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REVIEW ARTICLE

Ultrasound guided lower extremity blocks

Sean Flack & Corrie Anderson

Department of Anesthesiology and Pain Medicine, Seattle Children's Hospital, Seattle, WA, USA

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Correspondence
Dr Sean Flack,
4800 Sand Point Way NE, PO Box 5371/B-9524, Seattle, WA, USA
Email: sean.flack@seattlechildrens.org

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Introduction

Lower extremity (LE) nerve blocks are increasingly popular in children. In a 1996 study by the French-Language Society of Pediatric Anesthesiologists (ADARPEF), these blocks comprised just 1.6% of regional blocks (1). In a repeat survey published in 2010, this rate had increased to 12.4% (2). Similarly, data from the Pediatric Regional Anesthesia Network (PRAN, a North American multicenter database of regional anesthesia) reveal that LE blocks comprised 12% of blocks reported in 2007 vs 23% in 2011 (Dr LD Martin, personal communication). Single-shot caudal use in the two ADARPEF series decreased from 49.6% to 27%, suggesting they have been replaced by LE blocks for certain surgeries. The increased use of ultrasound (US) guidance likely explains this change. PRAN data demonstrate that US use for single-shot LE blocks has increased from 35% to 88% over the last 4 years.

Procedures amenable to LE blocks are mostly orthopedic, but not exclusively so. Unlike the upper limb, analgesia for LE procedures frequently requires blockade of at least two peripheral nerves (3), for example, surgeries of the foot mostly require saphenous (or femoral) and sciatic nerve (SN) blocks. For anterior knee procedures, a femoral nerve block (FNB) may be sufficient. However, consideration should be given to adding an obturator nerve block for coverage of the medial aspect of the knee, while lateral femoral cutaneous nerve (LFCN) blockade is advised when the lateral aspect of the knee is involved. Similarly, the SN should be blocked when surgery involves the posterior aspect of the knee, such as in the case of anterior cruciate ligament (ACL) repair when hamstring allograft is performed.

Attention to ergonomics is important to facilitate successful block placement. The US machine should be positioned such that visualization of the screen, US probe, needle and operator's hands is achieved without the operator needing to turn his/her head. For most LE blocks in children, a high-frequency linear US probe is ideal; however, deep blocks may mandate use of a curvilinear probe (4). Probe sterility is ensured by the placement of a sterile transparent dressing or a standard sleeve cover. Air trapping between the probe and cover must be avoided to preserve image quality. For transparent dressings, this is achieved by stretching the dressing over the probe. Gel is placed inside sleeve covers to achieve the same result. Gel-free sleeve covers are also commercially available. Needle selection is determined by the observed depth of the nerve on US as well as the need for simultaneous stimulation. A nonstimulating, 50-mm 22-gauge needle is adequate for most blocks, but 100-mm needles are sometimes required. Alcohol-based chlorhexidine is the antiseptic of choice for skin preparation, and individual sterile packs of gel should be preferred over multiuse bottles.

The remainder of this article contains an overview of six US-guided LE nerve blocks performed in children.

Lumbar plexus block

Overview

The lumbar plexus or psoas compartment block is useful for hip, thigh, femur, and knee surgery. This plexus of nerves travels within the dorsal 2/3 portion of the psoas muscle comprises the ventral rami of the first four lumbar roots and frequently includes a branch of T12. These spinal nerves divide into ventral and dorsal branches as the plexus runs distally. Relevant nerves derived from this plexus include femoral, lateral femoral cutaneous, and obturator nerves (5).

Literature review

Information on lumbar plexus sono-anatomy is limited. In adults, the psoas major muscle is described as typically hypoechoic interspersed with hyperechoic speckles representing fibrous structures within the muscle that may impair visualization of the plexus. Also, acoustic shadows created by the transverse process of the fourth lumbar vertebra further hinder visualization (6). It has been suggested that in adults at least, the primary value of ultrasonography is the ability to visualize and mark both location and depth of the transverse process, thereby facilitating accurate needle placement (7). In addition, continued use of nerve stimulation to facilitate verve localization has been recommended (8).

