INTRODUCTION TO ANESTHESIOLOGY FOR CHILDREN AND ADOLESCENTS

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1. INTRODUCTION

We are pleased to present the second edition of this textbook, revised and expanded, with English corrections by a native speaker, John Filip Koladzyn, a medical student from New York City studying at our university. John has made every effort to ensure that the English version is both accurate and readable.We hope this guide will be a valuable resource for students and doctors working with children in the operating room. Anesthesia for a child is fundamentally different from anesthesia for an adult. Children differ significantly from adults in terms of anatomy, physiology, metabolism, and behavior. Additionally, factors such as age, the severity of illness, and the complexity of the surgical procedure further contribute to the challenges of pediatric anesthesia. Therefore, children should only be anesthetized by specialists with the necessary knowledge and, most importantly, experience in treating this patient group. Pediatric anesthesiology and intensive care are distinct fields of expertise developed through specialization in anesthesiology and intensive therapy.

This position was reinforced at the Helsinki Conference, where the pediatric anesthesiology section established safety guidelines for pediatric anesthesia. It emphasized that, due to the higher risk of complications (greater than in adult patients), children should be anesthetized by a pediatric anesthesiologist or an anesthesiologist with significant experience in this field.

In 2015, the European Society of Paediatric Anaesthesiology (ESPA) defined the minimum number of anesthesia procedures that a pediatric anesthesiologist must perform annually to maintain their skills: 12 anesthesias in neonates, 50 in infants, and 300 in children over one year of age.

The risk of complications is considered highest in children under one year of age. During this period, intraoperative complications occur in up to 9% of cases, with respiratory complications ranging from 55–77%. Literature also indicates a notably high risk of sudden cardiac arrest (SCA), with rates between 19 and 24 cases per 10,000 anesthetic procedures. In older children, the risk of SCA remains elevated, ranging from 1 to 7 events per 10,000 anesthetics.

Anesthesia involves established, structured procedures that require rapid responses to evolving clinical situations. Along with theoretical knowledge, manual dexterity is essential and must be continually practiced by the anesthetic team. Studies have shown that the number of correctly performed procedures directly impacts the safety and effectiveness of anesthesia. Furthermore, effective collaboration between the anesthetic team and the child’s parents is critical for creating a reassuring and safe environment during this important period for the child.

Proper monitoring of the child's respiratory and circulatory systems is crucial. Maintaining stable vital signs is essential for safe and successful anesthesia. Equally important is the careful selection of drugs to avoid life-threatening complications, such as sudden cardiac arrest (SCA), malignant hyperthermia, or hypoxia.

2. BASIC DIFFERENCES IN THE ANATOMY AND PHYSIOLOGY OF CHILDREN

Anatomical and physiological distinctions of the respiratory system in newborns and young children:

1. A newborn’s head is large in proportion to the rest of the body, and the occiput is strongly arched. Placing a newborn on their back can cause the head to press against the chest, impairing the patency of the upper airways.
2. The newborn’s chest is narrow and small, limiting their ability to take deep breaths.
3. Newborns breathe exclusively through their nose. Therefore, if nasal patency is impaired (e.g., by a probe in one nasal passage or nasal blockage due to secretions), breathing difficulties may occur.
4. Infants have a large tongue, which can easily obstruct the airway and pose challenges for mask ventilation. During sedation or anesthesia, an oropharyngeal tube or other airway management devices, such as endotracheal intubation, may be necessary.
5. In children under 6 years of age, the narrowest part of the larynx is located below the vocal cords, at the level of the cricoid cartilage, rather than at the level of the glottis (between the vocal cords) as it is in adults. This anatomical difference is referred to as subglottic stenosis.
6. In newborns, the epiglottis is large and elongated, making it difficult to visualize the entrance to the larynx.
7. Newborns struggle to maintain normal functional residual capacity, making them more prone to developing atelectasis.
8. A newborn’s lungs are stiff and have low compliance, whereas their chest is more flexible compared to older children.
9. The diaphragm is the primary muscle for respiration in newborns.
10. Newborns have a significantly higher metabolic rate than adults, leading to increased oxygen demand.
11. In preterm infants, 100% oxygen should not be used for ventilation as it increases the risk of retinopathy due to oxygen toxicity and bronchopulmonary dysplasia due to impaired lung development. Additionally, it can cause absorptive atelectasis.
12. Due to the immaturity of their lungs, children are more susceptible to lung damage from mechanical ventilation if excessive pressures or volumes are used. Excessive ventilation pressures may lead to complications such as pneumothorax or pneumomediastinum.
13. Milk teeth are less stable than permanent teeth. During laryngoscopy, special care must be taken to avoid damaging these teeth, which can fall out easily. In cases where teeth are very loose, they may need to be removed before the procedure.

Cardiovascular System in Neonates and Young Children:

- Neonatal Cardiac Output: In neonates and young children, cardiac output primarily depends on heart rate rather than the strength of myocardial contraction.
- Myocardial Contraction: The neonatal myocardium operates at its maximum contractile capacity. Increasing preload does not typically enhance contraction strength.
- Rapid Heartbeat: A newborn's heart rate averages 150 beats per minute to meet significant oxygen demands. The initial sign of hypoxia is often a decrease in heart rate. Maintaining age-appropriate heart rate and blood pressure is crucial for anesthesiologists.
- Vascular Resistance Post-Birth: After birth, pulmonary vascular resistance steadily decreases, whereas systemic vascular resistance increases.
- Anatomical Features: Shortly after birth, neonates exhibit anatomical connections, including the ductus arteriosus (Botall's duct) and the foramen ovale.
- Fetal Hemoglobin: Up to the fourth month of life, red blood cells contain fetal hemoglobin, which has a higher oxygen affinity but releases oxygen less readily.

Neonatal and Infant Body Function Differences:

1. Liver Immaturity: Underdeveloped hepatic metabolic pathways result in prolonged drug metabolism and delayed elimination.
2. Plasma Protein Levels: Lower levels increase the active fraction of administered drugs.
3. Extracellular Water: Neonates possess a greater extracellular water volume, increasing drug distribution.
4. Glycogen Stores: Limited glycogen stores and high caloric needs increase the risk of hypoglycemia during fasting.
5. Thermoregulation Challenges: Neonates lose heat more rapidly than adults due to higher metabolic rates and larger surface area relative to body weight. Meticulous temperature management during procedures is essential.
6. Intravenous Access: Establishing IV access and intubation is more challenging in neonates due to anatomical and physiological differences.

Photograph 1: Intubation

3. PREPARING THE CHILD FOR GENERAL ANESTHESIA AND SURGERY

An essential component of proper anesthetic management is the preparation of the child for anesthesia, known as premedication. This involves a preoperative assessment of the patient's health status, based on a thorough medical history and physical examination. It should be conducted for all patients scheduled for surgery or related anesthetic procedures. Ideally, these assessments should take place in an anesthesiology outpatient clinic.

For elective procedures, this evaluation should be completed no later than 24 hours before the procedure. However, for life-saving emergency procedures, the process may be adapted due to limited time for additional tests and consultations.

3.1. Anesthesiology Outpatient Clinic

Eligibility for anesthesia at the outpatient clinic involves a comprehensive process, including an interview, physical examination, medical record review, and discussion with the child's parents or legal guardians.

If needed, additional tests and consultations may be recommended by the anesthesiologist. The anesthesiologist will recommend an appropriate plan of action, including the type of premedication to be used. The patient, if their age and cognitive abilities allow, may also be involved in this discussion.

Parents or legal guardians must provide written informed consent for the proposed anesthetic procedure. Consent should outline the planned perioperative management. If parents have concerns, they should be given time to review the consent at home before signing.

The anesthesiologist's responsibilities in preparing a child for anesthesia include:

- Reviewing the medical referral (Medical history)
- Thoroughly examining the child's health record and information from previous hospitalizations
- Conducting an interview and assisting parents with completing the necessary forms
- Assessing the risk of major anesthesia-related complications according to the American Society of Anesthesiologists (ASA) classification
- Verifying the duration of the child's fasting period
- Ensuring that parents fully understand and sign the consent forms for both the procedure and the anesthesia

Table 11 in Chapter 7 shows an example of an anesthesiology survey used at the University Children's Clinical Hospital in Bialystok.

Photograph 2: The visit to the anesthesiology clinic should take place at least 7 days before the planned anesthesia, and premedication for surgery should occur at least 24 hours before the planned surgery.

Before the interview with the anesthesiologist, parents are asked to complete a survey (Table 1) by marking "YES" or "NO" in response to each question. The survey includes the following note:

Please provide additional details where necessary. If any question is unclear, you may clarify it during your discussion with the anesthesiologist. Please provide discharge summaries from previous hospital stays and any certificates from specialists.

Additionally, please submit the results of any tests. For newborns, the mother's PESEL number will be entered into the documents. If there is no PESEL number, please provide the name and number of the document confirming identity.

Table 1: Child Health Survey

Health Information *(Does not apply if anesthesia is repeated during the same hospitalization)*		
Was the baby born on time? If **NO**, in which month of pregnancy?	Yes	No
	☐	☐
Has your child received treatment in the past 12 months? If **YES**, for what disease?	☐	☐
Has your child been ill in the past 6 weeks (e.g., fever, cough, runny nose, vomiting)? If **YES**, when and what was the illness?	☐	☐
Has your child had contact with an infectious disease (e.g., chickenpox, whooping cough, measles, rubella, others) in the past month? If **YES**, which disease and when?	☐	☐
Is your child vaccinated according to the vaccination schedule?	☐	☐
Has your child received any vaccinations in the last 3 months? If **YES**, when and which vaccination?	☐	☐
Is your child currently taking any medication? If **YES**, please specify the name, dose, and how many times per day:	☐	☐
Is your child taking oral contraceptives?	☐	☐
Has your child undergone surgery with anesthesia in the past? If **YES**, when and for what reason?	☐	☐
Were any specific reactions observed during or immediately after anesthesia (e.g., trouble waking up, vomiting, breathing problems, hoarseness, others)? If **YES**, please describe:	☐	☐
Have you or any of your relatives experienced problems related to anesthesia? If **YES**, please specify when, what the issue was, and who experienced it:	☐	☐

Has your child ever received a blood transfusion? If **YES**, were there any complications? What kind?	☐	☐
Does your child have a muscle disorder or muscle weakness, such as myasthenia gravis? If **YES**, what kind?	☐	☐
Does your child tire easily or bruise during activities like playing or running?	☐	☐
Does your child have any heart problems (e.g., heart defect, arrhythmia, murmur, other)? If **YES**, what kind?	☐	☐
Does your child frequently get bronchitis?	☐	☐
Do any caregivers smoke cigarettes?	☐	☐
Does your child have asthma, tuberculosis, or another lung disease? If **YES**, what kind?	☐	☐
Has your child had infectious hepatitis (hepatitis B)?	☐	☐
Does your child have an increased tendency to bleed or bruise?	☐	☐
Has your child had kidney disease or urinary tract disease? If **YES**, which ones and when?	☐	☐
Has your child experienced seizures? If **YES**, when?	☐	☐
Has your child ever lost consciousness or fainted? If **YES**, when?	☐	☐
Is your child allergic to any medications, foods, powders, cosmetics, pollen, or other substances? If **YES**, which substances and under what circumstances?	☐	☐
Does your child have diabetes?	☐	☐
Does your child have any conditions related to the endocrine glands (e.g., thyroid, adrenal glands)? If **YES**, what kind?	☐	☐

Does your child have an eye disease? If **YES**, which one?	□	□
Does your child suffer from ear or throat conditions (e.g., tonsillitis)? If **YES**, what kind?	□	□
Does your child have damaged teeth (e.g., loose teeth, dentures, braces)? If **YES**, what type of defect?	□	□
Is your child receiving care from a specialized counseling center? If **YES**, which one?	□	□
Do you have any other comments about your child's condition?	□	□

Date, Name, and Relationship of the Person Completing the Survey	**Stamp and Signature of the Verifying Physician**
....	
Medical Data on the Patient *(To be filled in by the anesthesiologist)*	

3.2. Pre-operative Visit

In addition to the activities performed at the anesthesiology clinic, the anesthesiologist's responsibilities include conducting a preoperative assessment of the child, which must take place at least 24 hours before surgery. All diagnostic and therapeutic actions taken during this visit aim to reduce anesthesia-related risks and improve the patient's overall condition before surgery. The preoperative visit involves reviewing the medical history and questionnaire, as well as reassessing the patient according to the American Society of Anesthesiologists (ASA) classification. The anesthesiologist is responsible for verifying test results and ensuring that the medical history is complete. If any information is missing, the attending physician must provide the necessary details. If the child has not been seen in the outpatient clinic, the anesthesiologist must interview the parents and obtain their informed consent for anesthesia (which requires their signature on the questionnaire).

Based on the data collected, the anesthesiologist will assess the risks associated with general anesthesia. The ASA classification system, commonly used to evaluate the patient's health status, is as follows:

- **ASA I** – Healthy patient
- **ASA II** – Patient with mild systemic disease that does not affect normal functioning
- **ASA III** – Patient with severe systemic disorder that limits normal functioning
- **ASA IV** – Patient with severe systemic disease that is ongoing and a life-threatening risk
- **ASA V** – Patient who is dying and will not survive without surgery
- **ASA VI** – Patient declared brain-dead, with organs being harvested for transplantation
- **E** – Emergency or urgent surgery

Required Tests

Laboratory tests conducted before anesthesia aim to identify any abnormalities or conditions that could influence anesthetic or surgical management. The required tests are categorized based on the patient's ASA classification:

- **ASA I** – No tests are needed unless an abnormality is suspected or the procedure requires them. If necessary, the tests may include blood morphology, baseline electrolytes (Na, K, Cl), and activated partial thromboplastin time (APTT).
- **ASA II** – The required tests include blood type, complete blood count (CBC), baseline electrolytes (Na, K, Cl), and APTT. If there is any uncertainty about a systemic condition, consultation with a specialist in the relevant field is recommended.
- **ASA III and IV** – In addition to the tests mentioned for ASA II, further tests such as an electrocardiogram (ECG), chest X-ray, complete coagulation profile, urea and creatinine levels, blood gas analysis, and C-reactive protein (CRP) should be performed. If a heart defect is present, a cardiac echocardiogram (with ejection fraction) is required. A cardiologist may also be consulted to assess the patient's condition. Tests in this category are valid for two weeks.
- **ASA V** – The same tests as for ASA III and IV are required. Additionally, the operator's physician must provide a note on the patient's vital signs, and a personal conversation with the patient's parents is necessary.

