Chapter

Spinal Anesthesia in Pediatrics

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Abstract

The survival of preterm newborn patients (PNB) depends in a great extent on the anesthetic technique used. Spinal anesthesia (SA) is considered the best-tolerated regional anesthetic method for highly unstable newborn infants (NB) with high risk of complications during the perioperative period. SA has been recommended for children at high risk for postoperative apnea due to general anesthetics or prematurity. Bronchopulmonary dysplasia (BPD) in the newborn is a disease that accompanies the patient to the operating room with a high incidence of mortality. SA in emergency surgery is a well-tolerated anesthetic procedure with proven effectiveness, with less hemodynamic and respiratory repercussions. At the same time, it produces greater protection against surgical stress in the NB weakened by the premature condition. Hemodynamic stability remains constant even in the newborn with heart disease.

Keywords: spinal anesthesia, regional anesthesia, newborn

1. Introduction

The 8% of PNB require surgery to correct an organic birth defect in the first hours or days after birth. BPD in PNB is a serious disease with high mortality rates, which produces significant respiratory fragility with repercussions on the general condition of the patient. General anesthesia (GA) produces cardiovascular and hemodynamic changes that prolong intubation for hours or days after surgery, which complicates the underlying respiratory problem. Inhaled anesthetics, hypnotics, intravenous agents, and muscle relaxants can prolong and worsen the awakening of the NB.

In recent years, a large number of published articles have tried to demonstrate the existence of anesthetic agents that cause brain damage mainly in immature organs of preterm infants. The fundamental premise for the administration of anesthetics is their reversibility, which implies that the brain, spinal cord and peripheral nerves are anatomically and physiologically the same before and after the administration of any anesthetic agent. Therefore, the pediatric anesthesiologist faces the dilemma of which anesthetic agents cause less neurocognitive damage. An alternative to the problem of neurocognitive damage is spinal anesthesia, because local anesthetics (LA) produce a neuroprotective effect on the central nervous system, with minimal physiological changes [1].

The most frequent surgical procedures in the NB are inguinal hernia repair, duodenal atresia, pyloromyotomy, myelomeningocele repair, and imperforate anus repair. In most of these urgent surgical procedures, SA helps us to solve the surgical procedure with proven efficacy and safety. Hemodynamic stability remains constant even in PNB with heart disease, in non-cardiac surgery [2].

2. Neurocognitive damage

The neurocognitive damage produced by the use of anesthetic agents in immature brains has been well demonstrated in laboratory animal models. The effect of general anesthetics on brain development in children under three years of age can have an impact on the later life of the child. Modifications that have resulted in serious behavioral and memory changes in experimental animals. It is suspected that a similar situation could occur in children who manifest learning disabilities at school age. However, other variables must be taken into account, such as prematurity itself, and concomitant diseases such as seizures, prolonged ventilation in the neonatal intensive care unit, repeated and chronic administration of multiple medications and surgeries. The evidence of such harm in humans, with general anesthetics such as intravenous, hypnotic, and inhaled has been much more difficult to demonstrate. Until today there are two important concepts regarding accelerated apoptosis damage in immature organs; the damage is directly related to the dose and duration of exposure.

The combination of regional anesthesia and general anesthesia makes it possible to reduce the intraoperative exposure of general anesthetics and they are a good alternative for immature NBs. The concept of reversibility of anesthetics is being questioned [1, 3, 4].

3. Benefits of spinal anesthesia

3.1 Cardiorespiratory stability

SA is considered the best-tolerated anesthetic method for cardiovascular unstable NBs. In preterm and ex-preterm with congenital heart disease, SA has shown good stability in systolic, diastolic, and mean arterial pressure, due to the absence of arterial hypotension secondary to sympathetic blockade as observed in adults. The same occurs with the management of respiratory diseases such as BPD. Most NBs show a very low incidence of postoperative complications. Even those weakened NBs are able to maintain spontaneous breathing during surgery, avoiding intubation of the trachea and subsequent mechanical ventilation [5].