Descriptions of an US-guided technique for lumbar plexus block (LPB) in children are limited to a single observational study in 32 children aged 3–12 years (9). The plexus was visualized within the posterior part of the psoas major muscle in most patients. Based upon these findings, five children undergoing inguinal herniotomy successfully received US-guided posterior LPBs at the L4–L5 level. The ability to visualize the plexus may have been facilitated by a number of factors. First, the plexus depth was less than in adults, thus permitting the use of higher frequency probes. Second, the psoas major muscle appeared more hypoechoic, with less fibrous structures.

Contrary to the current trend away from nerve stimulation in favor of US-guided techniques, an approach to LPBs in children has been described that takes advantage of an accurate, patient-specific predictor for lumbar plexus depth in children, namely the distance from posterior superior iliac spine to intercristal line (10). The 1 : 1 relationship between these two measurements may be useful in facilitating US-guided approaches to the lumbar plexus.

Technique

The child is placed in the lateral decubitus position with hips and knees flexed (Sim's position) and the side to be blocked uppermost. The US probe is held parallel to the spinous processes, and transverse processes of L2, 3, and 4 are located (Figure 1). The lumbar plexus nerves are visualized within the psoas muscle as long continuous strands. A stimulating needle is advanced through the 'acoustic window' (the space between the transverse processes) and sequential stimulation of erector spinae, and abdominal oblique muscles are observed prior to successful quadriceps stimulation. An in-plane (IP) needle technique may be possible in larger children, but an out-of-plane (OOP) approach is likely necessary in smaller children. Local stimulation of quadratus lumborum or psoas muscle can occur and should not be mistaken for signs of a successful block. An initial

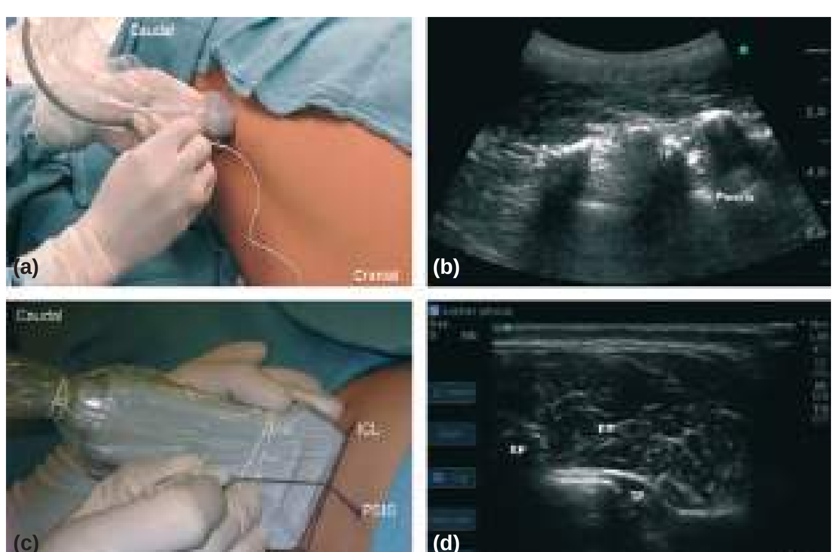

Figure 1 Lumbar plexus block. (a) Probe and needle position, in-plane technique. (b) Corresponding US view (TP, transverse process). (c) Probe and needle position, out-of-plane technique (ICL, intercristal line; PSIS, posterior superior iliac spine). (d) Corresponding US view (SP, spinous process; ES, erector spinae muscle; TP, transverse process).

bolus of 0.3–0.5 ml·kg^{-1} local anesthetic is appropriate to ensure complete plexus coverage. Marked lack of resistance to injection is a striking characteristic of correct needle tip position.

Comments

Specific complications include renal hematoma, epidural block, total spinal, intervertebral needle placement, and puncture of intra-abdominal structures (11). Although rewarding, this is a technically challenging block and its use should be preceded by thoughtful risk-benefit analysis.

Femoral nerve block

Overview

Derived from the dorsal divisions of the anterior rami of second, third, and fourth lumbar nerve roots, this nerve is the largest branch of the lumbar plexus (12). After passing under the inguinal ligament, the femoral nerve divides into an anterior and a posterior branch. The femoral nerve supplies sensation to the anterior and lower medial portion of the thigh, femur, and knee. The saphenous nerve (terminal branch of the posterior division of the femoral nerve) supplies sensation to the medial aspect of the leg below the knee down to the foot. The saphenous nerve splits off a branch to form the infra-patellar nerve. Articular nerves to the hip and knee joints also derive from the femoral nerve.