3.3. Disqualification

There are situations in which the date of surgery should be postponed. These include:

1. Child Immediately After Vaccination
   Anesthesia after vaccination can be administered depending on the type of vaccine, but not before:
   - 3 days after vaccination for inactivated vaccines, such as DTaP, polio, Haemophilus, and pneumococcus.
   - 14 days after vaccination for live attenuated vaccines, such as mumps, rubella, measles, and tuberculosis.
2. Contact with an Infectious Disease
   If the child has had contact with an infectious disease, anesthesia should be postponed until:
   - 21 days after contact with chickenpox
   - 24 days after contact with mumps
   - 12 days after contact with measles
   - 21 days after contact with rubella
   - 20 days after contact with pertussis

3. History of Infectious Disease
   If the child has had an infectious disease, anesthesia should not be performed until:
    - The last lesion has dried in cases of chickenpox
    - 10 days after the onset of skin lesions for mumps
    - 5 days after the onset of skin lesions for measles
    - 7 days after the onset of skin lesions for rubella
    - 21 days after the first symptoms or 6 days after starting antibiotics for pertussis.
4. Other Abnormalities Found on Clinical and Laboratory Tests that Disqualify from Scheduled Surgery:
    - Acute Upper Respiratory Tract Infection: Symptoms such as reddened throat, increased respiratory secretions, and possibly elevated body temperature (>37.8°C).
    - Leukocytosis: White blood cell count >20,000 cells/µl.
    - Anemia: Children with symptoms of anemia should not undergo elective anesthesia. Intervention through blood supplementation is necessary if:
        - Hb concentration <8 g/l and Ht < Higher values for children.
        - For newborns, transfusion is required if Hb <11 g/l and Ht <32.
        - If the procedure is scheduled, consider therapy with iron supplements to allow time for Hb levels to reach an appropriate level pre-procedure. Transfusions should only occur if the surgery cannot be postponed.
    - Dyselectrolytemia:
        - For sodium (Na+), the normal range is 135–145 mmol/l. Intervention is required if Na+ falls to <130 mmol/l.
        - For potassium (K+), the normal range is 3.5–5.2 mmol/l. Urgent correction should be considered if levels fall below 3.0 mmol/l or exceed 6.5 mmol/l.
        - For calcium (Ca), the normal total calcium range in children is 2.05–2.7 mmol/l (ionized calcium: 1.12–1.23 mmol/l). Elective surgery is not recommended if total calcium falls below 1.5 mmol/l (3 mg%).
    - Recent Respiratory Tract Infection: If the child has recovered from a lower or upper respiratory tract infection within two weeks of the scheduled procedure, it is recommended to postpone the surgery due to the heightened risk of respiratory complications during anesthesia.

Photograph 3: Supervision of a Child Requiring Monitoring

3.4. Premedication

Premedication in children completes the preparation process for surgery, following the anesthesiologist's assessment. The primary purpose of premedication is to significantly reduce or even eliminate anxiety, creating the optimal conditions for the induction of anesthesia.

Currently, the importance of **non-pharmacological premedication** is emphasized in preparing young patients for anesthesia. The first step involves familiarizing the child with the events associated with anesthesia. In Poland, a notable resource is the brochure *Julka in Hospital: A Primer for Children and Parents by Marcin Rawicz, MD*, which has been used by anesthesiologists for many years to help children and parents overcome fears related to anesthesia.

In recent years, there has been an increased focus on various **distraction techniques**. For example, mobile devices like smartphones or tablets can be provided to children before entering the operating room, allowing them to watch cartoons or play games up until the induction of anesthesia, thus diverting their attention from the operating room environment. Another innovative approach is hiring clowns to entertain and distract young patients before anesthesia. Additionally, allowing a suitably prepared parent to be present in the operating room is considered an effective measure in reducing the child’s anxiety.

However, in most cases, **pharmacological premedication** remains irreplaceable. Pharmacological premedication is not recommended for newborns and infants under 7 months of age. In children older than 7 months, midazolam is the most commonly used drug for premedication. Besides its strong anxiolytic and sedative effects, midazolam also induces “subsequent amnesia,” meaning the child will not remember events related to anesthesia. This drug can be administered through various routes: orally, intranasally, intravenously, or rectally. However, in some patients, midazolam can paradoxically produce a stimulant effect, in which case it should be avoided.

Diazepam can also be used for premedication in children. For patients who respond poorly to midazolam, α-2 receptor agonists such as clonidine and dexmedetomidine offer alternative options, providing both anxiolytic and analgesic effects. Intranasal administration of dexmedetomidine, midazolam, or even ketamine presents an interesting alternative to oral delivery due to its direct absorption into the bloodstream. This route avoids painful injections, bypasses degradation in the gastrointestinal tract, and circumvents the first-pass effect, biotransformation in the liver before systemic circulation.

Analgesics are increasingly used in premedication as part of preemptive analgesia. Paracetamol or ibuprofen are the most commonly administered analgesics for this purpose. Additionally, local anesthesia is applied to the skin at the site of the planned puncture using EMLA cream, EMLA patches, or lidocaine gel to further manage pain.

In recent years, gabapentinoids such as gabapentin and pregabalin have gained recognition in preparing patients for surgeries associated with high postoperative pain intensity. Their action includes both a fast phase (30-60 minutes) and a slow phase (10-20 hours). Studies indicate that the fast phase is particularly effective in managing perioperative pain by inhibiting neurons impacted by surgical trauma. The perioperative use of gabapentin has been shown to improve analgesia quality at rest and during movement, while also reducing the need for opioids post-surgery. Gabapentinoids help prevent hyperalgesia and allodynia, though they have minimal effect on nociception. Moreover, gabapentin and pregabalin can reduce opioid-related side effects such as vomiting, urinary retention, and nausea, regardless of the dose administered.

While gabapentin is approved for treating epilepsy in children older than 6, its use for premedication in children has not yet been fully established. Although promising data exists for gabapentin's use in premedication, it’s important to note that a defined safety profile and specific pediatric recommendations are still lacking. Current applications remain off-label and are primarily under investigation in clinical trials.

Drug Dosing in Premedication:

- Midazolam: Administer 0.25–0.3 mg/kg body weight (maximum 0.5 mg/kg if continuous nurse supervision is available). Can be given orally, rectally (for children under 1 year of age), or intranasally 30–60 minutes before anesthesia.
- Diazepam (Relsed): Rectal microinfusion containing 5 mg of diazepam in 2.5 ml of solution. Administer 0.5 mg/kg 30–60 minutes before anesthesia. After rectal administration, the child should lie on their stomach for approximately 15 minutes.
- Clonidine (Iporel): Administer orally at a dose of 5 mcg/kg body weight. Note that this is an off-label use, meaning it falls outside the approved indications.
- Dexmedetomidine: Administer intranasally at a dose of 1–2 mcg/kg body weight.
- Paracetamol: Administer orally (syrup or tablets) in the following doses:
    - Neonates: 10 mg/kg body weight
    - Infants: 15 mg/kg body weight
    - Older children: 20 mg/kg body weight or rectally at a dose of 40 mg/kg body weight.
- Ibuprofen: Administer orally (syrup or tablets) as a single dose of 6–10 mg/kg body weight.
- EMLA Cream or Patch: Apply 60 minutes before anesthesia.
- Lidocaine Gel: Apply under an occlusive dressing 30 minutes before the puncture.
- Gabapentin: Administer 60 minutes before surgery at a dose of 600–1200 mg, with attention to potential adverse effects (e.g., excessive sedation, dizziness, visual disturbances). For children aged 6 years and older, the effective dose is 25–35 mg/kg body weight per day.

Almost all patients experience some fear of anesthesia and surgery, although the intensity of this fear can vary. Such anxiety may disrupt a child’s psychological balance and often triggers vegetative reactions that can negatively impact the induction, maintenance, and recovery from anesthesia. While premedication is not mandatory, it frequently aids in anesthetic management. Below is a simplified scheme outlining the principles of premedication:

- Children under 7 months: No premedication.
- Children over 7 months, up to 35 kg body weight: Administer midazolam in a dissolved form or as swallowable tablets at a dose of 0.3–0.5 mg/kg, 60 minutes before the planned start of anesthesia.
- Older children, over 35 kg body weight: Administer a 7.5 mg midazolam tablet.
- Premedication Documentation: Premedication should be recorded in the anesthesia chart.
- Emergency Surgery: No premedication.

3.5. Last Feeding/Drinking

The general guideline for a child's last feeding before anesthesia follows the 2-4-6 rule:

- Clear liquids (such as water, tea, or clear apple juice) may be consumed up to 2 hours before the induction of anesthesia.
- Breast milk can be given up to 4 hours before anesthesia.
- Solid food or milk formula should be consumed no later than 6 hours before anesthesia.

4. GENERAL ANESTHESIA

General anesthesia is a state characterized by the loss of consciousness, suppression of pain and nerve reflexes, restriction of movement, and reduced muscle tone. During general anesthesia, almost all central nervous system (CNS) functions are inhibited, except for the autonomic centers in the medulla oblongata, such as the respiratory and vasomotor centers, which are essential for maintaining basic life functions.

The key components of general anesthesia include loss of consciousness, analgesia, and muscle relaxation. It is crucial to ensure that a child's entire experience in the operating theater is smooth and comfortable. Achieving this requires commitment and seamless coordination among the operating theater team and staff from the surgical wards. Such cooperative teamwork enhances safety, minimizes the potential for errors, and helps maintain the comfort and well-being of the child.

Photograph 4: The anesthesia machine prepared for surgery

Modern general anesthesia is a complex process. The effects of the primary anesthetic are enhanced or supplemented by the simultaneous administration of additional pharmacological agents, including anti-anxiety medications, analgesics, sleep-inducing drugs, striated muscle relaxants, and other adjuvants, such as antiemetics. This approach allows for lower, safer concentrations of each drug, thereby reducing the risk of adverse effects.

Table 2: Components of General Anesthesia

Components of General Anesthesia	Inhibited Physiological Response
Loss of Consciousness	System responds to stimuli other than pain
Analgesia	Pain stimuli do not elicit a systemic response
Skeletal Muscle Relaxation	Lack of response of striated muscles to stimuli
Overdose	Toxic effects on autonomic, circulatory, and respiratory systems

Figure 1: The different phases of general anesthesia and the effect of an adequate physiological response

In children, surgery or diagnostic procedures may be performed using various methods depending on the nature, extent, and degree of pain involved. These methods range from shallow sedation (which may be administered by non-anaesthesiologists) to moderate sedation, deep sedation, and general anesthesia. Regional anesthesia techniques should also be considered for this patient group.

4.1. Anesthesia of a Child for Surgery

The anesthesia nurse works closely with the anesthesiologist during anesthesia, forming an anesthesiology team—a standard procedure that also applies to anesthesia performed outside the operating room.

The anesthesiologist's duties and responsibilities prior to anesthesia include:

- Informing the person in charge of the surgical team about the planned method of anesthesia. Any deviation from the standard method should be documented on the anesthesia plan.
- Recording premedication details in the anesthesia chart.
- Noting any reservations or disqualifications from anesthesia in the medical history, while simultaneously notifying the patient's attending or operating physician.
- Checking the anesthesia station prepared by the nurse, including verifying the functionality of equipment and the availability of necessary drugs.

Photograph 5: Anesthesia station before surgery. It is important to check the efficiency of the anesthesia machine and ensure the presence of functioning equipment.

The anesthesia nurse's responsibilities include preparing the anesthesia station and ensuring the functionality of equipment:

- Anesthesia machine
- Endotracheal intubation set
- Monitoring equipment (cardiac monitor with ECG module, SpO_2, RR, $etCO_2$, temperature, anesthetic gas measurement), stethoscope
- Oxygen source and vacuum
- Suction device with a set of suction catheters in various sizes
- AMBU self-expanding bag and face mask
- Infusion pump
- Equipment to maintain proper body temperature, such as a heating mattress or incubator

The nurse also checks the medication kit. Each drug syringe is labeled immediately after preparation, indicating the drug name and concentration per 1 ml of solution.

The anesthesiologist's responsibilities include:

- Determining the method of anesthesia
- Verifying the technical readiness of the anesthesia machine
- Setting the patient ventilation parameters
- Checking the remaining anesthesia equipment
- Determining the medication dosages

Patient admission to the operating room takes place in the preoperative area, where the anesthesia team (physician and nurse) confirms the patient's identity.

Photograph 6: Handing over the patient in the OR sluice by the nursing and medical team. It is important to verify the patient's identity and confirm the type of procedure to be performed according to the scheduled operations list.

Completion of the anesthesia chart is required for all anesthesia procedures. The anesthesiologist is responsible for setting up the anesthesia chart, carefully completing the header with details such as the patient's name, surname, date of birth, PESEL number, diagnosis, planned procedure, weight, and body temperature, as well as recording relevant laboratory results.

The anesthesia chart also includes a detailed report on the course of anesthesia, documenting the patient's monitored physiological parameters, the drugs administered, and their respective doses. This information is recorded continuously throughout the procedure.

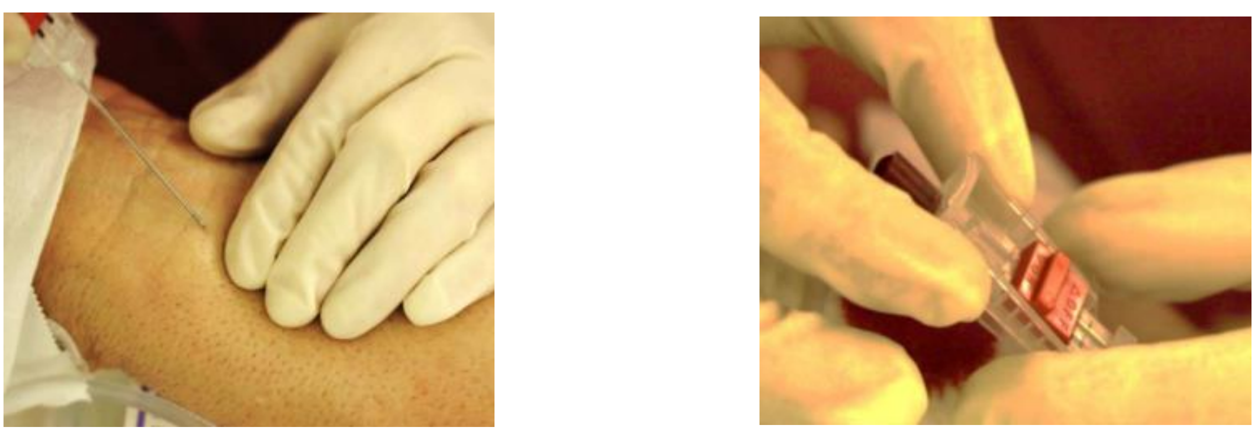
4.1.1. Intravenous or Inhalation Induction

Intravenous Injection

In children, it is most beneficial to establish intravenous access outside the operating theater. This approach minimizes unnecessary stress for both the child and the staff, while also improving workflow efficiency. If it is not possible to achieve venous access in the home ward, induction of anesthesia is performed via inhalation, after which the intravenous cannula is inserted.

