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REVIEW ARTICLE

Safety in pediatric regional anesthesia

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Summary

The use of regional anesthesia is increasingly common in pediatric practice. This review reports the complications and risks in pediatric regional anesthesia. Few large studies reported incidence of complications. However, the different studies have shown that regional anesthesia, when performed properly, carried a very low risk of morbidity in appropriately selected infants and children. In addition, the use of ultrasound-guided peripheral nerve blockade has shown some promise toward increasing the safety profile of these already safe techniques.

Introduction

Pediatric regional anesthesia has attained wide use internationally because of its efficacy and safety; its use is supported by the existence of extensive data from the international literature (1–4). Safer drugs and dedicated pediatric tools are the keys to this success. This is so despite the fact that general anesthesia is necessary in most children for the regional block to be performed easily, safely, and effectively. Indeed, placement of regional blocks of all types under general anesthesia is considered the standard of care in pediatrics (5). A common logical argument is that there is less risk of injury when placing a needle in an immobile child than in one who is struggling or might move unpredictably.

The benefit/risk ratio is excellent especially for peripheral blocks, even when beginners perform them. All the regional blocks necessitate complete knowledge of the anatomic landmarks, and specialists in pediatric anesthesia should supervise the training in their performance in order to prevent repetitive errors. Despite its well-known benefits, clinical failures can occur during the application of regional anesthetic techniques. Ultrasound guidance has been shown to improve block characteristics, resulting in shorter block performance time, higher success rates, shorter onset, longer block duration, reduction in volume of local anesthetic agents required.

Performing a regional block may result in different complications, most of which could have been avoided by learning the correct technique, using an appropriate equipment, and applying the very basic safety rules.

General epidemiology of complications

Complications were rare and similar in both ADARPEF's studies (1,4). As reported in the literature, they were more frequent (four times in the recent ADARPEF study) in children aged <6 months that in children aged >6 months (Table 1). Central regional anesthesia has the highest incidence of complications (six times higher that peripheral). Moreover, their incidence remained low despite an increase in use in the last 12 years. Complications have not reached extreme severity, despite results from a UK audit (5 years, 10 633 epidurals performed) reporting permanent residual neurologic deficit in a child aged 3-month (1-year follow-up), two epidural abscesses, one case of meningism, one postdural puncture headache requiring active blood patching, and one drug error resulting in cauda equina syndrome (2). The UK audit also reported five cases of severe neuropathy/

Table 1 Incidence of complications according to the age (n = 41) (4)

Complications	0–30 days premature n = 121	0–30 days full term n = 475	1–6 months premature n = 822	1–6 months full term n = 2442	6 months to 3 years n = 10 499	3–12 years n = 12 974	>12 years n = 3799
% of studied population	0.4	1.5	2.6	7.8	33.7	41.7	12.2
Relative % of complications	2.4	2.4	7.3	17.1	17.1	39	14.6
% of complications in the group	0.8	1	0.02	0.3	0.06	0.13	0.05

radiculopathy resolving over a period of 4–10 months using pharmacological therapy in a Pain Clinic. The recent ADARPEF study records a very low overall morbidity for peripheral blocks, almost six times lower than that in central regional anesthesia. Despite two colonic punctures, it should encourage anesthesiologists to use peripheral rather than neuraxial (including caudal) blocks as often as possible when appropriate. The use of catheters does not seem to increase the occurrence of complications, even if cardiac toxicity following a secondary injection through a catheter was attributed to an inadvertent displacement of the catheter. Some complications (at least drug error, wrong side, lower limbs rising resulting in extended spinal blockade) were avoidable. In the recent ADARPEF study, local anesthetic toxicity resulted in one case of convulsions while the UK audit reported only two respiratory arrests and one seizure following central regional anesthesia. They did not require treatment with Intralipid as reported in a child (6). Some other complications (such as extended spinal anesthetics in two ex-premies, drug error and a part of cardiac toxicity) were probably also avoidable. The Pediatric Regional Anesthetic Network (PRAN) database did not report any permanent nerve injuries from blocks of any type, and one only case of transient dysesthesia following a sciatic nerve block that resolved within 6 months (3).

