

Post-Operative Anesthesia in Newborns with Congenital Defects

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Abstract Pain perception in newborns is physiologically mature, and painful stimuli can significantly affect cardiovascular, respiratory, and metabolic stability. In neonates with congenital anomalies requiring surgery, inadequate assessment or management of postoperative pain can lead to cardiovascular instability, respiratory distress, hypoxia, stress-induced hormonal responses, and even long-term neurodevelopmental consequences. This review analyses modern strategies of postoperative analgesia in neonates, including multimodal approaches, pharmacological and non-pharmacological methods, and safety considerations. The paper discusses current pain assessment tools for newborns, individualization of dosing, and rational combinations of opioid and non-opioid agents. Based on recent clinical guidelines and evidence-based practices, optimal algorithms for postoperative pain management in neonates with congenital malformations are presented.

Keywords Newborn, Congenital anomaly, Analgesia, Postoperative pain, Multimodal therapy, Neonatal care

1. Introduction

Congenital malformations are one of the main causes of morbidity and mortality in infancy worldwide, with approximately 6 out of every 100 births having congenital malformations, and they occupy a high proportion of deaths in the 28-day period of newborns, which is especially pronounced in low and middle-income countries [34].

In congenital heart defects, abnormalities of musculoskeletal, digestive, and other systems, anatomical changes occur, requiring various surgical interventions. Operations performed in the neonatal period have a high risk due to the limited physiological reserves of the patient, the fragility of thermoregulation, respiratory, and hemodynamic systems. Effective and safe pain relief in the postoperative period is important in terms of preventing infections, increasing ventilation efficiency, and improving long-term neurological outcomes. Otherwise, if adequate analgesia is not provided, cardiac and pulmonary dysfunction, hypoxia, as well as various metabolic disorders may be observed [1]. The mechanism of neonatal pain is complex in development, and the processes of their peripheral and central nervous system have functions similar to those of adults, and the pharmacokinetics and pharmacodynamics of drugs differ significantly in newborns. For example, the volume of fluid in the neonatal organism is higher than in adults, liver and kidney metabolism is intensive, and the properties of blood circulation and the mechanism of action of drugs are different,

which complicates the selection and dosage of analgesics. Morphine, fentanyl, and other opioids require fine doses and monitoring due to differences in the levels of metabolism and excretion in the neonatal organism. Therefore, it is necessary to select medications individually, taking into account age-appropriate pharmacokinetic properties [14]. Evaluating postoperative pain in the neonatal period is also a specific problem, as infants cannot subjectively express pain, and therefore assessment systems based on objective and semi-objective criteria such as facial expression, changes in respiratory movements, heart rate, and oxygen saturation are used. In world practice, there are several evaluation scales, which are recommended for mandatory use to check the effectiveness of clinical procedures and therapy. At the same time, in practice, there are cases when pain assessment is not carried out through constant and systematic monitoring, which leads to analgesia deficiency [24].

The focus of modern approaches is on reducing opioid demand and limiting side effects through multimodal analgesia and regional blockades. Recent studies and clinical experience show that properly performed regional anesthesia reduces the need for postoperative analgesia in the neonatal period and can reduce the risk of respiratory depression, but these methods require the anatomical and physiological characteristics of the patient, as well as safety measures and special monitoring during implementation [21]. In this context, it is important to systematically review the strategies of postoperative anesthesia in newborns, in particular in patients who have undergone surgery for congenital malformations, including the selection and dosage of drugs in accordance with age, weight, organ maturity and surgical

invasiveness, the integration of multimodal and regional approaches, as well as the introduction of reliable pain assessment and monitoring protocols. This review article aims to analyze the latest literature in this field and recommend safe and effective postoperative analgesia algorithms.

2. Research Objective

Studying the possibilities of safe management of pain syndrome and reduction of side effects by increasing the effectiveness of postoperative anesthesia in newborns with congenital anomalies, applying the principles of multimodal analgesia.

3. Materials and Research Methods

Scientific articles published between 2015 and 2025 through the databases PubMed, Scopus, ScienceDirect, Google Scholar, and eLIBRARY were analyzed. In the search process, keywords such as "neonatal postoperative analgesia," "congenital anomalies," "newborn surgery," "multimodal analgesia," "regional anesthesia in neonates" were used.

The analysis included clinical studies, international recommendations, and meta-analyses devoted to methods of postoperative anesthesia in newborns. Among the sources, the practical recommendations of the WHO, the American Academy of Pediatrics (AAP), and the European Society of Anesthesiology (ESAIC) were also studied. In total, more than 120 articles were reviewed, of which 52 were selected. The obtained data were systematically analyzed according to pharmacological, regional, and non-pharmacological approaches to pain relief.