When an intravenous cannula is placed in the operating room, the anesthesia nurse will prepare a peripheral injection monitoring chart to document the procedure.

For extensive procedures with potential hemodynamic instability, such as prolonged surgeries to correct spinal curvature, the physician may insert an intra-arterial cannula for continuous monitoring. The radial artery is the preferred site for access, though the femoral artery or the ulnar fossa may also be used as alternatives.



Photograph 7: Radial artery puncture: left, localization of the site; right, checking arterial outflow in the peripheral arterial cannula.

Introduction to General Anesthesia or Sedation

Intravenous short-acting sleep medications are commonly used for intravenous induction. These include:

- **Propofol:** A widely used anesthetic, valued for its rapid elimination from the body.
- **Thiopental:** Often utilized in cases requiring CNS protection.
- **Ketamine:** Recommended for patients in shock, such as hypovolemic shock.
- **Etomidate:** Suitable for children with cardiomyopathy and/or an ejection fraction (EF) of <40%, typically for patients over 1 year of age. Alternatively, ketamine may be administered in these cases.

Table 3: Intravenous Drugs Used in Pediatric Anesthesia

Name	**Ketamine**	**Thiopental**	**Propofol**	**Etomidate**	**Dexmedetomidine**
Derived From	Phencyclidine and cyclohexylamine	Thiobarbiturate	Alkylphenol	Carboxylated imidazole	Organic derivative of ring imidazole and 1,2-xylene
Receptors	NMDA, muscarinic cholinergic, indirectly opioid μ, κ, δ	(+) GABA-A inhibition of neuronal activity	(+) GABA-A glycine, (-) 5-HT, nicotine	Stimulates GABA receptors	α2
Clinical Effects	Action: analgesics, stimulates the sympathetic nervous system	Sleeping and anticonvulsant effects	Sleeping and anticonvulsant effects	Little effect on circulation, tremors	Sleep-inducing, anti-anxiety effects; inhibits the sympathetic system
CNS	Nervous system - ICP↑, CBF↑, CMRO2↑,	Nervous system - CBF↓, ICP↓, IOP↓,	Nervous system - ICP↓, CPP↓, CMRO2↓	Nervous system - IOP↓, CBF↓, ICP↓, CMRO2↓	Nervous system - IOP↓, CBF↓, ICP↓, CMRO2↓

	IOP↑	CMRO2↓			
Circulatory Effects	Cardiovascular system - HR↑, cardiac output↑, BP↑, CVP↑	Depresses cardiovascular system - BP↓, CVP↓, negative inotropic effect, decrease in cardiac output, HR↓; risk of abnormal rhythms↑	Depresses cardiovascular system - BP↓, CVP↓, cardiac output↓; does not affect heart rate	Cardiovascular - MAP↓, HR↓	Cardiovascular - MAP↓, HR↓
Other Effects	Respiratory system - dilates bronchi; does not cause depression of respiratory system	Respiratory system - RF↓, TV↓	Respiratory system - TV↓, RF↑	Respiratory system - TV↓, RF↓	Respiratory system - TV↓, RF↓

CBF (*cerebral blood flow)*, ICP (*intracranial pressure*), IOP (*intraocular pressure*), $CMRO_2$ (*cerebral metabolic rate for oxygen*), HR (*heart rate*), CVP (*central venous pressure*), RF (*respiratory frequency*), TV (*tidal volume*), CPP (*cerebral perfusion pressure*), MAP (*mean arterial pressure*).

Note: Adrenal suppression may occur when used in long infusions. Seizure-like activity may be observed in EEG. These drugs can also affect QT segment prolongation and are noted for having the weakest yet dose-dependent anticonvulsant effect [9].

Anesthesia using only intravenous anesthetics is possible in children. This technique is known as **TIVA (Total Intravenous Anesthesia)** and is achieved through a continuous intravenous infusion of propofol combined with an infusion of the opioid remifentanil.

Photograph 8: Handy cabinet of anesthetic drugs

There are several validated schedules for propofol administration, such as the Roberts propofol model for manually controlled infusion. The induction dose is 3 mg/kg, followed by:

- Period I (10 minutes): 10 mg/kg/hour
- Period II (10 minutes): 8 mg/kg/hour
- Maintenance phase: 6 mg/kg/hour

The induction of anesthesia should be "smooth," meaning there should be no significant fluctuations in blood pressure or heart rate, regardless of whether intravenous or inhaled agents are used. The steps for induction include:

1. Oxygenating the patient with 80% oxygen.
2. Administering an induction dose of an analgesic.

3. Inducing narcotic sleep with an intravenous drug or sleep with an inhalant.
4. Achieving muscle flaccidity.
5. Performing intubation.

Fentanyl (1–2 mcg/kg body weight) or sufentanil (0.25 mcg/kg body weight) should be administered prior to the use of a sleep-inducing agent if intubation is anticipated. Strong opioids, such as fentanyl, must be titrated carefully to avoid chest muscle stiffness, which can occur if fentanyl is administered too rapidly, potentially impairing adequate ventilation of the child.

After induction of anesthesia, the child is ventilated with sevoflurane, transitioning to the maintenance phase of anesthesia. Sevoflurane is administered with a mixture of oxygen and air, or oxygen and nitrous oxide, unless there are significant contraindications to nitrous oxide, such as signs of shock, cyanotic heart disease, presence of air spaces in body cavities.

Inhalation induction is one of the most commonly used techniques in children. It is particularly suited for children with a strong fear of needles or those in whom establishing vascular access is very challenging.

Photograph 9: Inhalation induction with a high concentration of sevoflurane. This method may be used in cases of difficulty with vascular cannulation in a restless child.

Inhalational agents can be used for both the induction and maintenance of anesthesia. It is also possible to use an inhalant as the sole anesthetic drug throughout the procedure, a method known as **VIMA (Volatile Induction and Maintenance Anesthesia)**. The chosen management sequence should ensure a smooth course of anesthesia without disruptions to the body's vital functions. As a fundamental component of anesthesia, inhalational anesthetics provide significant flexibility by allowing quick adjustments to the depth of anesthesia and facilitating a seamless transition to more complex techniques involving opioids and muscle relaxants. Additionally, inhalational anesthesia supports rapid recovery following the procedure.

4.1.2. Intubation

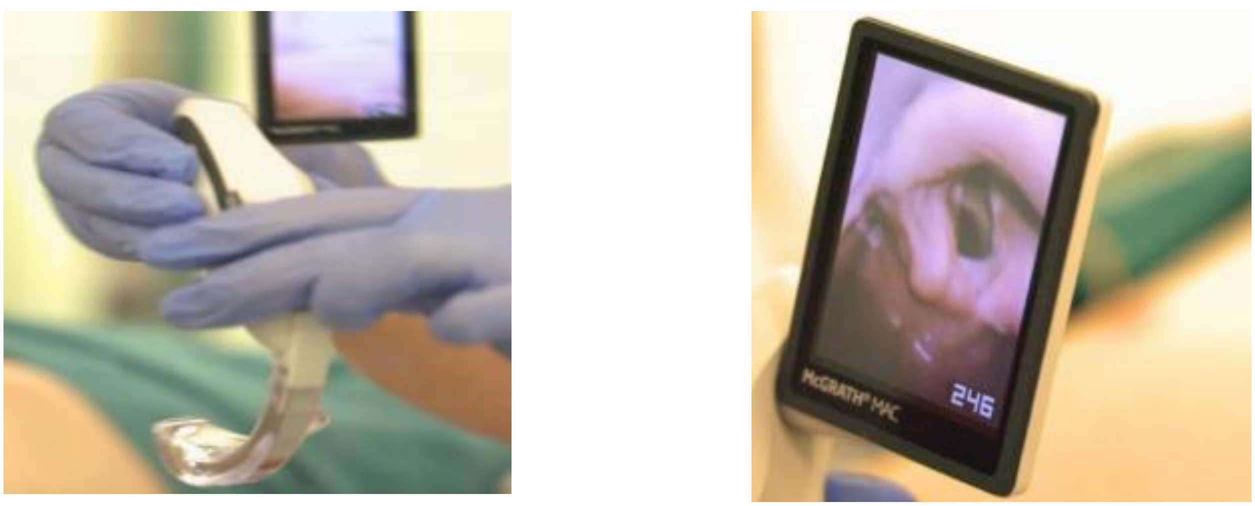
In children, intubation should generally be performed only after the administration of a non-depolarizing muscle relaxant. Modern non-depolarizing agents act rapidly and carry minimal risk of electrolyte or circulatory disturbances. Depolarizing agents, such as suxamethonium, should only be used in exceptional cases, such as when the patient has a full stomach or when difficult intubation is anticipated.

Suxamethonium should not be administered to boys under 2 years of age due to the risk of asymptomatic muscular dystrophies, such as Duchenne muscular dystrophy (DMD), which may still be undiagnosed at this age. Specific sensitivity to succinylcholine—manifesting as severe complications, including cardiac arrest—can occur well before the first symptoms of the disease appear.

When rapid intubation is required in this age group, the following regimen can be employed: propofol (2–3 mg/kg), fentanyl (1–2 mcg/kg), and rocuronium, with the potential to reverse neuromuscular blockade using sugammadex.

Intubation without muscle relaxation is also possible, but it must always be performed under deep sleep and with sufficient analgesia.

Photograph 10: The moment of intubation of a 7-year-old child.



Photograph 11: Left: Videolaryngoscope; Right: Image of the trachea as seen through the videolaryngoscope during intubation. The image shows paralyzed vocal cords and a wide "entrance" to the trachea.

4.1.3. Choice of Muscle Relaxant

The choice of muscle relaxant depends on the length and type of surgery, the clinical condition of the patient, and the anesthesiologist's preference. In cases of renal failure, short-acting drugs that are eliminated through hepatic metabolism, such as vecuronium and atracurium, are preferred. In patients with hepatic failure, agents eliminated through body temperature mechanisms, such as atracurium and its derivatives, are ideal. These drugs rely on Hofmann hydrolysis for their metabolism.

A list of available muscle relaxants is provided in Table 4. One of the longer-acting striated muscle relaxants is pancuronium, which offers exceptional hemodynamic stability but has a prolonged duration of action, lasting over 40 minutes.

Table 4: Selected Muscle Relaxants Used in Pediatric Anesthesia

Indications	**Preparation**	**Intubation dose (mg/kg)**	**Maintenance dose (mg/kg)**	**Duration of drug action (min)**
Basic	Rocuronium	0,6	0,2	30-40
Renal failure	Atracurium (Tracrium)	0,6	0,2	15-35
Newborns	Atracurium (Tracrium)	0,4	0,15	15-35
Anesthesia for 15 min	Mivacurium (Mivacron)	0,25	0,1	13-23
Anesthesia >20 min	Vecuronium (Norcuron)	0,15	0,05	20-40
Rapid intubation	Rocuronium	1,2	0,2	30-40

4.1.4. Mask Ventilation

Mask ventilation is typically performed using a mixture of oxygen (approximately 80%) and air. Ventilation with 100% oxygen is reserved for treating laryngospasm and other special situations related to the patient's clinical condition.

Ensuring the proper positioning of the mask is crucial to maintain a tight seal and an effective ventilation system. Proper mask ventilation can be monitored using the built-in systems of the anesthesia machine, which display respiratory pressures, carbon dioxide levels (via capnography), and tidal volumes.

Photograph 12: Mask ventilation: ambidextrous technique (when another person can assist) and one-handed technique (when the anesthetist must oxygenate the patient and manually establish an airway).

4.1.5. Laryngeal Mask

The placement of a laryngeal mask is indicated for short anesthesia procedures (up to 60 minutes) in children without full stomachs, directoscopy in young children, anticipated difficult intubation, A prior history of stridor.

The laryngeal mask can be used at any age. Redness may occur with its use, although it is not a required outcome.

When muscle relaxants are not used, intravenous anesthesia with **propofol** and an opioid such as **fentanyl** is the preferred choice. The procedure involves selecting a mask of the appropriate size (refer to **Table 5**) and lubricating its outer surface. The mask is inserted with the opening facing upward, and the cuff deflated, until it is positioned as far as it will go. The cuff is then inflated until the tube retracts spontaneously. Ventilation of the patient should be verified before securing the tube. The laryngeal mask is removed once the child has regained efficient breathing and is fully awake.

Table 5: Laryngeal mask sizes

Body weight (kg)	**Mask size**
<6	1
6-20	2
20-30	2,5
30-60	3
60-80	4
>80	5

4.1.6. Intubation Tube Selection, Tube Sizes

Intubation ensures an open airway and is performed when less invasive methods of oxygenating the patient are not possible. Indications for endotracheal tube intubation include procedures requiring mechanical ventilation and muscle relaxation. Intubation is also performed when it is necessary to place the patient on the operating table in an unusual position or when the risk of regurgitation is high.

Currently, tubes with a low-pressure sealing cuff are used in children of all age groups. Low-pressure cuffs do not damage the subglottic region of the larynx, prevent airway sores, and at the same time provide an effective seal of the trachea.

In the smallest children, neonates, and infants, tubes without a sealing cuff are still used. This allows the selection of a tube with a larger lumen, as the outer diameter of cuffed tubes is larger. In such narrow airways, this is crucial for achieving better ventilation conditions. It is worth noting that in previous years, the use of cuffed tubes was considered appropriate only for children older than 7 years.

For procedures in which an unnatural head position is anticipated (e.g., supine position for spinal surgery), reinforced tubes are recommended.

Particularly in pediatric anesthesia, precise sizing of the endotracheal tube is essential, as incorrect selection can lead to complications. A tube that is too large may cause damage to the larynx and trachea, while a tube that is too small increases resistance to respiratory airflow and reduces lung ventilation efficiency.