Large retrospective analyses of infections of epidural catheters have been reported in two series of children (7–9). The main risk factor are long-term catheter placement (≥3 days) (9), cancer, or acquired immunodeficiency syndrome patients. Fortunately, the authors confirmed that soft tissue infection manifesting as cellulitis and pus at epidural catheter exit is the main infectious complications with a good outcome. Several routes might be possible for the introduction of microorganisms into the epidural space. Infection might originated from the skin flora particularly if several attempts have injured the skin (10), hematological spread of bacteria, contamination of the local anesthetic solution, or direct contamination of the catheter during its insertion. However, the microorganisms cultured from the tips of the epidural catheters were most frequently *Staphylococcus aureus* and coagulase-negative staphylococci (11).

Complications of central blocks

Complications related to the technique

The technique of nerve/space location may produce complications. These include nerve damage, compressive hematoma, and definitive paraplegia, but also complications related to the medium used for the loss-of-resistance technique used to identify the epidural space, such as dilution and increase in the injected volume of local anesthetic if saline is used and headache, patchy anesthesia, lumbar compression, multiradicular syndrome, subcutaneous cervical emphysema, or embolism if air is used.

Epidural abscess, meningitis, arachnoiditis, radiculopathies, discitis, and vertebral osteitis have been reported following central blocks (2). Interposed bacterial filters are effective in preventing contamination of the local anesthetic solution. Inadvertent dural puncture with subsequent intrathecal injection of an epidural dose of local anesthetic results in total spinal anesthesia, the clinical expression of which is almost immediate respiratory arrest requiring rapid control of ventilation and, in adolescents, cardiovascular collapse. Subdural injection results in a delayed (20 min) and short-duration (60 min) block with an extensive distribution of analgesia (involving sometimes cranial nerves up to the fifth pair) but with no or minimal motor and sympathetic blockade. The injection of large volumes may result in excessive spread of the local anesthetic, which can reach distant nerves, or in too high levels of epidural/spinal anesthesia with subsequent respiratory failure because of intercostal muscle paralysis (above T4), or even in diaphragmatic paralysis (C4).

Finally, postdural puncture headache is a common complaint after spinal anesthesia in adults and has been reported to develop also in children under 10 years (12,13). Nonetheless, a much lower incidence and severity of postdural puncture headache in children have been reported during spinal anesthesia with a use of 24–29-G needles (13). However, epidural blood puncture with 0.2–0.3 $ml \cdot kg^{-1}$ of autologous blood is an effective treatment for severe and persistent headache in young children (14).

Complications of the catheters

Insertion of an epidural catheter can lead to several complications: misplacement, kinking, knotting, rupture (especially if attempts are made to withdraw the catheter through the epidural needle). Secondary migrations into the subarachnoid space, a blood vessel, the subdural space, or the paravertebral space are very rare. Leakage around the puncture point occurs in approximately 10% of cases, more frequently with smaller catheter (15), and inadvertent removal is not infrequent. Some pediatric cases of catheter infection have been reported. Complications, such as cutting and knotting, become apparent only on removal of the catheter; in most cases, they are directly related to the length of catheter introduced into the epidural space, which should not exceed 2–4 cm. The frequency of catheter-related complications has been noted to be as high as 11% in a pediatric series (15).

Complications of peripheral blocks

Complications related to the technique

When block needles are used blindly, they may damage a nerve trunk, especially when they are imprudently inserted. In addition, the use of ultrasound does not always show the tip of the needle, especially among beginners (16). Vascular lesions may lead to compressive hematoma. Other tissue lesions such as arterial wounds and pneumothorax can be produced by attempted peripheral nerve blocks, the presenting symptoms of which can be delayed by several hours.

Interscalene brachial plexus, lumbar plexus, and intercostal nerve blocks may lead to the same complications as with central blocks such as respiratory failure because of an epidural/spinal diffusion of local anesthetic or a diaphragmatic paralysis following an interscalene block.

Complications of the catheters

The indications of peripheral catheter insertion are fewer than those of epidural catheter. Most frequently reported complications with peripheral catheter involved mechanical problems as high as 20% (17).