4. Main Part

Pharmacological agents play a central role in reducing postoperative pain in newborns. Although the physiological mechanisms of neonatal pain are similar to those of adults, the pharmacokinetics and pharmacodynamics of drugs have significant differences. Therefore, the choice of medication, dosage, and method of administration should be evaluated individually [2].

Opioid analgesics are among the main drugs used to control pain in the postoperative period, and below we will discuss in detail their use, indications and contraindications, as well as possible side effects.

Morphine is one of the most studied opioid drugs in newborns and is used mainly for pain after severe surgical interventions, especially in surgeries on cardiovascular and abdominal organs. Morphine suppresses pain by acting on central μ -receptors, but can cause complications such as weakening of the respiratory center, bradycardia, and slowing of intestinal peristalsis. Therefore, it is recommended to use it in a minimal effective dose with constant monitoring of respiratory rate and saturation [16].

Fentanyl is 50-100 times stronger than morphine and has a shorter duration of action. It quickly reduces pain, stabilizes cardiac output, and improves hemodynamic status, which allows for its widespread use in cardiac surgery. At the same time, high doses of fentanyl can cause paralysis of the chest and abdominal muscles involved in respiration, therefore it is advisable to use a titrated infusion method [10]. Another drug with a similar mechanism of action is remifentanyl, which is a very short-acting opioid and is rapidly broken down by plasma esterases. Therefore, it is preferable for short-term operations or when dosing is necessary as needed. Remyfentanyl weakens the respiratory center less, but in cases of overdose, it can cause arterial hypotension [18].

Along with opioid analgesics, non-opioid agents are widely used in the postoperative period, and paracetamol is one of the safest non-opioid agents in the treatment of neonatal pain. It effectively inhibits the synthesis of central prostaglandins in mild and moderate pain. To alleviate pain in newborns, paracetamol is recommended to be administered intravenously at a dose of 10-15 mg/kg every 6 hours. Studies have shown that the combination of paracetamol with opioids can increase the analgesic effect and reduce opioid consumption by 30-40% [5].

Ketamine, as an NMDA receptor antagonist, reduces pain through central sensitization. It increases stroke volume, maintains stable blood pressure, and can be used in severe hemodynamic conditions during the neonatal period. It has been found in various observations that a low-dose ketamine infusion, when used in combination with opioids, better controls pain and reduces respiratory depression [27]. In addition, lidocaine is a pain reliever and has a mild sedative effect, reducing central sensitization. Studies have shown that lidocaine infusion reduces opioid demand after severe surgery [17].

Ibuprofen and other NSAIDs are used with extreme caution in the neonatal period, as they reduce renal blood flow and can cause premature closure of the ductus arteriosus. Therefore, these drugs are mainly used in special cases to close ductus arteriosus, but for non-analgesia purposes [28].

In recent years, the multimodal analgesia approach in pediatric anesthesiology - that is, the combined use of opioid and non-opioid agents - has been widely used as a highly effective method. This method allows for timely pain control, reduces the toxic effects of drugs, and shortens the recovery period. Meta-analysis shows that the use of multimodal anesthesia reduced respiratory complications by 25%, changes in heart rate by 30%, and recovery time by 18% [30].

In turn, regional anesthesia is an important component of the anesthesia used in newborns, which blocks pain impulses through the central nervous system and reduces the need for opioids. In recent years, this approach has been considered a key element of the multimodal analgesia strategy in neonatology [7]. Caudal epidural anesthesia is one of the most widely used methods of local blockade in newborns, which stops pain impulses at the level of the lumbosacral segments and is effective in postoperative pain in the abdominal cavity, lower segments, and pelvic organs.

Studies have shown that caudal blockade not only reduces pain but also stabilizes heart rate and reduces opioid demand by 35-50% [25].

The most commonly used local anesthetics for caudal blockade are bupivakaine (0.125-0.25%) or ropivakaine (0.2%), whose duration of action is 4-6 hours, and ropivakaine is used as a drug of choice due to its low risk of cardiac toxicity [31]. It was also found that caudal blockade is more accurate and safer when performed under ultrasound control, and needle placement errors are reduced by up to 10 times [12].

Thoracic or lumbar-epidural anesthesia is widely used in complex and prolonged surgical procedures in newborns, such as thoracotomy, diaphragmatic hernia, and abdominal reconstruction. Continuous epidural infusion helps maintain hemodynamic stability by suppressing central pain impulses [33] epidural catheters are usually placed through segments L3-L4 or T10-T12. It is recommended to use low concentrations (0.1-0.125%) of bupivakain or ropivakain at an infusion rate of 0.2-0.3 mg/kg/hour. Studies have shown that epidural anesthesia reduces pain scale scores by 40% and significantly decreases the need for additional analgesics within 12 hours after surgery [19]. However, it is considered that epidural anesthesia should be performed only by a specially trained doctor and under cardiomonitoring conditions, and the infusion rate is reduced in cases of arterial hypotension, bradycardia, or decreased cardiac output.