Table 6: Endotracheal tube sizes

Child's age	Tube inner diameter (mm)	Tube number (FG)
<28 weeks	2.5	12
28-36 weeks	3	14
Newborns - 3 months	3.5	16
3-10 months	4	18
10 months - 1.5 years	4.5	20
1.5-3 years	5	22
3-5 years	5.5	24
5-7 years	6	26
7-9 years	6.5	28
9-11 years	7,0	30
Boys >11 years	7.0 + cuff	32
Girls >11 years	6.5 + cuff	30

In intubation, both the size (diameter) of the endotracheal tube and the depth of insertion are critical. The distal end of the tube should always remain above the tracheal bifurcation to ensure proper ventilation and avoid complications. Below are practical guidelines for selecting the appropriate endotracheal tube size and estimating the depth of insertion.

It is recommended to prepare three tube sizes for intubation:

- The appropriate size based on the child’s age.
- One size smaller (half a millimeter smaller in diameter).
- One size larger (half a millimeter larger in diameter).

a) Endotracheal Tube Size

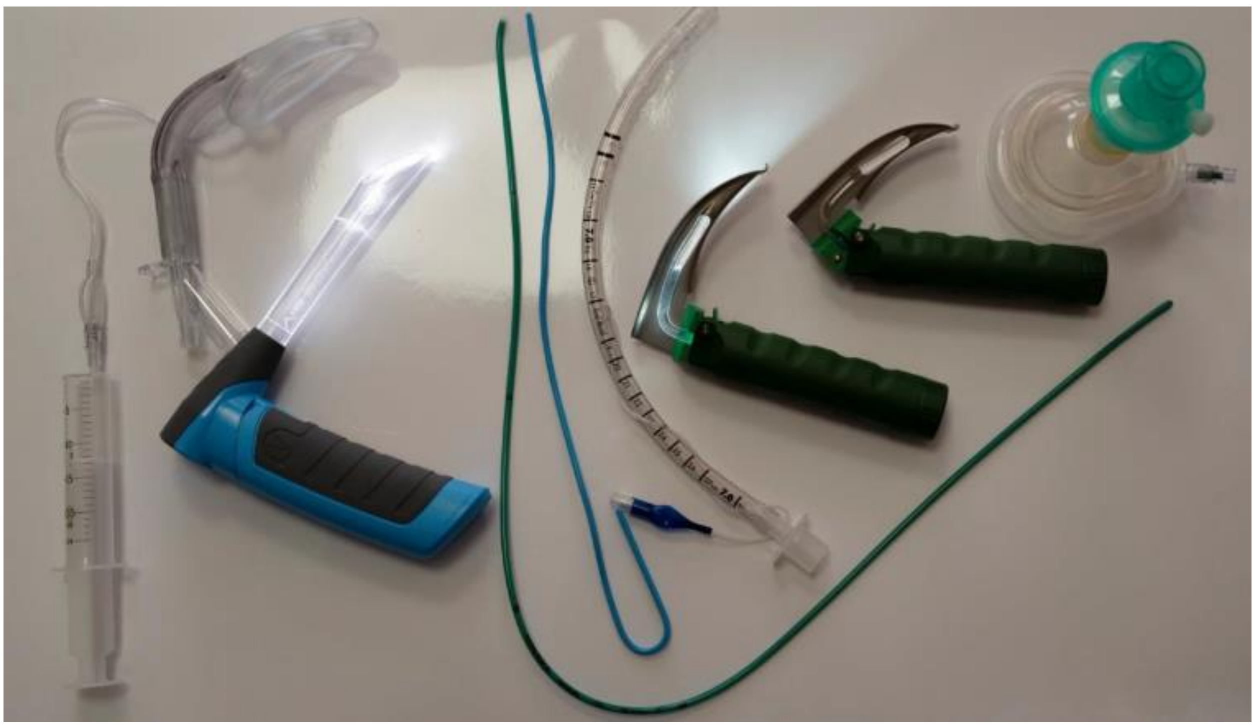
- Uncuffed tubes for infants: 3–4 mm ID (internal diameter).
- Uncuffed tubes for children 1–2 years: 4–4.5 mm ID.
- Uncuffed tubes for children >2 years:
    - Use the formula: ID in mm = (age in years ÷ 4) + 4 mm ID.
- Cuffed tubes for children >3.5 kg and <1 year: 3–4 mm ID.
- Cuffed tubes for children 1–2 years: 3.5–4 mm ID.
- Cuffed tubes for children >2 years:
    - Use the formula: ID in mm = (age in years ÷ 3) + 3 mm ID.

b) Depth of Endotracheal Tube Insertion

- Formula 1: Depth of insertion (cm) = (age in years ÷ 2) + 12 cm.
- Formula 2: Depth of insertion (cm) = inside diameter (ETT) × 3

4.1.7. Management of Difficult Intubation

There are numerous clinical situations in which maintaining an airway or inserting an endotracheal tube may be challenging. It is good practice to always prepare for the possibility of a difficult intubation.



Photograph 13: Example of selected equipment to ensure airway patency and facilitate intubation in difficult airway scenarios.

Difficult intubation is more likely to occur in newborns and preterm neonates with congenital malformations or head and neck disorders. Additional risk factors include Mallampati score over 2, Pierre Robin syndrome, Treacher-Collins syndrome, mandibular ankylosis, oral cavity tumors, peribronchitis, previous history of difficult intubation or unexplained anesthetic problems.

If a difficult intubation is anticipated, the standard management protocols described in anesthesia literature [1, 3, 4] should be followed. Prior to the induction of anesthesia, prepare appropriate equipment such as a fibrescope, video laryngoscope, and Bougie guidewire. The recommended steps for managing difficult intubation are as follows:

1. Perform inhalation induction after preoxygenation with a high oxygen concentration (80%), ensuring the presence of two anesthesiologists.
2. Check the feasibility of mask ventilation. If mask ventilation proves difficult, awaken the child immediately and consult with the team leader to develop an individualized plan (e.g., fiberoptic intubation or use of a Bougie guidewire).
3. If the laryngeal opening cannot be visualized, place a laryngeal mask, introduce the Bougie guidewire into the trachea, and then insert the endotracheal tube. If this fails, use the fiberscope for guidance.
4. In the event of sudden airway obstruction (where intubation or ventilation is not possible), follow these steps:
    - Place a laryngeal mask to restore oxygenation.
    - Guide the child back to spontaneous breathing.
    - If mask ventilation and laryngeal tube placement remain impossible, use the emergency kit:
        - Insert a brown venflon through the 2nd intercostal space of the larynx.
        - Attach an oxygen tube to the venflon; escaping gas will confirm correct placement into the larynx.

If intubation difficulties arise, it is crucial to immediately call for assistance from another team member.

Emergency Situations

In cases of unexpected intubation difficulties, the following protocol should be followed:

1. After the second failed attempt to place the endotracheal tube, a laryngeal mask should be placed to ensure airway patency.
2. The child should be awakened, and the surgery postponed until optimal conditions for intubation are achieved (refer to the management scheme above).
3. If postponement is not possible due to urgent indications, another anesthesiologist should be called to assist.
4. The procedure should then proceed following the previously outlined protocol for difficult intubation.

Photograph 14: Preparation of the laryngeal mask. Sealing after placement is achieved by inflating the cuff to ensure the mask properly covers the vocal cords.

4.1.8. Ventilation of the Child During General Anesthesia

Currently, children of all age groups are anesthetized using anesthetic machines with a circular system (semi-closed method). Depending on the age and weight of the anesthetized child, a system of different diameters is connected to the anesthesia machine, e.g., neonatal (up to 10 kg patient weight), pediatric (from 10 to 40 kg), or adult system (>40 kg). Anesthesia machines are equipped with ventilators that allow ventilation in both volume-variable and pressure-variable modes. Whichever ventilation mode is chosen, the principles of lung-conserving ventilation should be followed (e.g., TV within the limits of 6–8 ml/kg, plateau pressure less than 30 cm H_2O) and the use of positive end-expiratory pressures (PEEP).

During anesthesia, a fresh gas supply is continuously provided to the respiratory mixture with an oxygen concentration of at least 21% or more, depending on the patient's clinical condition. The fresh gas supply requirement is derived from the minute volume, which is determined by the volume of a single breath multiplied by its minute rate.

Depending on the gas flow in relation to the patient's minute demand, a distinction is made between high-flow anesthesia and low-flow anesthesia. High-flow anesthesia involves administering gasses in the respiratory mixture above the patient's minute demand. It ensures sufficient safe delivery of oxygen and elimination of carbon dioxide. Because of the high flow of the respiratory mixture, the patient may be exposed to breathing dry, non-humidified respiratory gasses and to heat loss. Excess gasses are excreted outside the respiratory system and lead to contamination of the operating room, as well as high consumption of anesthetics. This is important for long hours of high-flow anesthesia.

In children, low-flow or minimal-flow gas anesthesia may be used. In these techniques, the flow of the respiratory mixture is lower than minute ventilation. The return breath requires careful elimination of carbon dioxide, frequent replacement of lime in the CO_2 absorber, and less heat loss. Low flow requires close observation and monitoring of breathing and gas exchange. It is recognized that when anesthetizing children younger than 2 years of age or weighing less than 20 kg, caution should be exercised in their qualification for this technique because of the risk of hypoxia.

Photograph 15: Patient ventilation parameters monitor and gas monitor displaying concentrations of oxygen, nitrous oxide, and sevoflurane. The characteristic capnometry recording is visible, with spirometric values shown below and the values of the set ventilation mode and parameters displayed at the bottom of the screen.

4.1.9. Intraoperative Pain Therapy

The standard treatment for intraoperative pain in children is fentanyl. The administration schedule begins with an initial dose of 1–2 mcg/kg body weight, followed by supplemental doses as needed.

For children at an increased risk of postoperative vomiting (based on medical history) or those undergoing long surgeries, sufentanil is preferred. Sufentanil provides strong analgesia and excellent hemodynamic stability. It is particularly recommended for continuous infusion during long surgeries, such as scoliosis correction procedures.

For procedures requiring high controllability of analgesia, remifentanil, a short-acting opioid, is used. Its short duration of action and absence of active metabolites offer exceptional control over analgesia. However, due to its rapid offset, another sufficiently potent analgesic must be administered before discontinuing the remifentanil infusion to ensure continued analgesia. In some centers, prolonged infusions of remifentanil are also used during the postoperative period.

Regional anesthesia, performed after the induction of general anesthesia, is another effective method of providing analgesia. This includes central techniques, such as subarachnoid and epidural anesthesia from various access points, as well as peripheral nerve or plexus blocks. Details of regional anesthesia and its applications are discussed in a separate subsection.

4.1.10. Inhalational General Anaesthetics

The principles of induction are outlined in the section on anesthesia induction. Before intubation, the patient should be preoxygenated, administered an analgesic, anxiolytic, intravenous anesthetic, and a muscle relaxant.

During the maintenance phase of anesthesia, the primary objective is to ensure an appropriate depth of anesthesia, maintaining circulatory stability through adequate sedation, analgesia, and muscle relaxation. For procedures lasting over 60 minutes, anesthesia can be maintained using an infusion of propofol following the TIVA schedule, either in combination with intravenous drugs or solely with inhaled agents. Examples of inhaled drugs include:

- Desflurane at a MAC of 5–8.5% in the pediatric population.
- Sevoflurane at a MAC of 1.5–2.5% in the same age group.

In long-duration procedures, remifentanil infusion may be combined with inhaled anesthetics. Remifentanil is advantageous due to its lack of accumulation and elimination by plasma esterases, ensuring high controllability of the depth of analgesia. However, care must be taken to avoid errors, such as overly deep (cardiodepressive) or too shallow analgesia, which may lead to increased heart rate and blood pressure.

This precision is particularly critical for prolonged procedures requiring controlled hypotension, such as middle ear surgery, scoliosis correction, or neurosurgical procedures.

If laryngospasm occurs and urgent intubation of the child is required, it is essential to avoid performing the procedure without muscle relaxation due to the high risk of damage to the vocal cords and the speech apparatus.

Table 7: Physicochemical and Characteristic Properties of Inhalation Anesthetics

Properties	N_2O	Halothane	Isoflurane	Sevoflurane	Desflurane
MAC %	104	0.75	1.28	2.05	6
MAC % in 70% N_2O	-	0.29	0.56	0.8	2.83
Blood/Gas Separation Ratio	0.47	2.54	1.46	0.65	0.42
Fat/Blood Ratio	1.4	224	91	47	19
% of Drug Metabolized in the Body	0	20	0.2	3-5	0.02

4.1.11. Waking Up

Waking the patient after anesthesia involves the cessation of the anesthetic agents used. The most favorable and safest pharmacodynamic situation in pediatric anesthesia is when the drugs undergo natural metabolism without the need for additional antagonists or other medications to reverse the effects of anesthetics and muscle relaxants.

If laryngospasm occurs and urgent intubation of the child is required, intubation without relaxation should be avoided due to the high risk of vocal cord damage and harm to the speech apparatus.

At the end of anesthesia, the administration of anesthetics is gradually reduced and discontinued. Depending on the drugs used, the approach may differ. The dose and type of muscle relaxant should be adjusted based on the type of surgery. It is also critical to ensure the continuation of analgesia by administering appropriate analgesics. Awakening typically occurs within several minutes after the cessation of anesthesia.

Due to the accumulation of inhalation anesthetics in the tissues and their potential residual effects after awakening, there is a risk of hypoxia, even when the child appears conscious. To prevent this, passive oxygen therapy via a face mask or nasal cannula is required, alongside continuous monitoring of arterial oxygen saturation.

When nitrous oxide is used, oxygen therapy and monitoring of arterial blood saturation during and after awakening are essential to prevent diffusional hypoxia. This occurs when nitrous oxide, which is poorly dissolved in blood (blood/gas partition coefficient 0.47), rapidly moves from the blood to the alveoli, diluting the oxygen present. If the patient breathes atmospheric oxygen, this can lead to hypoxia. Over time, the risk diminishes as the nitrous oxide transfer slows, typically disappearing after 5–10 minutes.

If the anesthesiologist must awaken the patient in the operating room (e.g., in the middle of skin suturing), nitrous oxide and sevoflurane or desflurane should be discontinued, and the patient ventilated with a mixture of oxygen and air for at least 5 minutes. Alternatively, when ventilating with oxygen and air, sevoflurane should be stopped at the onset of skin suturing, while nitrous oxide and oxygen should be discontinued 10 minutes before the end of anesthesia. For TIVA, propofol should be turned off just before the start of skin suturing.