Local anesthetic toxicity

Systemic

During the early phase of the introduction of regional anesthetic techniques into routine pediatric anesthetic practice, the safe doses of local anesthetics had not been determined and, as a result, numerous case reports of local anesthetic toxicity were published, including both convulsions and cardiovascular complications. However, safe dosing guidelines for the use of bupivacaine in newborns, infants, and children were issued by Berde (18). With widespread adherence to these recommendations, reports of systemic toxicity from overdose of local anesthetic seem to have almost disappeared, but no publication bias is possible. A much debated issue is whether larger doses can be permitted when using the more modern and less toxic long-acting local anesthetics, ropivacaine and levobupivacaine. However, it should be remembered that the quality of a block is only very rarely improved by the administration of more than the maximum recommended dose of local anesthetic. The use of ultrasound guidance is associated with the need for lower volumes of local anesthetic (Table 2), and may therefore improve the safety margin for systemic toxicity by the use of lower total doses of local anesthetic.

Local

Continuous peripheral nerve blocks have been proposed as an effective technique for postoperative pain relief and chronic pain therapy, particularly in small children. Only one clinical report has described myotoxicity induced by bupivacaine in a child scheduled for cataract surgery performed with peribulbar anesthesia (19), in contrast with a larger number of observations in adults. Bupivacaine-induced myotoxicity can be explained by mitochondrial bioenergetics alterations; lower toxic effects of ropivacaine compared with bupivacaine anesthetic-induced myotoxicity have been

Table 2 Reduction in local anesthetic volume with ultrasound guidance

Technique	Ultrasound guidance dosages ($ml \cdot kg^{-1}$)	Landmarks dosages ($ml \cdot kg^{-1}$)
Supraclavicular block (37)	0.3	0.5
Infraclavicular block (32)	0.2	0.5
Sciatic block (38)	0.2	0.3
Femoral block (38)	0.15	0.3
Rectus sheath block (39)	0.1 (each side)	0.3
Ilio-inguinal block (40)	0.1 (each side)	0.4

reported in young rats (20). The clinical impact remains to be evaluated in practice, and the need for a clinical evaluation of local anesthetic myotoxicity in young patients remains to be defined.

Safety rules for performing regional anesthesia

Patient monitoring

Monitors should be applied and in use before any block is performed. In particular, the electrocardiogram should be adjusted so that the P wave, QRS complex, and upright T wave can be seen clearly. Baseline systolic blood pressure and heart rates should be noted.

Skin preparation

Bacterial colonization of epidural and caudal catheters in children occurs at a rate of 6–35%. Gram-positive organisms are most common, though Gram-negative colonization may also occur, particularly with caudal catheters. Children under 3 years of age are also most likely to have colonization of caudal catheters. Despite high rates of colonization, serious epidural infections are exceedingly rare (2,9). Disinfecting the skin with an alcoholic solution has proved to be effective in decontaminating the transient skin flora (21), but not the deeply placed resident flora, which remains colonized even after skin disinfection. In addition, insertion of an epidural catheter should be performed under strict aseptic conditions with a daily observation of exit site while the catheter is in place and for 72 h after catheter removal.

Test dose

While placement of regional blocks under general anesthesia is considered standard practice in children, the search for the ideal 'test dose' to reduce the risk of inadvertent intravascular injection continues. The original 'test dose' described an increase in heart rate and blood pressure following intravenous administration of epinephrine 0.5 $\mu g \cdot kg^{-1}$. In children, these hemodynamic changes vary with the anesthetic agent used (halothane, sevoflurane, isoflurane, or propofol) and whether prior atropine has been administered. However, an increase in heart rate of 10 $b \cdot min^{-1}$ above baseline occurring within 1 min of injection is a reasonable sign of intravascular injection for children anesthetized with sevoflurane. Monitoring the ECG changes, i.e., $>25\%$ change in T wave or ST segment changes irrespective of the ECG lead chosen, is considered by some to be more specific and more reliable (22). In the PRAN database, positive test doses were detected in 0.6% of single injection and 0.7% of catheter blocks (3).

The specificity of these changes has been questioned recently as it seems that similar changes in heart rate and blood pressure may be seen following a painful stimulus (too 'light' anesthesia during the performance of the block or intraneural injection). The temporal relationship is important and a secondary drop in pulse rate detected after intravenous epinephrine distinguishes this from the response seen after a painful stimulus (23). Nonetheless, as no method of test dosing is infallible, incremental injection is a critical safety technique over a period of at least 60–120 s, irrespective of the type of block, with repeated aspirations, whenever large volumes of local anesthetics are injected (24). Direct visualization of the location of the needle tip and the injectate with ultrasound may provide additional or alternative confirmation of lack of iv injection (25).