3.2 Hemodynamic stability

Spinal anesthesia produces a thoracic and lumbar sympathetic block and therefore vasodilation below the level of the block. However, due to the incomplete sympathetic innervation in children under eight years of age, SA is characterized by excellent hemodynamic stability that does not require prior administration of intravenous fluids or the use of vasopressors. The blood volume in the capacitance vessels of the lower limbs is less. However, when SA is administered with GA, hemodynamic stability is considerably modified due to the pharmacological action of general anesthetics. In the newborn with congenital heart disease, SA is preferred over GA, which produces minimal cardiovascular changes [6].

3.3 Short stay in the post-anesthesia care unit

Respiratory complications in the post-anesthesia care unit (PACU) are more common with the use of inhaled anesthetics, intravenous or opioids, concerning SA, especially in preterm or ex-preterm patients who are susceptible to relatively frequent periods of apnea and respiratory depression. GA and opioids are considered predictors of a longer stay in the PACU. SA has been the most important factor that has reduced the length of stay in the PACU [7].

3.4 Rapid recovery of gastrointestinal function

The restoration of intestinal function after gastrointestinal surgery in the newborn child, with postoperative ileus, has been rapid with SA compared to AG. A situation that is especially important in necrotizing enterocolitis and gastroschisis surgery during the neonatal period. Opioids administered during GA contribute to increased ileus.

Spinal anesthesia facilitates early restoration of intestinal peristalsis. The vasodilator effect of the blockade increases splanchnic perfusion and peristalsis, favoring the rapid restoration of the oral route [8].

3.5 Hypoxia

Most of preterm patients, especially the severely preterm, which is susceptible to a decreased response to hypoxia, and with it, the risk of apnea and perioperative hypoxia. Airway management is complicated in patients with hydrocephalus and Arnold-Chiari syndrome type II, a pathology that occurs in children with lumbosacral myelomeningocele. Other craniofacial syndromes that present with mandibular hypoplasia condition a complicated airway. SA has shown advantages over GA in children with myelomeningocele [9]. SA is particularly important to reduce the risk of postoperative apnea in high-risk NBs and allows a low incidence of respiratory complications [10].

3.6 Response to surgical stress

The degree of stress derived from surgery and anesthesia is directly related to the quality of postoperative analgesia, especially in children with comorbidities. Hormones related to the stress response, such as epinephrine, norepinephrine, cortisol, ACTH, prolactin, and blood glucose levels, are produced in lower amounts after SA due to an interruption in the transmission of pain in the afferent and efferent nerve pathways. These hormone values return to their preoperative baseline values within 24 hours [11].

3.7 Immune response

The immune response is stimulated by LA. It is well known that trauma and surgery favor susceptibility to infection due to immune suppression. Opioids

1.	Cardiorespiratory stability in preterm
2.	Short stay in the neonatal care unit
3.	Quick recovery of gastrointestinal function
4.	Less response to surgical-anesthetic stress
5.	Hemodynamic stability
6.	Accelerates awakening
7.	Postoperative analgesia
8.	Good immune response
9.	Quick onset of action

Table 1.
Benefits of spinal anesthesia.

also stimulate T lymphocyte activity, cell mediation, and antitumor immunity. Therefore, SA favors the immune response, allowing better possibilities of maintaining an adequate immune response to possible perioperative infections (**Table 1**) [12].

4. Anatomy

It is important to remember that the level of termination of the spinal cord depends on the age of the child. In the newborn, the spinal cord ends at L3, lower than in the adult. Therefore, it is prudent to do the lumbar puncture in the disc space between L4-L5 or L5-S1, below the termination of the spinal cord. Using the L4–5 or L5-S1 disc space is safe at this age. The intercrestal line or Tuffier's line can be used to determine the level of puncture since this line passes through these spaces.

During the first year of life, the dural sac regresses at the level of the adult and we find it at S1 and the spinal cord at the level of L1, which is the adult level. At this level, the depth to reach the subarachnoid space is 1 to 1.5 cm from the skin and 10 to 12 mm at one year of age. The volume of spinal fluid is 4 mL/kg, that is, twice that in adults [13]. The flexibility of the spinal column in children and the ease of touching and locating the intervertebral spaces facilitate spinal puncture [13].

