Current Trends in Pediatric Regional Anesthesia

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Noemi Vicchio, Valeria Mossetti and Giorgio Ivani

10.1 Review of Current Trends in Pediatric Regional Anesthesia

The pediatric anesthesiologist copes with respiratory depression on a daily basis because the surgical pediatric patient is always a patient under general anesthesia. Avoiding the major respiratory depressant drugs and reassuring parents using an alternative approach is mandatory from an ethical viewpoint. In our center, the pediatric patient undergoing plastic, thoracic, abdominal, urological, and orthopedic surgery does so under locoregional anesthesia (LRA) whenever possible.

Generally, LRA allows a safer anesthesia and postoperative period, with earlier tracheal extubation, gastrointestinal function recovery, and discharge from the intensive care unit and from hospital [1]. In interventions with moderate-to-severe pain, a single injection is followed by the placement of a catheter for continuous peripheral or central nerve block. The orthopedic patient in particular benefits from the continuous infusion of local anesthetic, as this increases the effectiveness of motor physiotherapy.

LRA involves several not uncommon risks that should be taken into account, particularly by the pediatric anesthesiologist. These are: the puncture of critical structures; toxic levels of the anesthetic; and intravascular injection of local anesthetic.

Child anatomy varies widely, depending on the stage of bone growth, and the thickness and hydration of the subcutaneous tissue. The likelihood of damaging the surrounding structures and of accidental intravascular injection increase when blind techniques are used. The execution of a nerve block using ultrasound guidance has been shown to be safer than traditional landmark techniques [2–5]; indeed, it allows the visualization of variations in anatomical relationships while avoiding the puncturing of important structures, such as the pleura in the case of a supraclavicular or infraclavicular brachial block, and vessel puncture of a

G. Ivani (✉)
Division of Pediatric Anesthesiology and Intensive Care
Regina Margherita Children's Hospital, Turin, Italy
e-mail: gioivani@libero.it

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minor artery, such as the transverse cervical artery when a supraclavicular brachial block is used.

Children under 1 year of age are especially susceptible to the neurological and cardiac toxicity of local anesthetics, which in particular cause a reduced metabolism and hepatic blood flow. In addition, low levels of alpha-1-acid glycoprotein result in higher levels of pharmacologically active, unbound drug. It is then important to reduce the amount of local anesthetic being administered, and inject it slowly and with precise movements under direct visualization of the needle's tip. Latzke and colleagues demonstrated that the effective dose, 99% response volume of local anesthetic for sciatic nerve block was 0.10 mL/mm^2 of the cross-sectional nerve area [6].

Furthermore, studies have shown that ultrasound-guided nerve blocks lead to a reduction of 30–50% of the quantity of local anesthetic used to block, and therefore nerve blocks can be achieved with significantly smaller volumes of local anesthetics. Multiple nerve blocks can then be applied with the highest safety profile [2].

When executing a nerve block, general anesthesia can hide the early symptoms of systemic anesthetic toxicity. The poor sensitivity of both blood aspiration and test dose in anesthetized children increase the risk of unknown intravascular injection [7]. Ultrasound-guided techniques increase safety via direct visualization of the spread of local anesthetic around the blocked nerve or plexus. Independently of ultrasound guidance, to perform a safe block, it is essential to have continuous electrocardiographic and blood pressure monitoring, since the first signs of systemic toxicity are cardiac manifestations, in particular T-wave amplitude or ST segment changes; maintaining spontaneous ventilation is needed to detect the possible cessation of the respiratory drive [7]. Furthermore, all drugs and equipment necessary for the immediate management of possible complications must be available, the earliest of these to be used being lipid infusion [8].

In terms of the quality of intra- and postoperative analgesia, the execution of a block using ultrasound guidance has been shown to be much more effective than traditional techniques in terms of the quality of intra- and postoperative analgesia.

For upper extremity blocks, ultrasound-guided practice has been shown to cause a reduction in pneumothorax and inadvertent intravascular injection in children, albeit with some limitations. Bernards and colleagues recommended against performing interscalene blocks in anesthetized or heavily sedated adults or pediatric patients, because of the high risk of spinal cord injury as documented by case reports [9]; however, some authors disagree with these conclusions [10,11]. We cannot exclude that ultrasound guidance may eventually overcome this limitation, by verifying the site of the cervical vertebrae and with the direct visualization of local anesthetic diffusion; further studies are indeed needed. Furthermore, it is noteworthy that the interscalene brachial plexus block is associated with a 100% incidence of hemidiaphragmatic palsy and a low anesthetic volume appears to decrease the incidence only when performed at the level of nerve root C7 [12].

Supraclavicular and infraclavicular brachial plexus approaches are potentially dangerous blocks in children, whose anatomical structures are enclosed within small spaces; therefore ultrasound guidance permits their safer use in children [13,14]. Marhofer and colleagues recommend an infraclavicular approach instead of a supraclavicular one when there is a large dorsal scapular artery at the supraclavicular level or an infraclavicular approach with greater visibility [14]. The axillary brachial plexus block is a safe block also in traditional landmark techniques; however, it is difficult to block all the branches, including the muscolocutaneus nerve. Furthermore, the area is rich of vessel and there is a high risk of intravascular injection, even when every precautionary measure is taken. Ultrasound guidance helps in overcoming this aspect, while also allowing a dramatic reduction in the dose of local anesthetic used. It is worth bearing in mind that children have thin septa between the radial, median, and ulnar nerve, and thus a better anesthetic spread than in adult patients [15].