Sympathetic tone

A clinically significant decrease in blood pressure related to sympathectomy from central neuraxial blocks is rare in children younger than 8 years of age (26), except in neonates following spinal block (27,28). Volume loading before such blocks, commonly practiced in adults, is unnecessary in this age group. In older patients, the sympathetic block results in a slight (20–25%) but consistent decrease in blood pressure. Even in adolescents, however, fluids or vasopressors are rarely required to treat the hemodynamic effects of central neuraxial blocks, excepted when clonidine is added to local anesthetics.

Contraindications

Contraindications are few and similar to those in adults. These include coagulopathy, infection at the needle insertion site, true local anesthetic allergy, and abnormal superficial landmarks or lumbosacral myelomeningocele because of the risk of malposition of the cord or dural sac. Progressive neurologic disease is a relative contraindication primarily because of medicolegal concerns. The safety of central neuraxial techniques in the presence of a ventriculoperitoneal shunt is discussed: indeed, the major risk of performing a caudal or epidural block in a child with a ventricular shunt device is not infection but modifications of intracranial pressure (29). Risks and benefits in these patients should be carefully considered on an individual basis.

Although it is rare to encounter opposition to the use of peripheral nerve blocks, certain conditions may call for a judicious avoidance of them. Relative contraindications include local infection, generalized sepsis, coagulopathy, risk of compartment syndrome, and parental or child dissent.

Impact of ultrasound on peripheral regional anesthesia on safety

A significant problem in regional anesthesia is that a large number of techniques still do not achieve a success rate close to 100%. Indeed, the key to successful regional anesthesia has always depended on the accuracy of needle and local anesthetic placement in relation to the nerve structures to be blocked. In 1994, Kapral introduced ultrasound guidance into regional anesthesia (30). Few years later, Marhofer introduced this technique into pediatric regional anesthesia practice (31,32). Real-time ultrasound guidance allows the demonstration of the target, whether it is a nerve, fascial plane, or anatomical space, and the monitoring of the distribution of the injected local anesthetic. Furthermore, ultrasound guidance allows the anesthesiologist to reposition the needle in the case of maldistribution of the local anesthetic. There is some evidence to support ultrasound for improving outcome in pediatric regional anesthesia (33).

Despite the theoretical advantages of ultrasound imaging during the performance of nerve blocks, no large prospective studies in pediatrics have so far been published in support of the notion that the use of ultrasound in fact does reduce the incidence of complications compared with alternative nerve blocking techniques. Because serious complications luckily are very rare following peripheral nerve blockade in infants and children (1,3), it is unlikely that even large-scale studies will prove ultrasound guidance to be superior to other approaches with regards to the rate of complications. However, it does not seem reasonable to expect that the use of ultrasound would result in an increased rate of complications.

Importance of proper education and training

The use of ultrasound to locate nerves is increasingly used in pediatric patients as it increases the speed of onset, reliability, and safety of peripheral nerve blocks. However, using this technique to identify the nerve is not a replacement for a good knowledge of the anatomy.

New data have emerged suggesting that the novice ultrasonographer makes repeated errors, the two most common being failure to visualize the needle tip during its progression into the tissues and unintentional movement of the probe. For this reason, the American Society of Regional Anesthesia (ASRA) and the European Society of Regional Anesthesia (ESRA) created a Joint Committee; the result was a document ‘to recommend to members and institutions the scope of practice, the teaching curriculum, the fellowship program and the options for implementing the medical practice of ultrasound guided regional anesthesia services’ (34,35).

Indeed, training in the use of ultrasound-guided techniques is not easy. Dedicated efforts must be made to allow the education of at least key individuals to attend focused training, so that these people can start to use and teach these techniques in their own institutions.

In conclusion, regional blockade in infants and children appears to have a very high degree of safety (36). The use of new technologies, such as ultrasound-guided regional anesthesia, has shown some promise toward increasing the safety profile of these already safe techniques. Thus, very reassuring data support the continued use of regional anesthesia in infants and children.

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Conflicts of interest

The author has declared no conflicts of interest.

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