Standard practice involves transferring the patient to a postoperative ward or recovery room for full recovery. In the recovery room, close clinical observation is performed, monitoring vital signs such as heart rate, blood pressure, respiratory rate, and oxygen saturation. The return of physiological reflexes, independent breathing capacity, and restoration of muscle strength are also assessed. The quality of patient interaction is evaluated, checking whether the child can follow simple commands and is neither confused nor agitated.

Sometimes, children remain unconscious in the recovery room due to the residual effects of anesthetic drugs. The awakening process differs across age groups. Younger children typically regain reflexes and muscle strength quickly but may experience delayed cognitive reactions. Upon waking, they may attempt to sit or stand despite drowsiness. A safe environment and close supervision are essential. Symptoms of disorientation occur sporadically after anesthesia. Adolescents usually wake more calmly, though occasional inadequate responses can occur due to the cognitive immaturity of the central nervous system.

The depth of anesthesia is monitored through BIS (bispectral index), CNS oxygenation via cerebral oximetry (using sensors placed on the frontal lobes), and the depth of relaxation by measuring TOF (train-of-four) relaxation.

Photograph 16: Cerebral oximetry monitor displaying CNS frontal lobe oxygenation. The visible value of 80 SO_2 represents the baseline set at the beginning of surgery, while 93 SO_2 and 87 SO_2 indicate oxygenation levels above the right (P) and left (L) frontal lobes, respectively. A decrease in oxygenation below the baseline during surgery signals reduced blood flow in the frontal lobes and an increased risk of CNS hypoxia.

Acetylcholinesterase inhibitors are used to reverse the effects of muscle relaxants that have not been metabolized. Neostigmine should be used as sparingly as possible due to its association with an increased incidence of postoperative vomiting. It is recommended only when there are clear signs of incomplete spontaneous resolution of the neuromuscular block (e.g., fewer than four TOF responses or only one DBS). The drug should be administered in two divided doses, with a maximum dose of 0.06 mg/kg. Prior to administering neostigmine, atropine (0.01 mg/kg) must be given to prevent bradycardia and excessive airway secretions. Typically, the drugs are given in a ratio of 0.2 mg of atropine to 0.5 mg of neostigmine.

Naloxone is used only in exceptional circumstances when clearly indicated, with a maximum dose of 3 mcg/kg body weight. Special attention must be paid to potential opioid redistribution in obese children, necessitating postoperative monitoring and naloxone availability.

Sugamadex (Bridion) is a natural antagonist of rocuronium and vecuronium. Administered at a dose of 16 mg/kg intravenously, it reverses the action of rocuronium within 120–150 seconds by irreversibly binding the muscle relaxant. Routine abolition of the neuromuscular blockade occurs at a dose of 4 mg/kg intravenously.

The endotracheal tube should only be removed once the child has regained protective reflexes and is responsive, such as opening their eyes and demonstrating active reactions.

Patients undergoing extensive and prolonged surgeries or those in a very poor general condition should be transferred to an intensive care unit appropriate to the specific surgical procedure.

Management of Glottic Spasm After Endotracheal Tube Removal

- Ventilation through a sealed face mask.
- Applying firm pressure to the angles of the mandible.
- Administering midazolam (0.1 mg/kg intravenously) or, if unavailable, propofol (1 mg/kg intravenously).
- Administering suxamethonium (1 mg/kg intravenously).

5. REGIONAL ANESTHESIA

In the pediatric patient population, in addition to general anesthesia, a wide variety of regional anesthetics analogous to those performed for intra- and postoperative pain relief in adults can be used. In children, it is possible to perform both deep tissue anesthesia and various types of peripheral and central blocks.

The idea behind local or regional anesthesia is to exclude pain stimuli from the operated area of the body. There are many advantages of using this anesthesia. Among them are good pain control, reduced opioid consumption, better hemodynamic stability, reduced risk of adverse effects, such as respiratory and circulatory depression, post-anesthesia agitation, postoperative nausea and vomiting, and accelerated recovery of bowel function. In adults, such anesthesia can be performed on a conscious patient, while in children, regional anesthesia is performed under sedation or general anesthesia.

5.1. Intravesical Anesthesia

Among regional anesthetics, infiltration anesthesia is commonly used, such as infiltrating the surgical wound at the site of a skin incision. Additionally, a catheter can be placed at the incision site to enable the continuous administration of local anesthetics, providing effective analgesia after surgery.

5.2. Trunk and Peripheral Nerve Block Anesthesia

- **In the upper limb:**
    - Brachial plexus
    - Forearm nerves
    - Finger nerves
- **In the lower limb:**
    - Femoral nerve
    - Vulvar nerve
    - Sciatic nerve
- Bier's segmental intravenous blockade
- Periapical blockade
- Pleural blockade
- Intercostal nerves
- Sheaths of the rectus abdominis muscle
- Lower abdominal nerves
- Penis

For procedures in the upper and lower extremities, either nerve plexus anesthesia or anesthesia of individual nerves is used. In the former, the anesthetic agent is administered depending on the extent of necessary analgesia in areas such as the axillary fossa, the clavicular region, or the neck muscles, guided by the topography of anatomical structures. To localize the plexuses, characteristic anatomical points are identified with the assistance of an ultrasound machine with a linear head and a peripheral nerve stimulator.

Older children, if conscious, may experience sensations of pressure, tingling, or a mild electrical current passing through the limb along the course of the nerves during localization and administration. For younger children and for sensitive or uncooperative patients, this anesthesia is performed under sedation.

Drugs for regional anesthesia may be administered via a single puncture or through a catheter placed in the nerve region. The advantage of the catheter-based method, known as continuous regional anesthesia, is the ability to provide prolonged postoperative analgesia. However, this method carries the drawback of potential catheter dislocation when the child moves, necessitating careful monitoring and observation during the postoperative period. As a result, this approach is not always recommended.

5.3. Central Locking Devices

5.3.1. Subarachnoid Anesthesia

This type of anesthesia is commonly used for abdominal and lower extremity procedures, particularly in orthopedic and urologic surgeries, as well as abdominal skin surgeries.

Subarachnoid anesthesia involves puncturing the space between the spinal vertebrae at the lumbar level. The anesthetic is administered into the intradural (subarachnoid) space, which is filled with cerebrospinal fluid (CSF) and located between the lamina propria and the soft dura. This space contains blood vessels, connective tissue, and nerve roots—the target of the anesthetic. The effect of the anesthetic begins within a few minutes, resulting in autonomic blockade, sensory (including pain) abolition, and motor blockade.

The local anesthetics used may be hypobaric, isobaric, or hyperbaric relative to cerebrospinal fluid. The baricity of the drug affects its spread and the extent of anesthesia:

- Hyperbaric drugs (heavier than CSF) tend to migrate lower in the subarachnoid space.
- Hypobaric drugs (lighter than CSF) migrate higher when administered in a sitting child. In smaller children or those anesthetized in the lateral recumbent position, the effects of hyperbaric and isobaric solutions are similar, making baricity less relevant compared to when administered in the sitting position.

Anatomical and Physiological Differences Between Adults and Children

There are key anatomical and physiological differences between adults and children that influence the approach to central blocks:

- In children, the subarachnoid meningeal sac and spinal cord extend lower than in adults.
- Newborns have a narrower subarachnoid space and lower cerebrospinal fluid pressure.
- During development, the meningeal sac initially ends at S3, and the spinal cord ends at L3. By age 2, these levels reach adult-like positions at S2 and L2, respectively.
- In children younger than 1 year, lumbar puncture should be performed lower than in adults, typically at the L4-5 or L5-S1 level, to minimize the risk of unintentional spinal cord injury.

The anesthetics commonly used for subarachnoid blocks include iso- and hyperbaric bupivacaine and spinal morphine, administered into the subarachnoid space. High doses of bupivacaine (>1.0 mg/kg) should be used cautiously due to the risk of cardiotoxicity and neurotoxicity.

5.3.2. Epidural Anesthesia

The epidural space extends from the great foramen to the sacrococcygeal ligament. It is wide and relatively empty, which allows for easy catheter guidance to higher levels. The yellow ligament is the only notable resistance encountered during needle insertion. The distance between the skin and the epidural space can be estimated using the formula: 1 mm/kg of body weight.

In pediatrics, epidural blockade is commonly used to supplement general anesthesia and provide postoperative analgesia. Local anesthetics such as ropivacaine or bupivacaine are typically administered epidurally via a lumbar approach. These anesthetics may be supplemented with fentanyl or sufentanil, along with a test dose of adrenaline. Lignocaine is not recommended for epidural use due to its short duration of action. The preference for ropivacaine is attributed to its minimal cardiotoxicity and reduced likelihood of motor nerve and muscle paralysis. Alternatives to opioids include the addition of clonidine or dexmedetomidine.

Epidural anesthesia administered in the thoracic spine (referred to as thoracic access) can be used for thoracic procedures. This technique enhances analgesia and improves respiratory mechanics in patients undergoing thoracic or cardiac surgeries.

Sacral epidural anesthesia involves puncturing the epidural space near the sacral foramen. Short needles are used for the puncture, saline (instead of air) is employed to identify the epidural space, and a test dose of epinephrine is administered. This is the most commonly used block technique in children, particularly for same-day surgeries, due to its excellent perioperative analgesia with minimal side effects. It is simple and safe to perform.

The extent of anesthesia depends on the volume administered and can cover the area from the umbilicus downward. Sacral epidural anesthesia is most commonly performed in young children undergoing major lower extremity, urinary tract, or lower abdominal procedures.

5.4. Characteristics of Drugs Used for Regional Anesthesia

Local anesthetics work by paralyzing nerve fibers and blocking the conduction of pain and motor impulses. Their anesthetic effect is reversible, and the duration of the effect depends on the physicochemical properties of the molecule. The potency of a regional anesthetic, a key determinant of its quality, depends on the drug's lipid solubility and ability to penetrate cell membranes. A greater fat solubility and higher affinity for plasma proteins, such as albumin and alpha-1-glycoprotein acid, prolong the duration of action.

Regional anesthetics are categorized into two pharmacological groups: ester derivatives and amide derivatives. The safer amide derivatives, which include a lipophilic aromatic group and a hydrophilic amino group, are preferred for regional anesthesia. These drugs act by reducing the permeability of the cell membrane to sodium ions (Na^+) by blocking sodium channels. Physiologically, it is believed that the site of action is at the Ranvier nodes, where blocking two to three nodes eliminates active depolarization, effectively preventing action potential transmission and blocking neuronal signaling.

Lidocaine is one of the most commonly used local anesthetics for regional analgesia in children. It has a short duration of action, is poorly protein-bound, and is primarily utilized in intrathecal analgesia. The maximum recommended dose for regional anesthesia in children is 3 mg/kg of body weight. The dose should always be individualized based on the child's weight and overall condition, with close supervision and vital sign monitoring during anesthesia.

The potency and duration of lidocaine depend on the concentration and volume of the solution used. Increasing both the volume and concentration can enhance, prolong, and intensify the local anesthetic effect. Lidocaine, like other local anesthetics, must be administered slowly with a prior aspiration test to avoid inadvertent intravascular administration.

Repeated doses of lidocaine can lead to significant increases in serum concentrations, with potential central nervous system (CNS) toxicity. Early symptoms of CNS toxicity include a metallic taste in the mouth, restlessness, tinnitus, dizziness, visual disturbances, muscle tremors, or drowsiness. Special caution must be taken when administering lidocaine in the head and neck regions, as symptoms of intoxication can occur even when using an otherwise acceptable dose.

Mepivacaine is a local anesthetic prescribed for both local and regional anesthesia, commonly used in dental surgery for adolescents and children over 4 years of age (weighing approximately 20 kg). When used for peripheral nerve blockade, mepivacaine acts rapidly, typically within 3-5 minutes. The duration of anesthesia varies depending on the administration method:

- Approximately 25 minutes following intrathecal administration.
- Between 40 to 120 minutes with regional anesthesia.

Mepivacaine is recognized for its wide safety margin. In cases of relative overdose, symptoms generally appear within 1-3 minutes. For absolute overdose, symptoms of toxicity may manifest later, typically 20-30 minutes after injection, depending on the injection site.

Although considered safer than some alternatives, the toxic effects of mepivacaine are similar to other local anesthetics. These effects usually progress in the following order:

1. Neurological symptoms: These begin gradually and may escalate in severity. Early signs include:
    - Agitation,
    - A feeling of intoxication,
    - Numbness of the lips and tongue,
    - Paresthesias around the mouth,
    - Dizziness,
    - Visual and hearing disturbances,
    - Tinnitus.
2. Vascular symptoms: These may follow the initial neurological effects.
3. Respiratory symptoms: These occur in more severe cases.

The occurrence of any of these symptoms during administration serves as a critical warning signal. It necessitates the immediate discontinuation of the drug to prevent further complications.

Ropivacaine is a local anesthetic commonly used in regional anesthesia. Its onset of action varies based on the route of administration:

- 10-25 minutes for peroneal administration,
- 1-15 minutes for small peripheral nerve or intrathecal anesthesia,
- 10-20 minutes for the epidural route.

The duration of action also depends on the concentration and site of administration:

- 5 to 8 hours for nerve plexus anesthesia,
- Shorter durations of 2 to 4 hours for peripheral nerve or intrathecal anesthesia.

Ropivacaine exhibits a stronger inhibitory effect on sensory fibers compared to motor fibers. This property makes it particularly useful in situations requiring effective sensory blockade with minimal or preserved motor function. As a result, ropivacaine is often preferred for peripheral nerve anesthesia.

Due to its large safety margin and considerable potency, ropivacaine is considered a safer choice compared to other anesthetics. Additionally, its limited motor blockade is a distinct advantage, particularly in clinical scenarios where motor function preservation is desirable.

Bupivacaine is a long-acting local anesthetic with an amide structure, similar to other local anesthetics. It has a strong inhibitory effect on nerve impulse conduction in both sensory and motor fibers, making it particularly suitable when effective sensory and motor blocks are required. Like other local anesthetics, bupivacaine produces a reversible blockade of nerve impulses by inhibiting sodium channels in the cell membrane.

Bupivacaine is metabolized in the liver, primarily through aromatic hydroxylation to 4-hydroxybupivacaine and N-dealkylation to pipecolylxylidine (PPX). These processes are mediated by cytochrome P450 3A4, and interactions affecting its metabolism may interfere with bupivacaine's breakdown. This is significant because an overdose of bupivacaine can be dangerous, with potential cardiotoxic effects such as cardiac arrhythmias, as well as neurological symptoms like impaired consciousness and seizures. It may also lead to respiratory and circulatory depression, either from overdose or unintentional intravascular administration of the drug.