The position of the femoral nerve immediately lateral and slightly posterior (deep) to the artery is well known and may be easily remembered by use of the mnemonic NAVEL (from lateral to medial, the structures are nerve, artery, vein, empty space, and lymphatics) (13). At the level of the femoral crease, the nerve lies underneath two fascial layers – fascia lata and fascia iliaca (ileopectineal fascia) – and above the hypoechoic psoas and iliacus muscles. The ileopectineal ligament separates nerve from femoral artery and vein.

Surgical procedures in the pediatric population that are amenable to FNB include femur fractures, knee arthroscopies, ACL reconstructions, patellar ligament realignment, and vastus lateralis muscle biopsies. The block is easily performed, has a high success rate with few complications, and multiple indications for use. Consequently, it is the most commonly performed LE block in children (14).

Literature review

The use of US to facilitate FNB was first described by Marhofer *et al.* (15) in 1997. US guidance for FNB in children increased the mean duration of analgesia compared with nerve stimulator guidance (508 vs 335 min) in a study of 24 children aged <8 years (16). Furthermore, the same study demonstrated that smaller volumes of local anesthetic were required when using US guidance (0.2 vs 0.3 ml·kg^{-1}). Volume reduction is advantageous in limiting the risk for local anesthetic toxicity. This is particularly true in pediatric practice as lower plasma concentration of alpha-1 acid glycoprotein predispose children to higher free plasma concentrations of local anesthetics (17,18).

Technique

The femoral crease is identified with the child in the supine position, and mild abduction of the ipsilateral leg is advised. The anesthesiologist stands on the side of the patient where the nerve is to be blocked, with the US machine located on the contralateral side. The US probe is placed along the femoral crease and the pulsing, circular, anechoic artery located (Figure 2). If two arteries appear, the probe should be moved cephalad. The nerve, typically triangular in shape, should be traced proximally and distally to ensure that the structure identified is not a lymph node. A block needle is inserted at a flat angle to the skin in an IP direction and advanced in a lateral to posteromedial direction. Fascia lata and fascia iliaca are pierced lateral to the nerve and the needle advanced until the tip is positioned immediately lateral to the nerve. Local anesthetic is injected above and below the nerve, taking care to avoid intraneural injection.

Comments

Parents and children should be warned that weight-bearing activities must be avoided until resolution of the blockade. Intraneural or intravascular injections are the most likely complications, although easily avoided if careful attention is paid to needle tip position. Also, the superficial location of the nerve and vessels is often quite striking. If the nerve is not easily identified, the needle tip should be placed lateral to the artery, at a distance from the artery equivalent to the artery's diameter. Following injection of a small amount of local anesthetic, the nerve is usually easily visualized. As with other ultrasound-guided blocks, the end-point to injection is achieved once the nerve is surrounded with local anesthetic (the 'donut' sign). However, deliberate injection of additional volume may lead to lateral spread beneath fascia iliaca and blockade of LFCN.

Figure 2 Femoral and LFCN block. (a) Probe and needle position for right FNB. (b) US image of left FN, (V, femoral vein; A, femoral artery; N, femoral nerve). (c) US image of right LFCN, (ASIS, anterior superior iliac spine; LFCN, lateral femoral cutaneous nerve; FI, fascia iliaca). (d) US image of left FNB, (N, femoral nerve; LA, local anesthetic).

Lateral femoral cutaneous nerve block

Overview

This purely sensory nerve is a terminal branch of the lumbar plexus that innervates lateral buttocks below the greater trochanter and antero-lateral aspect of the thigh. Beneath the inguinal ligament, it runs immediately medial to the anterior superior iliac spine (ASIS), between fascia lata and fascia iliaca (19). LFCN block is useful for skin grafting, vastus lateralis muscle biopsy, prevention of tourniquet pain, treatment of myalgia paresthetica and as an adjunct to FNB for knee surgery.

Literature review

Cadaveric and adult volunteer studies have demonstrated that US guidance is preferable to landmark-based approaches to LFCN block (19,20).

Technique

The patient is positioned as for a FNB. Following identification of femoral nerve and vessels, the hyperechoic fascia iliaca is traced laterally toward the ipsilateral ASIS until the round hyperechoic nerve is identified (Figure 2). Sweeping the probe up and down, the expected course of the nerve will help confirm that the structure identified is indeed the nerve. IP or OOP approaches may be used.

