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Erector spinae plane block in children: a narrative review

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Review Article

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The erector spinae plane block (ESPB) is a novel technique used in both adult and pediatric patients. Its use in children has mostly been described in terms of perioperative pain management for various types of surgery. After its introduction, anesthesiologists began using ESPBs in various surgical settings. As adequate analgesia along with a low complication rate were reported, interest in this technique dramatically increased. Many studies in adults and children, including randomized controlled trials, have been published, resulting in the emergence of different clinical indications, with various technical and pharmacological approaches currently evident in the literature. This narrative review aims to analyze the current evidence in order to guide practitioners towards a more homogeneous approach to ESPBs in children, with a major focus on clinical applications. The ESPB is an efficient, safe, and relatively easy technique to administer. It can be applied in a wide range of surgeries, includes thoracic, abdominal, hip, and femur surgery. Its usefulness is evident in the context of enhanced recovery after surgery protocols and multimodal analgesia. Single-shot, intermittent bolus, and continuous infusion techniques have been described, and non-inferiority has been observed when compared with other locoregional techniques. Even though both the efficacy and safety of the procedure are widely accepted, current evidence is predominantly based on case reports, with very few well-designed observational studies. Consequently, the level of evidence is still poor, and more well-designed double-blind, randomized, placebo-controlled trials are needed to refine the procedure for different clinical applications in the pediatric population.

Keywords: Analgesia; Anesthesia; Child; Conduction anesthesia; Nerve block; Newborn infant; Review.

Introduction

The erector spinae plane block (ESPB), which was first described by Forero in 2016 [1] for the treatment of thoracic neuropathic pain, was applied in the pediatric population for postoperative pain management as early as 2017 [2]. Subsequent interest in this technique has rapidly expanded and expertise has increased, with applications not only for the management of perioperative analgesia but also for non-surgical pain management in the pediatric population (Table 1).

Despite more extensive series and observational evidence in the current literature, very few rigorous, well-designed trials have been conducted (Table 2). While these include a few randomized controlled studies, the protocols and indications used have been highly variable. The efficacy and safety of ESPBs in perioperative pain management have been explored in many case reports and observational studies compared with other loco-re-

Table 1. Case Reports in the Literature Search

Case reports	Cases	Age	Indication	Timing	Intervention	Block-related adverse events
Muñoz et al. 2017 [2]	1	7 years	Chest wall surgery	Postoperative	Single shot T8 14 ml bupivacaine 0.5% with epinephrine 5 μg/ml	None reported
Adler et al. 2019 [4]	1	3 weeks	Thoracic surgery	Preoperative catheter placement	Initial postoperative bolus through catheter 0.1% (0.25 mg/kg/h) ropivacaine in infusion for 48 h Catheter removed after 48 h	None
Darling et al. 2018 [14]	1	11 years	Iliac crest autograft	Preoperative Postoperative	Single shot catheter tip at L2 15 ml 0.5% ropivacaine intraoperative 11 ml 0.2% ropivacaine every 2 h on postoperative days 0–5	None reported
Balaban et al. 2019 [15]	1	6 years	Femur fixation	Postoperative	Single shot T5 20 ml 0.25% bupivacaine	None reported
Bosinci et al. 2021 [16]	2	2 years 7 years	Hip surgery	Preoperative	Single shot T4 Lidocaine 2% 2 ml and levobupivacaine 0.25% 14 ml Single shot lidocaine 2% 4 ml and levobupivacaine 0.25% 17 ml then continuous infusion levobupivacaine 0.125% 4–8 ml/h via infusion pump Catheter removed at 72 h	None reported
Hernandez et al. 2018 [17]	1	3 years	Thoracic surgery	Preoperative	Single shot T1 0.1 ml/kg bupivacaine 0.25% 0.1 ml/kg lidocaine 1%	None reported
Altıparmak et al. 2019 [20]	1	2 days (32 weeks PCA)	Thoracic surgery	Preoperative	Single shot T4 T6 0.5 ml 0.25% bupivacaine (x2)	None reported
Gomez-Menendez et al. 2019 [21]	1	13 months	Thoracic surgery	Preoperative	Single shot T4 5 ml bupivacaine 0.25%	None reported
Hagen et al. 2019 [22]	7	37 days–9 years	Thoracic surgery	Preoperative	Single shot 0.5% bupivacaine + dexamethasone (1 bilateral)	None reported
Wyatt and Elattary 2019 [23]	1	17 years	Thoracic surgery	Preoperative	Single shot T5 with catheter placement 25 ml 0.5% ropivacaine Continuous infusion through catheter 0.2% ropivacaine 8 ml/h during surgery 0.1% ropivacaine 10 ml/h postoperative Rescue bolus 4 ml bupivacaine 0.25% mixed + 1 ml lidocaine 2% upon arrival in ICU; Catheter removed at 96 h	None reported
Aytuluk et al. 2020 [24]	1	5 years	Chest tube insertion	Preoperative	Single shot T6-T7 7 ml 0.5% bupivacaine	None reported
Çiftçi and Ekinci 2020 [25]	1	12 years	Thoracic surgery	Preoperative	Single shot T5 15 ml 0.25% bupivacaine	None reported
Gupta et al. 2020 [26]	1	2 years	Thoracic surgery	Preoperative	Single shot T5 8 ml 0.375% ropivacaine + 10 μg clonidine	None reported