Bupivacaine is particularly recommended when a long duration of anesthesia is desired. It is used in various applications, including:

- Infiltration anesthesia,
- Peripheral nerve anesthesia,
- Epidural anesthesia.

Table 8: Characteristics of local anesthetic drugs used

Drug	Start of Operation	Operating Time	Duration (Hours)	Power of Action	MLAC EC50	Toxicity
Lidocaine	Quick	Short	2	Mean	8	Mean
Mepivacaine	Quick	Average	3	Mean	6	Mean
Ropivacaine	Average	Long	4	High	4	Mean
Bupivacaine	Free	Long	6	High	2	High

5.5. Risks of Anesthesia and Possible Complications

Regional anesthesia, like any other form of anesthesia, involves an invasive procedure that alters the patient's physiological state, suppressing natural defensive reflexes. This intervention comes with inherent risks, particularly in pediatric patients.

Children, especially neonates, exhibit a significantly higher cardiac output compared to adults, leading to increased systemic absorption of local anesthetic drugs (LMZ). Neonates also have reduced plasma levels of proteins, such as acid α-1 glycoprotein, which preferentially bind to local anesthetics. Normal plasma levels of this protein are typically achieved after the first year of life. Inadequate levels of this protein result in higher plasma concentrations of the free fraction of the anesthetic, which primarily contributes to toxic effects.

Additionally, infants up to six months of age generally have immature hepatic metabolic processes, with hepatic metabolism reduced by approximately 50%. This immaturity leads to prolonged drug elimination times in comparison to adults.

The factors outlined above significantly heighten the risk of LMZ toxicity in neonates and infants. Therefore, the maximum recommended doses for local amide anesthetics must be adjusted and reduced for this group of pediatric patients.

A parameter that values the use of an anesthetic drug for analgesia is MLAC *(minimum local analgesic concentration)*, or the minimum effective concentration or dose of a local anesthetic required to be effective in 50% of patients *(median effective concentration, EC50)*.

The local anesthetics most commonly used in conductional analgesia include bupivacaine, ropivacaine, mepivacaine, and lidocaine. In children over one year of age and adolescents, the pharmacokinetic properties of LMZs are similar to those of adults.

When administering central anesthesia to patients receiving anticoagulant drugs, consideration should be given to the type of anticoagulation used, the time of last administration, and any monitoring of clotting parameters or platelet levels.

It is believed that after the use of low molecular weight heparin in a prophylactic dose, central blocks can be performed 12 hours after the last administration of the drug and 24 hours if the therapeutic dose is used. When used for more than 4 days, the patient's platelet levels should be checked. Precise recommendations for individual preparations are given in the guidelines of the societies.

It is important to remember that in addition to many common anticoagulants, drugs that interfere with blood clotting include serotonin reuptake inhibitors (SSRIs), such as fluoxetine, citalopram, paroxetine, and others, as well as herbal preparations. Therefore, check your child's past treatment history for records of medications used.

Due to the differences between regional and general anesthesia, a good standard is the precise description of the anesthetic procedure and agents administered. To facilitate and systematize the entries in the documentation, the peripheral nerve block chart was created. It contains the most important information regarding details of the procedure and its monitoring. In addition, the Regional Anesthesia Society recommends that photographs of the procedure, such as ultrasound projections, be taken and included in the documentation or that photographs or videos be saved on disk.

Załącznik nr .... Wydanie III z dnia 29.06.2015 r.

KARTA BLOKAD NERWÓW OBWODOWYCH

Nazwisko i imię pacjenta		
Wiek:	ASA:	Alergie:

Procedura chirurgiczna: ....

Strona: ☐ Lewa ☐ Prawa

WYKONANA BLOKADA: ☐ KOŃCZYNA GÓRNA

☐ Splotu szyjnego ( ) .... ml
☐ Splotu ramiennego ( ) .... ml
Dostęp: ☐ między mm. pochyłymi ☐ nadobojczykowy ☐ podobojczykowy ☐ pachowy
☐ N. promieniowego ( ) .... ml
Dostęp: ☐ na poziomie ramienia ☐ na poziomie przedramienia
☐ N. pośrodkowego ( ) .... ml
☐ N. łokciowego ( ) .... ml

☐ KOŃCZYNA DOLNA

☐ Przedziału powięzi biodrowej ( ) .... ml
☐ N. udowego ( ) .... ml
☐ N. skórnego bocznego uda ( ) .... ml
☐ N. kulszowego ( ) .... ml
Dostęp: ☐ podkolanowy ☐ podpośladkowy
☐ N. zasłonowego ( ) .... ml
☐ N. udowo – goleniowego ( ) .... ml

☐ POZOSTAŁE

☐ TAP Block ( ) .... ml ☐ IiN i IhN ( ) .... ml ☐ Rectus Sheeth ( ) .... ml

Odpowiedź ruchowa	Min. prąd przed iniekcją (mA)	Jakość obrazu USG	LMZ	Stężenie (%)	Objętość (mL)	Adrenalina/ Inne
		☐ Dobra	☐ (B)upiwakaina			☐ 1/__00000
			☐ (L)ignokaina			
		☐ Niezadowalająca	☐ (R)opiwakaina			☐ Inne ....

Data: ___/___/____ Czas rozpoczęcia (:) Czas zakończenia (:)

Parametry życiowe: BP: ___/___ HR: ___ satO_2___%

Pacjent podczas wykonywania blokady: ☐ Pełna świadomość ☐ Sedowany ☐ Znieczulony

Premedykacja: ☐ Midazolam ....(mg) ☐ Fentanyl ....(mcg) ☐ Dexaven ....(mg)

Pozycja pacjenta: ☐ na plecach ☐ na brzuchu ☐ na boku ☐ siedząca

Monitorowanie: ☐ BP ☐ EKG ☐ O_2 Sat ☐ Podaż tlenu ☐ Sprzęt resuscytacyjny

Zachowanie aseptyki: ☐ Tak ☐ Nie

Technika: ☐ pojedyncze wkłucie ☐ cewnik

Igła: ☐ 2" 22G ☐ 1" 24G ☐ 18G Tuohy ☐....... ☐ Inna ....

Znieczulenie skóry: ....mL ☐ Lignocainum ☐ Inne: ....

Monitorowanie blokady: ☐ USG ☐ Stymulator nerwów ☐ Parestezje ☐ BSmart

→*głowica:* ☐ *Liniowa* ☐ *Convex* ☐ *In plane* ☐ *Out of plane*

Ból/parestezje w trakcie iniekcji: ☐ Tak ☐ Nie

Stopień blokady: ☐ Całkowita ☐ Częściowa ☐ Brak blokady ☐ Nie do oceny..................

Parametry życiowe po wykonaniu blokady: BP: ___/___ HR: ___ satO_2___%

☐ CIĄGŁA BLOKADA NERWÓW OBWODOWYCH

☐ Cewnik Contiplex D ☐ Cewnik Contiplex C ☐ Inny..........
☐ Głębokość zaimplantowania cewnika ....cm
☐ Pompa elastomeryczna Easypump 270ml / 54h ☐ Inna...................
☐ Pompa strzykawkowa (Do strzykawki o pojemności **50 ml**, nabrać ....
dopełnić **0,9% NaCl do 50 ml**. Wlew ciągły przy użyciu pompy z przepływem.......ml/h.

UWAGI:
....
....

Podpis i pieczątka lekarza

Figure 2: Regional anesthesia chart

http://anestezjologiaregionalna.pl/karta-blokad/

6. PERIOPERATIVE FLUID THERAPY

6.1. Crystalloids

The objective of perioperative fluid therapy is to supply the child with the necessary amount of fluids and electrolytes while addressing potential deficiencies. This ensures proper tissue perfusion, adequate oxygen delivery, and efficient removal of metabolic waste. Fluids are categorized into colloid fluids, crystalloids, and osmotic or electrolyte-neutral fluids based on the dissolved substances.

Crystalloids are typically administered during surgery and anesthesia. They vary in sodium and potassium electrolyte content, as well as their composition, environmental pH, and osmolarity. Crystalloids are known to briefly remain in the intravascular space before diffusing into the extravascular space. Their action enhances blood pressure, replenishes the vascular bed, and mitigates systemic water deficit, thereby preventing perioperative electrolyte imbalances. Multi-electrolyte fluids are especially utilized for this purpose.

Historically, solutions such as 2:1 or 1:1 fluids (mixtures of 0.9% NaCl and 5% glucose) were used perioperatively. However, due to their low sodium concentration (compared to plasma sodium concentration of ~140 mmol/L) and rapid cellular absorption of glucose, they are considered hypotonic solutions. These solutions risk inducing or worsening cellular edema and should not be used in operating rooms or intensive care settings.

In the initial treatment phase (up to 4 hours), the goal is to increase intravascular volume. Sodium, an essential extracellular ion, is vital for managing dehydration. Thus, isotonic fluids, with sodium concentrations balancing plasma volume, are recommended. Multi-electrolyte fluids are particularly suitable for intraoperative use.

Table 9 provides an example of the electrolyte composition and osmolarity of commonly administered parenteral polyelectrolyte fluids.

Table 9: Electrolyte composition and osmolarity of selected intravenous fluids available in Poland, values are in mEq/l.

Parameter	Plasma	0.9% NaCl	Mixture of 5% glucose and 0.9% NaCl (1:1)	Mixture of 5% glucose and 0.9% NaCl (2:1)	5% Glucose with electrolytes (including buffer, GNAK)	Ringer's solution	Modified Ringer's solution	Hartmann's solution	Poly-electrolyte solutions (Benelyte, Optilyte, Plasmalyte, Sterofundin ISO, Venolyte)
Na+ (mmol/L)	135 - 145	154	76.9	51.3	40	147 - 155	112	131	140 - 147
Cl- (mmol/L)	95 - 105	154	76.9	51.3	40	115 - 125	112	111	98 - 107
K+ (mmol/L)	3.5 - 5.0	0	0	0	5.36	4 - 5	4 - 5	5	5
HCO3- (mmol/L)	24 - 32	0	0	0	23 (Acetate)	28.3 (Lactate)	29 (Lactate)	30 (Acetate)	23 - 34 (Acetate, citrate, gluconate, malate)
Ca2+ (mmol/L)	2.2 - 2.6	0	0	0	0	2.2 - 2.25	1.84	1.2	0
Mg2+ (mmol/L)	0.8 - 1.2	0	0	0	0	0	0	1.5	1.5
Glucose (mmol/L)	3.5 - 5.5	0	139	278	278 (50 g/L)	0	0	0	0
pH	7.35 - 7.45	5.0 - 7.0	5.5 - 7.0	5.0 - 7.0	4.5 - 6.5	5.5 - 6.5	5.5 - 6.5	5.5 - 6.5	6.9 - 7.9
Osmolarity (mOsm/L)	275 - 295	308	302	309	290	274 - 278.5	274 - 278.5	278 - 351	286.5

Retrieved from: National Institute for Health and Care Excellence, https://www.mp.pl/interna/table/016_2214, accessed May 18, 2021, modified in 2021.

6.2. Colloids

Colloids are aqueous solutions of macromolecular substances, most commonly polymers of sugars or gelatin. They include solutions such as modified gelatin (Gelofusin), starch derivatives (hydroxyethylated starch, HAES), isotonic or hypertonic (e.g., Voluven in concentrations of 6% and 10%), glucose polymers - dextrans and albumin protein solutions.

Colloid fluids remain in the vascular bed much longer than crystalloids; however, they burden systemic metabolism, including the kidneys and liver. In critical situations, colloid fluids replace blood preparations by filling the vascular bed.

Currently, excessive administration of colloids is considered questionable. Numerous scientific studies indicate that only small amounts of colloids should be used for hypovolemia therapy.

6.3. Intraoperative Fluid Use in the Operating Theatre

Basic fluids are commonly used in the operating theatre, including balanced isotonic multi-electrolyte fluids such as Optilyte, Sterofundin, or Ringer's fluid (containing acetate or lactate). Newborns are typically given 10% glucose solution, or Benelyte – a multi-electrolyte fluid with added glucose (1 g per 100 ml). Ringer's lactate is also frequently administered. Colloid fluids are employed to manage fluid loss within the vascular bed, especially in cases of sudden hypovolemia caused by hemorrhage, hypotension associated with regional analgesia, or other forms of shock.

For the management of hypovolemia, Geloplasma and HAES 10% are appropriate options, while HAES 6% is recommended for children under 2 years of age according to current guidelines. Both HAES 10% and 6% are indicated solely for cases of hypovolemia and sudden blood loss as specified in the recommendations.

Because young patients are at high risk of hypothermia, transfused fluids must be warmed. For larger transfusions, rapid drip transfusion sets and infusion pump delivery are utilized. Intraoperative fluid requirements are determined based on the child's age and are detailed in Table 10.

Table 10: Intraoperative Fluid Requirements

Age Group	Operations of Low Extent of Injury	Operations with Opening of Body Cavities	Major Intestinal and Pancreatic Surgeries
Newborns	1 ml/kg/day of life/hour	5 ml/kg/hour	10 - 15 ml/kg/hour
Infants	8 ml/kg/hour	10 ml/kg/hour	15 ml/kg/hour
1 - 5 years	6 ml/kg/hour	10 ml/kg/hour	15 ml/kg/hour
6 - 10 years	4 ml/kg/hour	8 ml/kg/hour	12 ml/kg/hour
Over 10 years	2 ml/kg/hour	4 ml/kg/hour	12 ml/kg/hour

NOTE: For epidural and subarachnoid analgesia, the vascular bed should be additionally filled with a single transfusion of compensatory fluid at 10 ml/kg for 15 minutes due to accompanying vasodilation of the peripheral vascular bed. Fluid filling is recommended in children above 6 years of age, who are more susceptible to drops in blood pressure caused by deficient volemia.

In children with heart defects, fluid restriction should be the opposite, and the above requirement should be halved or adjusted individually under control of hemodynamic conditions. In children with renal failure, management must be individualized according to the child's condition, taking into account the guidance of pediatric nephrologists, including the possibility of potential dialysis.