Comments

This block is usually combined with a FNB. In small children, an IP approach from lateral to medial may permit both femoral and LFCN block via a single skin puncture. If the nerve is not visualized, successful blockade may be achieved by local anesthetic deposition deep to fascia iliaca, immediately medial to ASIS.

Obturator nerve block

Overview

This mixed motor and sensory nerve, derived from the anterior rami of L2–4, enters the thigh via the obturator canal and then divides into anterior and posterior branches. The anterior branch descends in front of adductor brevis, and behind pectineus and adductor longus, whereas the posterior branch descends between adductor brevis in front and adductor magnus behind (21). The anterior branch supplies sensation to the medial thigh as well as motor branches to adductor longus and brevis, gracilis, and rarely, pectineus. The posterior branch supplies adductor magnus, brevis (if not supplied by anterior division), and obturator externus and has an articular branch to the knee joint.

Literature review

A review of the literature reveals some confusion regarding relevant anatomy, and pediatric studies are lacking (22). On the other hand, the ultrasound appearance of this block has been well described in an adult volunteer study (23).

Technique

With the child supine, the US probe is placed at the ipsilateral inguinal crease and the femoral artery is identified. The probe is moved medially toward the pubic tubercle until the three adductor muscles are visualized. The two branches of the obturator nerve are seen superficial and deep to the middle muscle, the adductor brevis (Figure 3). Correct identification is confirmed by tracing the nerves proximally until the common obturator nerve is seen. Using an IP technique, the needle is advanced in a posteromedial direction. Nerve stimulation may be used as an adjunct, when necessary. Prominent movement of the adductor muscles is produced when the obturator nerve is stimulated.

Occasionally these nerves are not well seen, and only the fascial layers they pass through are identified. Injection into the interfascial layers will block the nerves (24). Obturator artery and vein should always be identified because they are very near the nerve.

Comments

The importance of the obturator nerve with regard to sensory innervation of the medial and posterior knee should not be underestimated (25,26). With respect to the technique, Soong *et al.* observed that imaging occurred best with the leg straight and just slight external rotation (22).

Saphenous nerve block

Overview

A purely sensory terminal branch of the posterior division of the femoral nerve, the saphenous nerve, innervates anteromedial and posteromedial aspects of the LE from distal thigh to foot (27). It descends lateral to the femoral artery within the adductor canal. Distal to the canal, it separates from the artery to lie superficial at the medial aspect of the knee. It divides into an infrapatellar branch that provides sensation to the knee and a sartorial branch that descends along the medial tibial border.

Literature review

The feasibility and efficacy of a variety of subsartorial and adductor canal approaches have been demonstrated in adults (28,29). Miller described an US-guided, proximal tibial paravenous approach in children (30). Using an IP technique, the needle tip was directed to a position inferolateral to the saphenous vein. A maximum volume of 6 ml local anesthetic was injected. Although the nerve position varied, it was usually seen posterior or posteromedial to the vein.

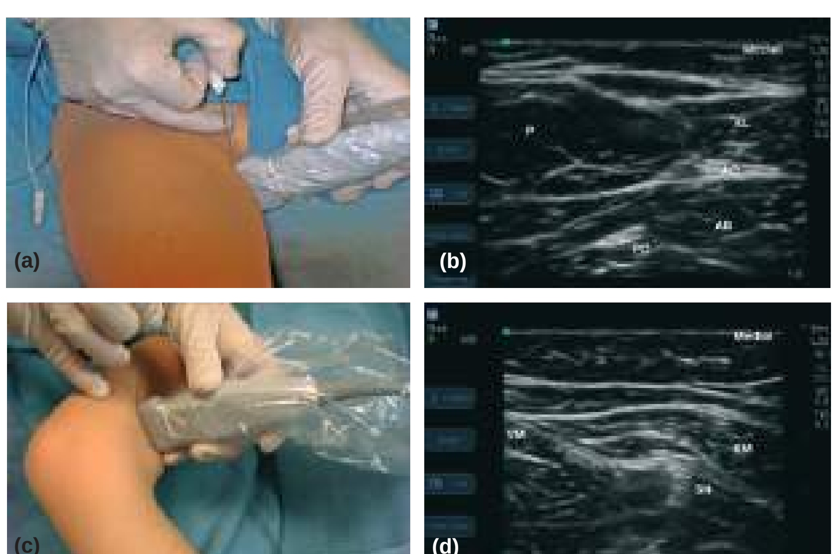

Figure 3 Obturator and saphenous nerve blocks. (a) Probe and needle position for ONB. (b) Corresponding US image (P, pectineus muscle; AL, adductor longus muscle; AO, anterior obturator nerve; AB, adductor brevis muscle; PO, posterior obturator nerve. (c) Probe and needle position for saphenous nerve block. (d) Corresponding US image (VM, vastus medialis muscle; SM, sartorius muscle; SN, saphenous nerve).