Insufficient myelination and a weak layer of the endoneurium in the nerve tracts produce a weak and ineffective barrier for the diffusion of LA, which translates into a rapid onset of action. There are two other important factors to consider; a high cardiac output and a relatively wide vascularization, which help to maintain a short duration of action of SA [14].

5. Spinal anesthesia technique

The most common way to perform SA is to have the child seated with the back flexed. The assistant is responsible for firmly maintaining the sitting position and with the neck extended because flexion of the neck in very young children can cause moderate hypoxia. The child can also be placed in the slightly flexed lateral position. Avoid extreme flexion of the neck as it can also cause airway obstruction and cause hypoxia. A second assistant may be administering oxygen with a face mask. A 45-degree head tilt can help maintain increased CSF pressure, especially in children under one year of age. The depth of insertion of the needle is variable and was described in the anatomy section.

Ultrasound can help decide the puncture site, needle path, and needle depth. Today there are a variety and types of needles for spinal application; however, the most common is the pencil-point needle. The stylet of the needles is necessary to avoid the remote possibility of an epidermoid tumor. Needles 26 and 27 with a pencil point, for pediatric use with a length of no more than 50 mm, produce a low incidence of post-puncture headache [15]. The reflux of the CSF through the needle indicates that the placement of the needle is correct, and the LA should be injected within 20 seconds. Once the needle is withdrawn, the lower extremities should not be elevated because it can result in a high spinal block [14].

6. Clinical monitoring of spinal block

The clinical evaluation of the spinal block is practical during the entire surgical procedure, but especially during the first 10 to 20 minutes of its application, to detect possible complications associated with the technique or the LA used. Most of the immediate complications are due to errors in the dose of LA, generally higher than required. The unwanted effects of LA can be masked by the simultaneous combination of GA. In which case it will be more difficult to notice possible reactions to LA. If the child remains conscious, the side effects of SA can be detected quickly.

Verification of sensory block usually consists of loss of skin sensitivity to cold, gentle pinching or touch. The motor block is also installed progressively and immediately, depending on the type of LA applied. Bupivacaine produces a total motor block. While ropivacaine and levobupivacaine produce a motor block of less intensity. The level of motor block can be verified by gentle puncture of the extremities, hips, and upper abdomen or thorax, being better evaluated using the modified Bromage scale. In sedated children, electrical stimulation is better and a more reproducible method, however, it is not always possible to do [16].

7. Local anesthetics

The most commonly used LA are 0.5% bupivacaine and tetracaine, at doses of 0.3–0.6 mg/kg. Although ropivacaine and levobupivacaine are also safe and effective agents. Ropivacaine 0.5% at doses of 0.5–1 mg/kg, produce a good quality block. With ropivacaine, the motor block is significantly shorter and less intense than with bupivacaine. Levobupivacaine 0.5% at a dose of 0.3–1 mg/kg, is also used clinically with a less intense motor block, similar to ropivacaine.

Bupivacaine, ropivacaine, and levobupivacaine are drugs that are broken down by enzymes in the liver. Therefore, they should be used carefully in PNB because they have a lower capacity to metabolize both anesthetics due to their immaturity [17]. Term NB metabolize LA well, but not preterm infants or patients with other comorbidities.

The duration of action of all spinal LA is one of the great limitations of using this route, since its duration is relatively short, it does not exceed 80 minutes in most of them. Postoperative analgesia is very short. For this reason, many clinicians have used so-called LA adjuvants such as adrenaline, morphine, or fentanyl, to prolong its duration. Most of them manage to extend the duration of action for a time no longer than 30%. However, their safety is questionable due to the possible toxicity of the adjuvants to the development of the spinal cord, which can be vulnerable. Intrathecal medications can allow the development of toxicity by altering the neuronal activity of the spinal cord [18–20].

8. Complications of spinal block

The complications of SA in children are similar to those in adults. However, the evaluation of signs and symptoms is difficult to identify, especially in NB or younger than one year compared to older children. Physiological and behavioral changes rather than verbal ones manifest their conditions.

The main complications of SA may result from the technique used or from the action of the LA itself. In general, the incidence of side effects is low and permanent secondary sequelae have not been reported in most clinical studies. They are shown in **Table 2** [14].