7. DOCUMENTATION

7.1. Documentation of the Preoperative Visit

Documentation is an integral part of the medical procedures performed. For legal, but also substantive reasons, reliable documentation is extremely important. Properly prepared documentation and its appropriate filling help in the work of both the doctor and the medical personnel. It also protects against accusations of lack of proper supervision over the provision of services and simplifies proceedings in case of claims.

Medical records are also helpful to the child's parents in making them aware of the extent of the procedure and the potential risks of anesthesia. An example of such documentation is the anesthesia questionnaire used during the anesthesia visit. The questionnaire is discussed in the section on preparing the child for surgery, and below is the general section on the introduction to general and regional anesthesia.

Table 11: Anesthesiology Survey - General Information

Description of General Anesthesia	General anesthesia removes consciousness and pain sensation. During this state, the child is in a sleep-like condition, and medications are administered intravenously or through inhalation via a face mask or an appropriate endotracheal tube. Additional follow-up is often necessary, which may include the administration of intravenous fluids or, in rare cases, a blood transfusion.
Description of Regional Anesthesia	Regional anesthesia involves administering local anesthetics or analgesics into the area around a nerve or the spinal cord. This results in a temporary loss of pain sensation and is often safer and more beneficial for the patient than general anesthesia in many cases.

Security and Risks	The risks associated with anesthesia are influenced by several factors, including the patient's age, body weight, gender, and pre-existing medical conditions such as heart disease, kidney issues, or liver dysfunction. For planned procedures, a thorough medical history and physical examination are essential. This ensures that the anesthesiologist is familiar with any past complications or sensitivities, thus reducing the likelihood of adverse events. Additionally, during surgery and anesthesia, the anesthesiologist remains vigilant to address complications promptly, supported by intensive therapy and monitoring.
Complications Related to Proposed Anesthesia	Modern anesthesia techniques and continuous monitoring significantly reduce complications. However, unforeseen events may occur. Common complications include headaches after subarachnoid anesthesia, difficulty opening eyes, lack of strength in the limbs, and temporary difficulty breathing upon waking. Less frequent complications might involve nausea, vomiting, blurred vision, pain at the surgical site, irritation to the trachea or vocal cords, and difficulty urinating after a central block. Rare but severe complications include soft tissue damage, allergic reactions, critical hypoxia, or cardiac arrest.
Preparation for Proposed Anesthesia	Before anesthesia and surgery, unless otherwise directed by a physician, the patient should follow these guidelines: ● Maintain fasting for at least six hours before anesthesia. ● Take prescribed medications as advised. ● Remove contact lenses, jewelry, makeup, and nail polish to minimize risks during the procedure.

7.2. Operating Theatre Records

In the operating theater, documentation of performed procedures and anesthesias is kept as standard. The operative book contains a detailed description of the procedure immediately after surgery and a description of anesthesia. It is good practice to fill in the perioperative control chart, which serves as a kind of checklist of the performed surgery and anesthesia.

On one sheet, a designated person—commonly a coordinator, such as an anesthesiologist or an anesthesiological nurse—marks the completion of procedures by confirming individual critical points before anesthesia, during surgery and anesthesia, and after surgery. Both the operative book and the perioperative checklist, when the information system allows it, can also be maintained in electronic formats. This facilitates and simplifies the procedure of systematic record-keeping.

7.2.1. Documentation of Anesthesia

A typical anesthesia chart should be filled in during each anesthesia session. It should be standardized, easy to follow, and completed in a unified manner to ensure it is understandable for other medical professionals. Observations should be recorded at least every five minutes. This guideline also applies to short-term anesthesia.

The original of the anesthesia chart is always attached to the patient's medical history. Below is an example of an anesthetic chart designed to be completed by both the anesthetist and the anesthetic nurse.

ANESTHESIA CHART

PREMEDICATION

Name:

Date of birth

History No.

Date of Anesthesia:

Blood type: i Rh

Recognition:

Legend:

ASA	Weight	Temp.	RR	Hb	Ht	Alergia:

ECG

Chest X-ray chest

In

Ex

Start/End

an

Self-breathing

+++

Control Breath

Breath

#

Recall

RR X

Pulse -

Temp.

Operational Notes:

Oral intubation /rhinotracheal

Tube with/without sealing

No.

Clamp on h...

Clamp off hour...Child after anesthesia:

□ cardiovascular

□ respiratory

The child was transferred to: □ POP □ ICU

Transfused during surgery:

....

ml...........................

....

ml...........................

....

Signature and stamp of the anesthesiologist

Hour.							
1. *drugs:*							
2.							
3.							
4.							
other							
O							
N_2O							
Gas							
PC O_2							
SAT.							
Temp.							
38°							
200							
36°							
180							
160							
34°							
140							
120							
32°							
100							
40							
28°							
20							
26°							
Breathe							
Liquids							

Anesthesiologist	Nurse	Opera	Aces

Nowadays, in some medical centers, computer systems are implemented to record a child's status parameters during surgery. The data are automatically transferred from the anesthesia machine monitor and the hemodynamic status monitor to the individual patient panel. It is the responsibility of the physician and anesthesiological nurse to supervise this record, ensuring its accuracy, and to supplement the data with information about the drugs administered and the specific activities performed during anesthesia.

Photograph 17: The electronic anesthesia chart, produced by a Polish manufacturer, is displayed on a touchscreen attached to the anesthesia machine. This panel is electronically integrated with the anesthesia machine's gas monitor and the hospital's archiving system.

7.3 Records from the Recovery Room

Electronic record-keeping significantly simplifies work processes and enhances the reliability of medical documentation. According to data from companies providing such systems, the implementation of the Electronic Anesthesia Card offers numerous benefits. It saves time, ensures more precise documentation, and broadens the scope of recorded parameters. The system's automatic readings from anesthesia machines, patient monitors, and other devices allow medical personnel to concentrate more on monitoring the patient's condition while reducing the manual activities required during surgery. Additionally, the system ensures improved safety by accurately recording data through continuous device downloads, tracking parameters, and generating comprehensive, personalized final reports.

Photograph 18: The recovery room is equipped for full nursing and medical supervision. It ensures the continuation of ventilation and comprehensive monitoring, as conducted in the operating room. A child transferred to the mother unit should be fully awake and free of pain, ensuring their safety and comfort during the postoperative recovery phase.

The post-operative ward, commonly referred to as the recovery room, maintains both individual records for children receiving healthcare services and collective records for all patients under care. According to regulations, individual child observation charts are managed by a nurse under a physician's supervision. These charts document vital hemodynamic parameters like blood pressure, heart rate, heart rhythm, diuresis, and gas exchange metrics such as saturation. Additionally, they record the time and mode of ventilator use, extubation details, and all medications administered, including pain relief drugs.

Documentation may also be stored electronically, as seen with anesthesia charts. Another critical document is the pain assessment chart. This chart tracks pain parameters based on a selected scale, medications provided, and outlines a pain management plan to be implemented upon the child's discharge to the home ward.

8. BLOOD AND ITS PREPARATIONS

A procedure for transfusion of blood or a blood component is defined as: "The transfusion of the right unit of blood, to the right recipient, at the right time and in the right place and according to the right instructions." The optimal use of blood and its components is considered to be that which is safe (no adverse reactions), clinically effective (to the benefit of the patient), and productive (no unnecessary transfusions). In Poland, the principles of blood donation are determined by the Act of August 22, 1997, on Public Blood Service [25].

Załącznik nr 5

WZÓR

Podmiot:..

Jednostka lub komórka organizacyjna:...

(pieczątka jednostki lub komórki organizacyjnej składającej zamówienie) ....dnia ....

(miejscowość)

ZAMÓWIENIE INDYWIDUALNE NA KREW I JEJ SKALDNIKI

Nazwisko i imię pacjenta...

Numer PESEL lub data urodzenia ....

Jeżeli pacjent NN: numer księgi głównej ...., **numer księgi oddziałowej**......................

lub niepowtarzalny numer identyfikacyjny...

Grupa krwi pacjenta ....

Przeciwciała odpornościowe..

Rozpoznanie choroby ....

Wskazanie do transfuzji...

PROSZĘ O WYDANIE

....

(pełna nazwa zamawianego składnika)

Liczba jednostek lub opakowań

Grupa krwi ABO

RhD *(słownie)*

Fenotyp krwinek czerwonych *(jeśli potrzeba)*

....

....

(data, podpis i pieczątka lekarza zamawiającego)

*** Układ graficzny nieobowiązujący.**

Whole blood is not usually transfused; instead, red blood cell concentrate (RBC) is used for transfusion and blood replenishment. RBC is a blood component obtained from one unit of whole blood after removing most of the plasma and preservative fluid. It contains all the red cells from one unit of whole blood and, depending on centrifugation conditions, varying amounts of platelets and white cells. In blood donation centers, the red cell fraction is processed in a specific way by removing the leukocyte-platelet capsule layer and a small volume of plasma from the red cell fraction. This results in leukocyte-poor red cell concentrate enriched with a solution, which is beneficial to the recipient as it reduces the risk of alloimmunization with HLA antigens and transmission of CMV infection.

The minimum amount of transfused RBC is 10 ml/kg. If the assessed losses are lower, blood is not transfused unless necessary for cardiological or nephrological patients, where individual indications apply. Erythrocyte mass and plasma are always transfused at a temperature of 37°C.

Blood, plasma, and platelet preparations are transfused in ratios of 1:1:1 or 2:1:1. It is important to remember that blood transfusions should be limited to the necessary minimum, in accordance with the recommendations of transfusion societies.

During anesthesia procedures, a Perioperative Control Sheet is used to document and mitigate adverse events related to anesthesia and surgery. This includes ensuring the availability of blood products, managing potential adverse reactions to transfusions, and minimizing errors during blood transfusion.

The completion of the control card and repeated verification of the crossmatch number, blood group, and compatibility of the blood product with the one ordered is vital to eliminating critical transfusion errors. For the purpose of documentation, a transfusion book is maintained where every transfusion of a blood product is recorded. This includes detailed parameters such as the time (hours and minutes) of the transfusion and necessary data to identify the blood sample. The perioperative chart also plays a critical role in minimizing other errors, such as patient identification mistakes, confusion over the surgical site, or leaving surgical materials like instruments or gauze pads in the surgical field. Additionally, it ensures the proper functioning of monitoring equipment.

To prevent these errors, heightened staff attention is essential. This often requires maintaining a solemn and focused environment in the operating room, underscoring the significance of diligence during surgical procedures. This standard is not just a protocol but a necessity for ensuring patient safety.

Autotransfusion methods have become increasingly common in recent years, particularly in pediatric surgery and orthopedics, where they are often used for older children. A consent form for autotransfusion is attached as part of the process.

szpital oddział nr ks. gł. pacjenta

KARTA AUTOTRANSFUZJI

imię nazwisko data urodzenia

adres

grupa krwi przewidywana data zabiegu

rozpoznanie i rodzaj planowanego zabiegu

Kwalifikacja do zabiegów autotransfuzji

rodzaj donacji objętość liczba planowanych donacji częstość donacji

uwagi

podpis lekarza kwalifikującego

Wyrażam zgodę na zabieg autotransfuzji. Zostałem poinformowany o sposobie przeprowadzenia zabiegu i możliwych powikłaniach.

Children may qualify for the autotransfusion procedure provided that written parental consent is obtained. While no strict lower age limit exists, children weighing less than 10 kg are generally not considered suitable candidates for autotransfusion due to technical challenges in blood collection (e.g., limited vein access) and the potential lack of cooperation from the child. For children weighing between 10 and 20 kg, it is often necessary to compensate for lost blood volume with infusion fluids, such as plasma replacement transfusions.

It is important to note that unused autologous blood components cannot be transfused to another recipient or utilized for factory fractionation. Instead, they must be destroyed in accordance with regulations applicable to allogeneic blood.

9. POSTOPERATIVE PERIOD

Every child requires observation following surgery. This observation typically takes place in the recovery room or, as it is otherwise known, the intensive postoperative care room. After undergoing an inpatient procedure, each child is transferred to a postoperative ward. Children who were intubated for surgery are connected to a ventilator. Extubation occurs when the patient awakens and demonstrates efficient, spontaneous breathing. This approach minimizes the use of drugs designed to reverse anesthetic effects and ensures a gentle awakening process.

Children who are extubated in the operating room or who did not require intubation during surgery are also transferred to the postoperative ward. Here, they are closely monitored and assessed for respiratory and circulatory function, the return of consciousness, and their perception of pain.

Transport of the patient immediately following anesthesia is supervised by an anesthesiologist. The process involves using a portable oxygen source, Ambu bag ventilation, vital signs monitors, and any additional equipment necessary to ensure the child's safety.

In the post-anesthesia care unit, the anesthesia team, comprising a physician and nurse, identifies the patient and transfers them to a bed or warmed incubator. The team ensures the patient is connected to a ventilator if needed and continuously monitors vital signs. The post-anesthesia care sheet is completed in this department, documenting the patient's condition, the degree of pain assessed using an appropriate scale, and the type of analgesics administered.

9.1 Treatment of Postoperative Pain

Pain management in children is a priority intervention, as inadequate treatment can lead to significant physical and psychological consequences, increase perioperative complications, and even mortality. Pain in children during the postoperative period occurs with a frequency similar to adults. However, studies show that children tend to experience pain for longer durations compared to adults. This is compounded by their limited ability to verbalize their needs and complaints, making it essential to properly recognize, assess, and address their pain.

Postoperative pain in children, as in adults, is primarily receptor-mediated. It arises from stimulation of Aδ and C-fiber nociceptors due to damage to the skin, fascia, and muscle continuity. Uncontrolled acute pain can progress to chronic pain in both children and adolescents. Inadequate pain management during neonatal stages can have lifelong implications, including heightened pain sensitivity. This underscores the critical importance of effective pain treatment in pediatric care.

The physiological response to pain includes symptoms such as dilated pupils, tachycardia, tachypnea, hypertension, and reduced hemoglobin saturation. Metabolically, pain triggers catabolic processes through the increased secretion of catecholamines, glucagon, and steroids. These responses delay wound healing, reduce mobility, cause hypoventilation, decrease food intake, disturb sleep, and increase irritability.

Unmanaged pain during and after surgery lowers the pain threshold in later years, contributing to an increase in complications during the perioperative period. This includes higher risks of infection, replacement ventilation, and vascular cannulation.

Recent advancements emphasize treating the child as both a patient and an individual within their caregiver-family unit. A child’s comfort is closely tied to the well-being of their caregiver, as parents or guardians often have intimate knowledge of their child's behavior and can accurately assess the severity of pain. Even in the youngest patients, caregivers can utilize numerical scales to evaluate pain levels, an assessment that young children alone are unable to articulate effectively.