At the same time, in newborns, ilioinguinal, transvers abdominis plane (TAP), femoral, or penile peripheral nerve blockades are effective in post-small-scale postoperative pain, and in TAP blockades, the need for opioids is reduced by up to 40% by blocking the nerves passing through the abdominal wall [29]. Penil nerve blockade is a widely used technique in practices such as circumcision or urinary tract reconstruction, which can completely eliminate the need for central opioids such as morphine or fentanyl [15].

The use of ultrasound control for all regional methods increases safety and helps determine the correct location of the anesthetic. In the 2022 meta-analysis, it was found that ultrasound blocks reduced the number of complications by 45% compared to traditional techniques [15]. During each operation, it is necessary to constantly monitor heart rhythm, respiratory rate, and oxygen saturation. The recommendations of ESAIC (European Society of Anaesthesiology and Intensive Care) for 2021 emphasize that all neonatal local blockades should be performed under ultrasound control and with the participation of experienced specialists [8].

Along with pharmacological methods, non-pharmacological approaches are also important in reducing postoperative pain in newborns. Such methods reduce the need for medications, help control pain at the physiological level, and ensure the patient's psycho-emotional stability [3]. Since the assessment of neonatal pain is subjective, scales based on special visual and physiological indicators in newborns have been developed, and Premature Infant Pain Profile (PIPP-R), Neonatal Infant Pain Scale (NIPS), and COMFORTneo Scale are most commonly used in practice. These scales assess the patient's condition based on changes in respiratory rate, heart rate,

facial expressions, hand-movement reactions, and oxygen saturation [23]. Studies show that regular pain assessment reduces drug intake and the frequency of complications associated with later pain outcomes [20].

In newborns, a sharp change in body temperature intensifies pain, increases the release of stress hormones, and disrupts heart rhythm. Therefore, maintaining thermoregulation in the postoperative period, reducing heat loss, and maintaining an optimal temperature of 36.5-37 °C in the incubator are considered physiological factors that reduce pain [4]. Additionally, it has been proven that a soft supporting position, wrapping with a sheet, and a state of free breathing reduce pain and stress [6]. At the same time, skin-to-skin contact, i.e., placing a newborn on the mother's chest, is one of the proven non-pharmacological methods of reducing pain and stress reactions, which stabilizes heart rate, increases oxygen saturation, and reduces cortisol levels [11]. In addition, the method of music therapy has also been widely studied in the postoperative period. Playing light rhythmic music in the background reduced pain assessment scores by 20-25%, slowed heart rate, and reduced oxygen consumption [13]. Today, stimulation of the sucking reflex is also used as a mechanism for pain reduction. Oral stimulation with a sugar solution (24% glucose) or breast milk during painful manipulations, such as catheter insertion, venous puncture, reduces cortisol release and pain assessment scores [22].

Studies have shown that parental involvement, voice calming, and maintaining communicative contact through touching the baby reduce stress and shorten recovery time. In the 2022 randomized follow-up, the pain scale scores in the group of infants with active parental involvement were 30% lower, and the heart rate was 15% more stable [9]. In particular, the use of non-pharmacological methods in combination with pharmacological analgesia is an integrated multimodal approach, which is the most effective analgesia strategy in newborns. This approach reduces the toxic effects of analgesics, increases physiological stability, and accelerates the recovery process [32].

5. Conclusions

Postoperative anesthesia in newborns with congenital anomalies is one of the most important clinical problems of modern neonatology and pediatric anesthesiology. Effective management of pain syndrome contributes to ensuring hemodynamic stability in newborns, supporting the healthy development of the central nervous system, and reducing the recovery time after surgery.

When using pharmacological agents, it is necessary to take into account the intensity of pain, the child's age, body weight, and physiological condition. Opioid drugs are the main remedy for severe pain, while non-opioid drugs have a complementary and reducing toxic effect. At the same time, the use of drugs in titrated, individual doses is considered important from a safety point of view. Local anesthesia methods, in particular caudal, epidural, and peripheral nerve blockades, significantly reduce pain and ensure cardiovascular

stability by reducing the need for opioids, and, of course, ultrasound-controlled blockades increase accuracy and reduce the risk of complications.

Non-pharmacological approaches, namely pain assessment systems, maintaining a thermal environment, skin contact with parents, music therapy, and stimulating the sucking reflex, help reduce pain naturally, improving the patient's emotional state and reducing the stress response. Thus, in order to further increase the effectiveness of anesthesia, measures for the widespread introduction of an individualized dosage model of drugs, a new generation of analgesics, safe monitoring systems, and non-invasive pain assessment technologies are relevant.

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