Technique

A subsartorial approach in the distal thigh is preferred as the nerve is easily visualized, and the risk of intravascular injection is minimized (Figure 3). The child is placed supine with external rotation of the hip and slight flexion of the knee. A mid-thigh, short-axis view of the femoral artery beneath the elliptical sartorius muscle is obtained. The nerve and artery typically create a small indentation of the posterior aspect of the muscle. Scanning in a caudad direction, separation of artery and nerve is observed. The probe is positioned such that the needle may be advanced in an anteroposterior direction between vastus medialis and sartorius muscles to reach the hyperechoic, round nerve.

Comments

In combination with a SN block for foot and ankle surgeries, selective blockade of the saphenous nerve is preferable to FNB as quadriceps muscle weakness is avoided (31). If the nerve is not well seen, a FNB may be substituted.

Sciatic nerve block

Overview

Derived from the sacral plexus, this mixed motor and sensory nerve is the largest and longest peripheral nerve in the body and innervates posterior thigh and most of the lower leg below the knee. The SN exits the pelvis through the sciatic notch and descends caudally between greater trochanter of femur and ischial tuberosity (32). Thereafter, it travels anterior to the adductor magnus muscle until it reaches the popliteal fossa where the popliteal vessels lie medial and anterior to the nerve. The SN comprises two divisions, the tibial nerve and the common peroneal nerve, contained within a common perineural sheath. These divisions typically diverge at the apex of the popliteal fossa, although interindividual variability exists (33). The tibial nerve supplies innervation to the dorsal leg and plantar surface of the foot. The common peroneal nerve is responsible for motor and sensory innervation to the lateral leg and dorsum of the foot. This block is useful for surgery of the tibia, fibula, posterior knee, ankle, and foot.

Literature review

A subgluteal approach to the SN was the first US-guided nerve block described in children (34). The close proximity of the posterior cutaneous femoral nerve to the SN at this level permits reduction in tourniquet-related pain if it is blocked concomitantly (16). Subsequently, successful visualization of the SN and its divisions in the popliteal fossa of 12 children up to 45 kg bodyweight was described (35). Efficacy of these two approaches was compared in 45 children aged between 8 months and 16 years (36). The authors observed that the SN had an oval, honeycombed, and hyperechoic appearance proximally, gradually becoming more rounded and less hyperechoic distally. Excellent analgesia without complications was obtained in all children.

The utility of combining nerve stimulation with US guidance was assessed in a study of 45 children aged 7 months–2 years (37). The SN was visualized in 44 of 45 children, and all blocks were successful. However, motor response to stimulation was evident in only 22% of patients. Block characteristics did not differ significantly between patients with or without a motor response. The authors concluded that when SN is clearly seen with US, attempting to elicit a motor response is unnecessary and may lead to excessive needle manipulations.

A study of 100 adult patients undergoing popliteal SN block determined that circumferential spread of local anesthetic surrounding the SN was an important parameter for rapid onset of surgical block. Furthermore, the highest success rate was obtained when the divisions of the SN (tibial and common peroneal nerves) were each surrounded by local anesthetic (38).

Further adult studies have demonstrated faster time to complete SN block following local anesthetic placement distal to the bifurcation vs proximal placement (33,39). These findings may reflect easier local anesthetic penetration of the smaller branch nerves compared with the larger SN. Consequently, these findings may be more relevant to adolescent patients than infants and small children.

