{-1}$ | 4–6 | 30 mg kg$^{-1}$ |
| | Oral | 7.5–10 mg kg$^{-1}$ | 4–6 | 40 mg kg$^{-1}$ |
| | Intrarectal | 15 mg kg$^{-1}$ | 4–6 | 60 mg kg$^{-1}$ |
| 5–10 | Intravenous | 10 mg kg$^{-1}$ | 4–6 | 40 mg kg$^{-1}$ |
| | Oral | 10–15 mg kg$^{-1}$ | 4–6 | 40–60 mg kg$^{-1}$ |
| | Intrarectal | 15–20 mg kg$^{-1}$ | 4–6 | 60–90 mg kg$^{-1}$ |
| 10–50 | Intravenous | 15 mg kg$^{-1}$ | 4–6 | 60 mg kg$^{-1}$ |
| | Oral | 15 mg kg$^{-1}$ | 4–6 | 60 mg kg$^{-1}$ |
| | Intrarectal | 20–40 mg kg$^{-1}$ | 4–6 | 80–160 mg kg$^{-1}$ |

is tailored to the patient's individual needs. This requires constant monitoring of the child's clinical condition. Properly tailored pain management can ensure greater comfort and a faster recovery. When planning pain treatment for a child, it is important to provide parents or legal guardians and primary care staff with information about the pain management plan, including a gradual, rational reduction of analgesic doses after the patient is discharged from hospital.

**TABLE 20.** Dosage of metamizole in children

| Body mass [kg] | Route of administration | Dose | Interval between doses [hours] | Maximum daily dose |
|---|---|---|---|---|
| < 10 | Intravenous | 8–15 mg $kg^{-1}$ | 6–8 | 60 mg $kg^{-1}$ |
| | Oral | 8–15 mg $kg^{-1}$ | 6 | 60 mg $kg^{-1}$ |
| 10–50 | Intravenous | 10–15 mg $kg^{-1}$ | 6 | 60 mg $kg^{-1}$ |
| | Oral | 10–15 mg $kg^{-1}$ | 6 | 60 mg $kg^{-1}$ |
| | Intravenous infusion | 2.5 mg $kg^{-}$ $h^{-1}$ | – | 60 mg $kg^{-1}$ |

**TABLE 21.** Dosage of nonsteroidal anti-inflammatory drugs (NSAIDs) in children

| NSAIDs | Route of administration | Dose | Interval between doses (hours) | Maximum daily dose |
|---|---|---|---|---|
| Ibuprofen > 3 months | Oral, intrarectal | 10 mg $kg^{-1}$ | 8 | 30 mg $kg^{-1}$ |
| Diclofenac > 1 year | Oral, intrarectal | 0.5–3 mg $kg^{-1}$ | 8 | 3–9 mg $kg^{-1}$ |
| Naproxen > 2 years | Oral, intrarectal | 5–7.5 mg $kg^{-1}$ | 12 | 10–15 mg $kg^{-1}$ |

**TABLE 22.** Dosage of opioids in children

| Opioid | Route of administration | Dose | Interval between doses (hours) | Infusion |
|---|---|---|---|---|
| Morphine | Intravenous, subcutaneous | 25–100 μg $kg^{-1}$ | 3–4 | 10–40 μg $kg^{-1}$ $h^{-1}$ |
| | Intravenous | 20–50 μg $kg^{-1}$ | 4 | |
| Fentanyl | Intravenous | 1–2 μg $kg^{-1}$ | – | 0.5–2 μg $kg^{-1}$ $h^{-1}$ |
| Sufentanil | Intravenous | 0.5–1 μg $kg^{-1}$ | – | 0.05–0.15 μg $kg^{-1}$ $h^{-1}$ |
| Tramadol | Intravenous | 1–1.5 mg $kg^{-1}$ | 4–6<br>Max. 8 mg kg $day^{-1}$<br>Max. 400 mg kg $day^{-1}$ | 0.07–0.25 mg $kg^{-1}$ $h^{-1}$ |
| | Oral | 50–100 mg | 4–6<br>Max. 400 mg $day^{-1}$ | – |
| Oxycodone | Intravenous, oral | 0.05–0.15 mg $kg^{-1}$ | 3–4 | – |
| Nalbuphine | Intravenous | 0.1–0.2 mg $kg^{-1}$ | 3–6 | Bolus 0.2 mg $kg^{-1}$<br>Infusion 0.05–0.1 mg $kg^{-1}$ $h^{-1}$ |

**TABLE 23.** Dosage of local anaesthetics in children

| | Bupivacaine | Levobupivacaine | Ropivacaine | Lidocaine | Prilocaine |
|---|---|---|---|---|---|
| Onset of action | 10–15 min | 10–15 min | 10–15 min | 5–10 min | 5–10 min |
| Maximum dose (without adrenaline) | 2,5 mg $kg^{-1}$ | 2,5 mg $kg^{-1}$ | 2 mg $kg^{-1}$ | 4 mg $kg^{-1}$ | 6 mg $kg^{-1}$ |
| Maximum dose (with adrenaline) | 2,5 mg $kg^{-1}$ | 2,5 mg $kg^{-1}$ | Not used | 7 mg $kg^{-1}$ | 8 mg $kg^{-1}$ |
| Duration of action (without adrenaline) | 3–12 h | 3–12 h | 3–12 h | 1–2 h | 1–2 h |
| Duration of action (with adrenaline) | 4–12 h | 4–12 h | No data | 2–4 h | 2–4 h |

Detailed information on the principles of acute pain management in children, pain pharmacotherapy, drug dosing, and pain relief algorithms after surgical procedures is included in the document "Guidelines for the Management of Acute Pain in Children – Position Statement of the Paediatric Section of the Polish Society of Anaesthesiology and Intensive Therapy" [74].

The dosages of the most commonly used analgesics in children are given in Tables 19–23.

## SUMMARY

Perioperative care of neonates, infants and small children up to 3 years of age is difficult and demanding, which is largely due to the specific nature of this developmental period, different physiology, pathophysiology of diseases, and significant immaturity. All these factors mean that the risk of intra- and postoperative complications in these children is incomparably higher than in the adult population. The homeostatic balance of a child's body is extremely fragile and only the knowledge and experience of the anaesthesiology team responsible for the child during and after anaesthesia is the basic guarantee of its safety.

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