Complications include headache and low back pain, neurological complications, nausea, vomiting, and cardiorespiratory changes. Elevated levels of spinal block, above T4, reduce the expansion movement of the lower rib cage, decreasing intercostal muscle activity and paradoxical respiratory movements may occur.

Kokki 2000	Post-puncture headache
Puncuh 2004	Blockade failure, arterial hypotension, desaturation, airway obstruction, post-puncture headache.
Kokki 2005	Block failure, bradycardia, hypotension, desaturation, post-puncture headache
Imbelloni 2006	Blockade failure, bradycardia, hypotension, bronchospasm, and post-puncture headache
Williams 2006	Blockade failure, bradycardia, desaturation
Kachko 2007	Bradycardia, block failure, high block, apnea.
Ecoffey 2010	High spinal block

Table 2.
Complications of spinal block in children [14].

Monitoring of oxygen saturation and an oxygen source are necessary. Post-puncture headache is the most frequent complication, it has an incidence of 3 to 4%, even with the use of spinal needles 25–27, and the incidence increases with spinal needles number 22. The headache appears in the first 24 hours post-puncture and may be unilateral or bilateral. It worsens with changes in position from lying to sitting and some children may manifest nausea and vomiting, which may be accompanied by blurred vision, vertigo, and tinnitus. These symptoms usually disappear spontaneously in three to five days, and in some children, they can continue for several more days. Caffeine is the pain reliever of choice in children [21].

9. Spinal anesthesia and short-stay surgery

Another reason to prefer SA in the child is the low cost compared to GA, in addition to the rapid recovery from short-stay surgery and early return home. These advantages include a rapid recovery derived from the short duration of SA with rapid recovery of mobility of the lower extremities, and prompt restoration of the oral route, with a low incidence of postoperative nausea and vomiting [22].

10. Sedation

Sedation is often used in the child, for the application of the spinal puncture. The goal of sedation is to produce anxiolysis and to ensure that the child remains motionless during the lumbar puncture. Movement during puncture can cause significant trauma to neurovascular structures. Midazolam, ketamine, propofol, dexmedetomidine, or inhaled sevoflurane can be used. However, any of them can be associated with periods of apnea. The safest are inhaled agents like sevoflurane. Dexmedetomidine produces a natural sleep state and produces anxiolysis and analgesia. Sedatives should be avoided in preterm, weak or high-risk newborns [15].

11. Discussion

SA has been used for a variety of surgical procedures, including inguinal hernia, exploratory laparotomy, omphalocele, and gastroschisis repair, multiple orthopedic procedures mainly of the lower extremities, pylorotomy, and surgery of the anus, bladder, and penis. Epidemiological data show that newborns have a higher risk of complications associated with GA. In multiple studies, the technique that has shown efficacy and safety and that has avoided the use of general anesthesia in the group of preterm, ex-preterm, or high-risk patients has been SA. Most clinicians prefer SA because it is associated with great respiratory and cardiovascular stability, allowing greater survival for newborns. In large study populations on the usefulness of SA, it has been shown that oxygen desaturation of <90% is rarely observed, and < 5% of newborns require supplemental oxygen, although neonates are notoriously susceptible to present hypoxia in response to external stimuli such as surgical stress.

The incidence of apnea in the NB in the first 12 hours postoperatively associated with GA, ranges between 10% and 30%. This seems to be directly related to prematurity and general anesthetics, 70% of apnea is of central origin, 10% obstructive and 20% combined. To the multiple advantages of SA in children, we can add postoperative analgesia with a short hospital stay, a lower cost for the hospital, and a lower incidence of mechanical ventilation after surgery [14, 15, 17, 23].

12. Conclusion

SA in experienced hands has allowed the survival of the preterm or high-risk newborn in a surprising way. The anesthetic technique of choice in children with concomitant diseases is SA, due to the many advantages. Allows for a quick recovery with minimal side effects. LA such as ropivacaine produce fewer motor changes after spinal block. Pencil point needles and ultrasound have greatly improved the side effects of EC.

Conflict of interest

The authors declare that they have no conflicts of interest.

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