9.2 Postoperative Pain Assessment

The anesthesiologist is responsible for determining the type and dosage of pain medication. Analgesics, as prescribed by the anesthesiologist, are administered by the anesthesia nurse. The nurse also completes the Pain Management Chart to document the patient’s pain levels and the effectiveness of the analgesic therapy provided. Pain assessment is conducted using commonly utilized scales in the unit, such as VAS, CRIES, FAC, or FLACC.

Once the patient is transferred to the ward, the treating physician (e.g., surgeon or orthopedist) takes over the responsibility of planning and prescribing pain therapy. This therapy is tailored according to hospital standards, with the physician monitoring its implementation and effectiveness.

In cases of same-day surgery, it is crucial to avoid opioid medications that could cause respiratory depression. Parents should be provided with written instructions for managing the child’s pain at home.

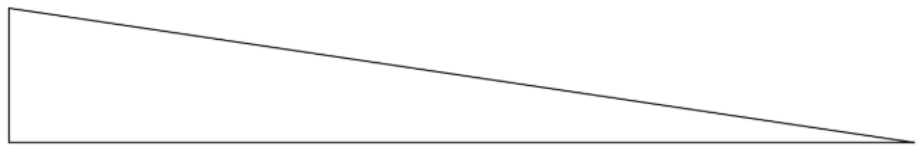


Figure 3: The Visual Analog Scale (VAS) is represented in the form of a triangle, where pain intensity is marked. The strongest pain is indicated on the left side, and the weakest on the right side of the triangle. A vertical line is used to denote the location corresponding to the perceived level of pain.

Table 12: CRIES Pain Rating Scale

Category	**0**	**1**	**2**
Crying	Does not cry	High-pitched cry	Won't calm down
Requirement for supplemental oxygen supply (for saturation >95%, assessed by pulse oximetry)	Does not require	$FiO_2 \geq 30\%$	$FiO_2 > 30\%$
Vital signs (heart rate, blood pressure)	At preoperative level	Increase of <20%	Increase of >20%
Facial expression	Normal	Crooks	Croaking, groaning, moaning
Sleep pattern	Correct	Wakes up a lot	Awake

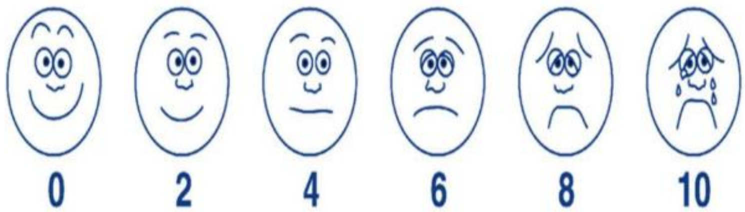


Figure 4: The FACES pain rating scale, based on the Wong-Baker Faces scale (modified), features a sequence of facial expressions to help patients, especially children, convey their pain level. Each face corresponds to increasing pain severity, from a smiling, pain-free face to a crying, distressed expression. This adaptation provides a straightforward and accessible method for pain assessment in clinical settings, ensuring better communication of patient discomfort.

The FLACC (Face, Legs, Activity, Cry, Consolability) scale is a behavioral pain assessment tool tailored for children, particularly those unable to verbally express their discomfort. This scale evaluates five parameters—facial expression, leg positioning, activity level, crying, and ability to be soothed. Each parameter is scored from 0 to 2 points, and the total score provides an overall indication of pain intensity. Designed for children lacking verbal communication, the FLACC scale ensures effective pain assessment and management in pediatric patients.

Category	0	1	2
Facial Expression	Face with no particular expression or smiling	Periodic grimaces, frowning eyebrows, frowning, uninterested	Frequent or constant grimacing, trembling chin
Positioning of the Legs	Casual, relaxed	Restless, tense	Digging, leg pull-ups
Activity	Lies quietly in normal position, moves easily	Wiggles, shifts forward/backward, tense	They bend, stiffen, jerks
Crying	They're not crying	They cry, moan, quiver	They cry all the time, sobbing or screaming
Consolability	Peaceful and pleased	They're calming down with stroking, cuddling, talking to him, but restless	They're hard to console

Postoperative pain should be prevented whenever possible. This includes avoiding unnecessary procedures and planning treatments in advance of surgery. Pain assessment should employ validated, age-appropriate tools to ensure accurate evaluation.

Currently, it is recommended to use combinations of two or more analgesics or techniques that have different mechanisms and sites of analgesic action. This approach, known as multimodal analgesia, is particularly effective in managing pain in children, providing comprehensive and balanced pain relief.

Multimodal or balanced analgesia offers several advantages, including improved pain relief, reduced reliance on opioids (opioid sparing), and minimized opioid-related side effects. The key components of multimodal analgesia include:

Local/Regional Techniques

- Local anesthetic drugs should be utilized, when possible, to block nerve activity before, during, and after surgery.
- Recommended methods include nasal anesthesia at the surgical site, peripheral nerve blocks, and central nerve blocks.

Systemic Analgesics
Medications that can be safely administered to children and neonates, provided the dose is weight-adjusted and adjusted for metabolic differences, include:

- Paracetamol (Acetaminophen): A commonly used analgesic.
- Metamizol (e.g., Metamizol Kalceks): Suitable for children from 3 months of age.
- Nonsteroidal Anti-inflammatory Drugs (NSAIDs): Includes ibuprofen and ketoprofen.
- Opioids: Morphine and nalbuphine for controlled use.
- Gabapentin: Applied in specific cases for pain management.
- Ketamine: Effective for pain and sedation under medical supervision.

In addition, the use of nonpharmacologic methods of pain control, such as psychological and physical methods, is recommended. These are relevant, inexpensive, and safe. They should be available to all patients. These include preparing the child for surgery by explaining the procedure, talking, distraction, visualization, and relaxation. Relaxation involves learning deep breathing, correct posture, and gentle movement.

Postoperative pain management should begin even before anesthesia and surgery, at the premedication stage. Such action is referred to as pre-emptive analgesia. In premedication, analgesics may be ordered in addition to sedative drugs. This approach is particularly useful in children admitted to the hospital due to trauma or those scheduled for a short, painful procedure. To reduce perioperative stress in elective procedures, multimodal analgesia is recommended according to the analgesic ladder. This involves starting with the combination of non-steroidal anti-inflammatory drugs (e.g., ibuprofen or ketoprofen in older children) and paracetamol or metamizol, both in the highest permissible doses. These drugs work synergistically by utilizing different mechanisms; therefore, they should be administered together in saturating doses.

The preferred route of administration for these drugs is intravenous and/or rectal, which is particularly suitable for the youngest children. Another important element of pain therapy is the intravenous administration of long-acting opioids, such as morphine, at the end of surgery. However, its administration after surgery completion is delayed and less effective due to the pharmacodynamics of the drug.

The main principles of proper postoperative pain management in children include:

- Regular assessment of pain intensity at least three times a day.
- Administering analgesics at even intervals consistent with their duration of action or by continuous infusion.
- Additionally, prudent choice of route of administration is critical, with an absolute prohibition on intramuscular injections.
- There should be a good knowledge of adverse reactions to analgesics used and the ability to treat them promptly.
- Multimodal analgesia is encouraged, combining local anaesthetic techniques (such as intrathecal Anesthesia of the wound margins or surgical site, or continued regional Anesthesia of the extremities or central blocks) with pharmacological treatment using non-opioid analgesics and opioids, if necessary.

9.3 Fluid therapy in the postoperative period

In the postoperative period, the most commonly used fluids in children are lactate Ringer's fluid, multi-electrolyte fluids such as Optilyte and Sterofundin, and multi-electrolyte fluid with glucose, such as Benelyte.

Paediatric fluids, specifically mixtures of glucose 5% with NaCl 0.9% in the ratio 2:1 and 1:1, should not be routinely used as they are hypotonic fluids. These fluids reduce plasma sodium concentration (Na), thereby decreasing its osmotic pressure. This reduction leads to water escaping from blood vessels to tissues, including the brain. The glucose content in these fluids is rapidly metabolized, further increasing the amount of free water in circulation and intensifying the associated effects, which can result in brain edema and electrolyte disturbances in children.

Fluid requirements in the postoperative period depend on the child's age and are significantly lower due to increased secretion of antidiuretic hormone. These requirements are outlined in Table 13. It is recommended that dosing be calculated by 10 a.m. the next day.

Table 13: Fluid requirements in the postoperative period

Age Group	Amount of Liquids
Newborns	0.7 ml/hr/day up to day 10
Infants	6 ml/kg/hour
Children 1-2 years	4 ml/kg/hour
Children 3-5 years	3-4 ml/kg/hour
Children 6-10 years	3 ml/kg/hour
Children over 10 years	2.5 ml/kg/hour

9.4 Documentation and Additional Notes on the Postoperative Period

All recommendations and a description of the patient's condition after surgery should be entered into the records. Orders, in addition to the written form, should be verbally communicated to the Postoperative Subdivision (POP) staff receiving the child.

The patient’s condition should be documented as precisely as possible before transfer from the POP to the medical ward. This documentation is based on the post-anesthesia care sheet completed in the post-operative care unit at specific time intervals (usually no longer than every hour) by nurses under the supervision of a physician. Necessary items to include in this chart are blood pressure, heart rate, number of breaths per minute, Hb saturation (pulse oximetry), diuresis, type and amount of fluids given, medications administered, body temperature, level of consciousness/awareness, oxygen therapy (type of method and flow of oxygen delivered).

It is also essential to record all episodes that occurred and were treated in the POP. Additionally, an observation chart is established for venous and arterial accesses and other elements of continued therapy, such as infusion pump drug infusions and evaluation of access points like epidural or subarachnoid catheters for continued analgesic administration.
The duration of the child's stay in the POP depends on the type of anesthesia performed and the child's general condition. The following guidelines apply:

- A minimum of 30 minutes after general, intravenous, or regional anesthesia when the patient is breathing efficiently on their own.
- A minimum of 45 minutes after general anesthesia with endotracheal intubation while connected to a ventilator.

The decision to discharge a patient from the post-operative ward is made by the anesthesiologist, who confirms this with a signature in the documentation (post-operative ward anesthesia care sheet). If the child's clinical condition requires transfer to the intensive care unit, the decision is made by the anesthesiologist or POP physician, in agreement with the ICU physician on duty.

Criteria for Transferring a Patient to the Home Unit:

- The patient scores at least 9 on the Aldrete scale, assessed twice no less than 30 minutes apart.
- There are no signs of active bleeding from the surgical wound.
- Postoperative recommendations have been fully completed.

Documentation of patient assessment prior to transfer from POP to the ward: Aldrete Scale (Table 14)

Table 14: Assessment of patient status before transferring from the operative block - Aldrete scale

Criterion	Points (Pkt)	Study
Moving the limbs	2	Moves all
	1	Moves two
	0	Does not move
Breathing	2	Deep, efficient
	1	Cough, dyspnea, shallow breathlessness
	0	No breathing
Circulation	2	RR ± 20 mm Hg from baseline
	1	RR ± 20-50 mm Hg from baseline
	0	RR < ± 50 mm Hg from baseline
State of consciousness	2	Conscious
	1	Wakes up on command without reacting
	0	Unresponsive
Skin color	2	Normal
	1	Pale, blotchy, yellowing
	0	Cyanosis

Postoperative orders on the Post-Operative Phase (POP) are written by the anesthesiologist. After the patient is transferred to the home department, the treating physician continues or modifies these orders. This division is designed to ensure responsibility for treatment and patient safety remains consistent within the POP. It also prevents the possibility of conflicting postoperative orders being written by different specialists.

The transfer from the POP to the home ward includes a brief description of the patient's condition by the anesthesiologist. The condition is described in terms of consciousness, logical contact, cardiorespiratory efficiency, absence of fever, and the lack of need for oxygen therapy.

The post-anesthesia care sheet for the post-operative ward requires authorization from the transferring physician, including their signature and stamp, as well as authorization from the nurse.

Photograph 19: A group of students in the operating theater of the Department of Pediatric Surgery, UDSK in Bialystok, 2021.

In summary, Anesthesia is a major intervention in the metabolism and homeostasis of the child's system. Constant observation, monitoring of heart and respiratory function, assessment of consciousness, warming, and maintenance of appropriate body temperature of the child, supplementation of fluids, and ensuring painlessness after the procedure are the tasks of both the operating theatre team during Anesthesia and the POP team.

Their duties also include ensuring the efficiency of the equipment, use of high-quality equipment and drugs, and gaining qualifications and experience when the whole team, including the anaesthesiologist and anaesthetic nurses, collaborates. Such measures help to minimize the risks associated with Anesthesia. However, there is no completely safe method of Anesthesia, and therefore the accepted rules and standards should be followed. Particularly, care should be taken to ensure training and acquisition of both theoretical and practical knowledge.

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From the Reviewers of the Monograph: *Principles of Anesthesiological Management in Children*

The basis of pediatric anesthesiology is a thorough understanding of the anatomical and functional peculiarities of childhood, which the authors present in a concise yet comprehensive manner. They discuss the preparation of children for general anesthesia, providing clear criteria for eligibility and disqualification, premedication strategies, and general anesthetic principles for intubation and ventilation. Additionally, the authors address intraoperative and postoperative pain management, including regional anesthesia, treatment techniques, and pharmacological interventions. An essential section of the paper is devoted to the current documentation of anesthesia, aimed at improving the safety of both patients and therapists. The text also covers fluid therapy, blood product management, and protocols for cases of sudden cardiac arrest.

The authors provide practical and accessible knowledge essential for working with children in anesthesia. This monograph, primarily targeted toward students, addresses an existing gap in the field. It is also a valuable resource for novice anesthesiologists and physicians of other specialties who work with pediatric patients undergoing anesthesia.

Prof. dr hab. n. med. Wojciech Dębek

The monograph is a highly valuable initiative, intended to provide medical students with a comprehensive resource to distinguish between anesthesiology practices for adult and pediatric patients.

The chapters clearly outline the fundamental principles of preparing a child for surgery under general anesthesia. Topics include pharmacological and alternative premedication methods, induction and maintenance techniques, and regional anesthesia. A dedicated chapter addresses postoperative care, with a focus on the critical subject of postoperative pain therapy.

In my view, the monograph comprehensively addresses the most critical aspects of pediatric anesthesiology, tailored to the needs of medical students. It undoubtedly fulfills its educational objectives.

Marzena Zielińska, MD