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Table 1. Continued

Case reports	Cases	Age	Indication	Timing	Intervention	Block-related adverse events
Swenson Schalkwyk et al. 2020 [27]	1	2 days	Thoracic surgery	Preoperative	Catheter T5-T6 with hydrodissection + 2 ml 3% chloroprocaine 1 ml 0.1% at surgery Continuous infusion: 1.5% chloroprocaine at 0.25 ml/kg/h Catheter removed at 140 h	None
Wong et al. 2018 [28]		17 years	Cardiac surgery	Preoperative catheter placement and bolus; postoperative PIB	Bilateral catheters tip T7 10 ml 0.5% ropivacaine (x2) preoperative, then postoperative alternating catheter boluses of 10 ml 0.1% ropivacaine every 60 min Catheter removal at 72 h	None reported
Moore et al. 2018 [29]	1	1 year	Abdominal surgery	Preoperative catheter placement and bolus; postoperative continuous infusion	Bilateral catheters T8-T10 1 ml 0.2% ropivacaine followed by 0.5 ml/h 0.2% ropivacaine intraoperative Postoperative 0.5 ml/h 0.1% ropivacaine until catheter removal 72 h postop	None reported
Aksu and Gürkan 2018 [30]	2	6 months 7 years	Nephrectomy	Preoperative	Single shot T12 0.5 ml/kg 0.25% bupivacaine	None
Thomas and Tulgar 2018 [31]	1	11 years	Abdominal surgery	Preoperative	Single shot bilateral T9 0.25% bupivacaine 0.5 ml/kg (x2)	None reported
Munshey et al. 2018 [32]	1	11 months	Open pyeloplasty	Preoperative	Catheter tip T8 Bolus 0.3 ml/kg ropivacaine 0.2% every hour during surgery, then 0.3 ml/kg ropivacaine 0.5% at end of surgery; Catheter removed at 48 h	None reported
Aksu and Gürkan 2019 [33]	3	8, 11, 13 years	Laparoscopy	Preoperative	Single shot bilateral T7 0.5 ml/kg 0.25% bupivacaine (max 20 ml) (x2)	None reported
Ince et al. 2019 [34]	1	13 years	Abdominal surgery	Preoperative	Single shot bilateral L2-3 LA not specified	None reported
Karaca and Pınar 2019 [35]	4	10–14 years	Abdominal surgery	Preoperative	Bilateral single-shot T7 Total 2.5 mg/kg bupivacaine	None
Aydın et al. 2020 [36]	1	9 months	Abdominal surgery	Postoperative	Single shot T10 + T11 Bupivacaine 0.25% (3 ml T10 + 3 ml T11)	None
Ekinci et al. 2020 [37]	1	2 years	Shock wave lithotripsy	Preoperative	Single shot T10 6 ml 0.25% bupivacaine	None reported
Tsui et al. 2020 [38]	1	16 years	Spinal surgery	Intraoperative surgical catheter placement	Bilateral catheter tips at T6 20 ml lidocaine 0.5% (x2) at end of surgery Postoperative boluses 20-22 ml 0.5% lidocaine alternating right and left side every 60 min; Catheter removed at 48 h	None reported
Aksu and Gürkan 2020 [39]	1	6 months	Genital surgery	Preoperative	Single-shot median sacral 8 ml of 0.25% bupivacaine	None