Technique

In anesthetized children, SN blockade is most easily performed via a lateral approach in the supine position (Figure 4). The leg is placed on a stand or bolster with the child supine following which the US probe is placed transversely in the popliteal fossa. Simultaneous flexion and extension of the foot while scanning cause the nerves to move in a characteristic 'pin-wheel' or 'seesaw' manner that greatly facilitates identification (40). If the foot is immobile, the tibial nerve is located superficial and close to the popliteal artery (41–43). The common peroneal nerve is observed lateral to the tibial nerve. The block may be performed above or below the bifurcation, depending upon where nerve visualization is

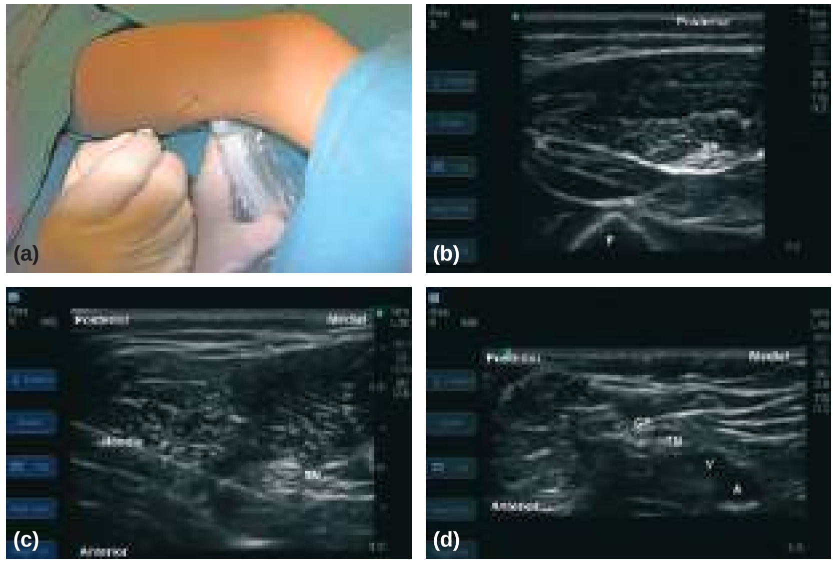

Figure 4 Sciatic nerve block. (a) Probe and needle position, lateral approach. (b) Corresponding US image, mid-thigh (F, femur; SN, sciatic nerve). (c) US image, in-plane needle view. (d) US image, popliteal fossa (CP, common peroneal nerve; TN, tibial nerve; V, popliteal vein; A, popliteal artery).

best. The needle is inserted in the groove between vastus lateralis and biceps femoris muscles and advanced parallel to the US probe until its tip is positioned alongside the nerve. Needle tip repositioning may be required to ensure circumferential spread.

A subgluteal approach with the patient in Sim's position is a useful alternative if the patient is already positioned laterally for a LPB or when analgesia of the posterior thigh is required (44,45). The nerve, typically hyperechoic and flattened in shape, lies midway between the greater trochanter and ischial tuberosity. Depending on the expected depth, a linear or curved probe may be used. IP and OOP approaches are described (36).

Anterior approach to the SN is useful when movement of the femur in an awake patient is problematic. Consequently, it's utility in anesthetized children is limited. The SN is visualized medial and posterior to the femur. Initial scanning in the transverse plane followed by a longitudinal scan and IP technique is recommended (46). Concomitant nerve stimulation may be required because of the deep nature of the block, but the associated discomfort may negate the reason for selecting this approach.

Comments

Despite its size, visualization of the SN may be difficult because of its anisotropic nature. As a result, for procedures below the knee, the nerve should be blocked wherever it is best seen. When visualization is difficult, nerve stimulation helps confirm that the structure in question is indeed the SN rather than tendon or muscle (47).

Summary

US-guided LE nerve blocks in children are performed with increasing frequency and offer alternatives to neuraxial techniques for analgesia following a variety of LE surgeries. However, a review of the literature reveals a paucity of pediatric studies. Technical descriptions in awake adults may not apply to anesthetized children; therefore, their recommendations should be adopted with caution (48). Pediatric-specific outcome studies would be valuable in answering certain questions and improving care. For example, is the quality of rehabilitation and functional outcome following surgery for foot deformities influenced by placement of a LE nerve block? Following ACL repair, are adolescents more likely to return to competitive sport if a LE nerve block was used to facilitate postoperative rehabilitation?

The large ADARPEF study and the ongoing PRAN database cited at the beginning of this article demonstrate the increasing popularity of LE blocks in children. It is intended that these efforts will inform pediatric anesthesiologists about block-specific efficacy and complication rates, thereby guiding appropriate selection of LE blocks in children.

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Conflict of interest

No conflicts of interest declared.

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