Before the diffusion of ultrasound guidance, an ilioinguinal/iliohypogastric block was associated with the use of high doses of local anesthetic and had a reputation for being difficult to perform, often with an unsatisfactory outcome. The blind technique with "fascial click," the technique most frequently performed by pediatric anesthesiologists, has a failure incidence of over 30%, which is not acceptable in modern anesthesia [16]. Weintraud argues that this high failure rate can be explained by the fact that the technique is based on studies conducted in adults. The high failure rate can then be explained by anatomical variations, a thicker subcutaneous layer, muscle development, and the incorrect distribution of local anesthetic [16,17].

The ilioinguinal/iliohypogastric block quickly became one of the most studied blocks with ultrasound guidance in pediatric patients, because of the obvious advantages. It has a 100% success rate when the targeted ilioinguinal/iliohypogastric nerves are visualized, reducing the volume of local anesthetic by six- to eightfold than that used in landmark techniques [18]. Such volume reduction means a reduction in the risk of toxicity but also in the risk of femoral palsy, an event possibly caused by excessive anesthetic spread that may delay ambulation and discharge [18].

Ultrasound-guided rectus sheath block, useful for midline surgical incisions and especially for umbilical hernia repair in children, is a simple and safe technique in which direct visualization avoids peritoneal, bowel, and mesenteric vessel puncture [3, 19]. This is valid also for the transversus abdominis plane (TAP) block, useful for abdominal surgical pain involving the T10–L1 nerves. In both cases, the identification of local anesthetic spread in the exact site increases pain control, both in quality and duration [20]. For rectus sheath block, the exact site through which local anesthetic has to spread is between the rectus abdominis muscle and the posterior aspect of the rectus sheath [3]. For TAP block, the local anesthetic has to spread between the transversus abdominis and the internal oblique abdominal muscle. In the study by Tran and colleagues [21], segmental nerves T10, T11, T12, and L1 were involved in the dye in 50%, 100%, 100%, and 93% of cases, respectively.

O'Sullivan and colleagues [22] reported that in penile block there was no significant difference between the ultrasound-guided technique versus the landmark technique, even if pain control in the pre-discharge stage was better with the former.

In order to increase safety, lower limb blocks should be chosen rather than central blocks, when possible. A large prospective French study showed that the incidence of complications related to pediatric LRA was very low (0.9/1000) and was related mainly to central blocks [23]. Moreover, unlike central blocks, peripheral blocks eliminate the risk of urinary retention, can be performed independently by coagulopathy, and limit the block to the surgical field.

In the case of lower limb blocks carried out using a blind injection, the block can appear incomplete [24] and ultrasound guidance, as shown by Oberndorfer and colleagues [5], increases the duration of sensory blockade when compared with nerve stimulator guidance, and prolongs the sensory blockade using smaller volumes of local anesthetic [5].

In pediatric patients and in particular in patients weighing less than 10–12 kg, visibility of the neuraxial structures is optimal when ultrasound is used. Being able to recognize the ligamentum flavum, dura madre, and epidural space is useful to confirm the correct positioning of the epidural catheter [25–27]. Another possible use of ultrasound guidance is to measure the angle and depth from the skin to the epidural space to guide the tip of the needle [28]. Rapp and colleagues [28] and Willschke and colleagues [29] positioned epidural catheters using real-time paramedian longitudinal probe position with reduction in bone contacts, faster catheter placement, and direct visualization of the local anesthetic spread. Limitations include the need for an assistant to handle the probe and the possible interference between the operator's hands, the needle, and the probe. Karmakar and colleagues used a real-time ultrasound-guided paramedian epidural access by means of a Tuohy needle/spring loaded syringe [30]. Perhaps this technique could also be piloted in children.

In caudal blocks, it is also important to detect the correct position of the needle to avoid intravascular or intrathecal injection, even if the risk is very low; therefore, ultrasound guidance has limited function in this context. However, in particular situations such as those involving obese patients or patients with a difficult anatomy, ultrasound guidance allows the identification of the sacral hiatus and the visualization of the cephalad spread [31].

Complications with ultrasound guidance are rare: the most frequent is the execution of an inadequate block; less frequent is nerve damage, which can be caused by a blunt needle of the correct size, but also by pressure injection of local anesthetic. A high injection pressure means that the needle is in an intraneural position, with high risk of severe and/or persistent neurological injury [32].

In addition to ultrasound guidance, known essential factors for reducing the risks and increasing the effectiveness of LRA are the levo enantiomer local anesthetics, ropivacaine and levobupivacaine, if possible combined with adjuvants. Levobupivacaine and ropivacaine compared with a racemic mixture have reduced cardiovascular and neurotoxicity. Additionally, a more selective sensory block tends to save the motor component [33–35]. The injection should be carried out slowly and after proof of aspiration, even if under ultrasound guidance. To increase safety, it can also be combined with adjuvants such as clonidine and ketamine to reduce the amount of local anesthetic to be administered and to extend the analgesic effect, with negligible side effects [36–45].

A balance between the efficacy of an anesthetic block and patient safety remains a major challenge for pediatric regional anesthesia. Ultrasound guidance is the main tool we have at our disposal and we need to disseminate the need for this fundamental technique.

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