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Table 1. Continued

Case reports	Cases	Age	Indication	Timing	Intervention	Block-related adverse events
Ince et al. 2020 [40]	1	4 years	Hip surgery	Preoperative	Single shot L4 ESPB in combination with pericapsular nerve block 0.25% bupivacaine (total 20 ml 0.25% bupivacaine)	None
Baca et al. 2019 [41]	1	15 years	Palliative pain	Catheters placed under general anesthesia in hospital before release to home care	Bilateral tunneled catheters T8 (advanced to T12) Single shot 11 ml 0.5% ropivacaine PIB 10 ml 0.2% ropivacaine every 2 h alternating sides Catheter removed after 7 days	None
Kupeli et al. 2021 [42]	9	2–10 years	Multiple surgery	Preoperative	Preoperative single shot upon catheter placement, 0.25% levobupivacaine 0.4 ml/kg Postoperative continuous infusion through perineurial catheter 1–5 ml/h 0.125% levobupivacaine Level T5 for thoracotomy; T8 for nephrectomy; T12–L2 for appendectomy and inguinal hernia; L1–2 for orchidopexy and ureterocele; and L4 for hip surgery Catheters removed within 24 h after surgery	None reported
Le et al. 2020 [43]	1	17 years	Ravitch procedure	Preoperative	Bilateral catheters T5 20 ml 0.2% ropivacaine preoperative Continuous infusion 6–8 ml/h ropivacaine 0.15% Rescue bolus 6 ml ropivacaine 0.15% on each side on postoperative day 1 Catheters removed at 72 h	None reported
Bonfiglio et al. 2021 [44]	1	19 years	Thoracoscopy	Preoperative catheter placement and bolus; postoperative continuous infusion + patient-controlled infusion	Single shot T4 18 ml of 0.25% levobupivacaine + 30 µg of dexmedetomidine Continous infusion 0.125% levobupivacaine 10 ml/h + PCI 5 ml with 60-min lockout Catheter removed on postoperative day 3	None reported
Bakshi et al. 2020 [45]	2	3 years 4 years	Spine surgery	Preoperative catheter placement; catheter placement on postoperative day 4	Intermittent bolus 6 ml 0.25% levobupivacaine every 8 h for 4 days Intermittent bolus of 5 ml 0.25% bupivacaine every 8 h for 4 days	None
Patel et al. 2019 [46]	1	6 years	Thoracic surgery	Preoperative	Single shot T5 10 ml of 0.5% ropivacaine Continuous infusion through catheter 0.2 mg/kg/h ropivacaine Catheter removed at 96 h	None reported
De la Cuadra-Fontaine et al. 2018 [47]	1	3 years	Thoracic surgery	Preoperative catheter placement and bolus; postoperative continuous infusion + patient-controlled infusion	Single shot T9 8 ml of 0.25% levobupivacaine;Continuous infusion 0.1% levobupivacaine 3 ml/h + PCA 1.5 ml with 30-min lockout Catheter removed at 96 h	None reported
Basaran and Akkoyun 2020 [48]	1	1 days (30 weeks PCA)	Abdominal surgery	Preoperative	Single shot bilateral T7 0.5 ml 0.25% bupivacaine (x2)	None reported

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Table 1. Continued

Case reports	Cases	Age	Indication	Timing	Intervention	Block-related adverse events
Aksu and Gürkan 2019 [49]	2	11 years	Abdominal surgery	Preoperative	Single shot T11 bilateral 0.25% bupivacaine 0.5 ml/kg	None
Aksu and Gürkan 2019 [50]	2	2 years 5 years	Inguinal hernia repair	Preoperative	Single shot lumbar ESPB 0.25% bupivacaine 0.5 ml/kg (does not specify vertebral level)	None
Cesur et al. 2019 [51]	5	3–12 years	Inguinal hernia repair	Preoperative	Single shot 0.25% bupivacaine with a volume of 0.5 ml/kg (vertebral level not specified)	None reported
Hernandez et al. 2018 [52]	1	2 months	Inguinal hernia repair	Preoperative	Single-shot T6 0.2 ml/kg bupivacaine 0.25% 0.2 ml/kg lidocaine 1%	None
Elkoundi et al. 2019 [53]	1	4 years	Hip surgery	Preoperative	Single shot L2 0.3 ml/kg 0.25% bupivacaine	None reported
Uysal et al. 2020 [70]	1	5 months	Diaphragmatic hernia	Postoperative	Single shot (twice) T6 T10 0.5 ml/kg 0.25% bupivacaine	None
Paladini et al. 2019 [71]	1	5 months	Thoracic surgery	Preoperative Postoperative	Single shot T4 (twice) 4 ml 0.2% levobupivacaine after induction 4 ml 0.1% levobupivacaine before emergence	None
Kaplan et al. 2018 [72]	1	7 months	Thoracic surgery	Preoperative	Single shot T6 2 ml of 0.2% ropivacaine for hydrodissection and catheter placement, then continuous infusion through catheter 0.2% ropivacaine 1 ml/h Catheter removed at 72 h	None
Gurbuz et al. 2021 [77]	2	1 day 25 days	Thoraco-abdominal surgery	Postoperative; preoperative	Single shot T4; T8 0.75 ml 0.2% bupivacaine	Bradycardia 10 min after block (treated with atropine) in 1 case

ESPB: erector spinae plane block, LA: local anesthetic, ICU: intensive care unit, PCA: post conceptual age, PCI: patient's controlled infusion.

Table 2. Case Series in the Literature Search

Case series	Cases	Age	Study design	Indication	Timing	Intervention	Block-related adverse events
Kaushal et al. 2020 [5]	80	Mean age 28.5 months	Prospective randomized single-blind comparative trial	Cardiac surgery	Preoperative	Single shot bilateral T3 1.5 mg/kg 0.2% ropivacaine (x2) vs. no block	None
Macaire et al. 2020 [6]	50	Mean age 25 months	Prospective randomized double blind controlled trial	Cardiac surgery	Preoperative followed by postoperative programmed intermittent bolus regimen	Induction single shot in bilateral T3-T4 catheter 0.1%–0.2% ropivacaine followed by postoperative PIB 0.1%–0.2% ropivacaine for 48 h vs. sham PIB with saline for 48 h	Accidental catheter removal or displacement
Aksu et al. 2019 [7]	57	1–7 years	Prospective double blind randomized trial	Pelvic small surgery	Preoperative	Single shot L1 ESPB vs. single shot quadratus lumborum block 0.5 ml/kg 0.25% bupivacaine	None
Mostafa et al. 2019 [8]	60	3–10 years	Prospective randomized control trial	Open splenectomy	Preoperative	Single shot bilateral T7 0.3 ml/kg 0.25% bupivacaine (x2) vs. bilateral sham ESPB 0.3 ml/kg normal saline (x2)	None
Singh et al. 2020 [9]	40	2–10 years	Prospective randomized control trial	Lower abdominal surgery	Preoperative	Single shot bilateral L1 0.5 ml/kg 0.25% bupivacaine (x2) vs. no block	None
El-Emam et al. 2019 [10]	60	6 months–3 years	Prospective randomized control trial	Unilateral inguinal hernia repair	Preoperative	Single shot L1 level ESPB vs. ilioinguinal/iliohypogastric nerve block, 0.5 ml/kg 0.125% bupivacaine + fentanyl 1 µg/ml injectate	None
Jambotkar and Malde 2021 [19]	30	1–12 years	Prospective observational study	Thoracotomy	Preoperative	Single shot T4 0.25% bupivacaine 0.3 ml/kg	None
Aksu and Gurkan 2019 [69]	141	0.25–17 years	Retrospective cohort study	Thoracic, abdominal and pelvic surgery	Preoperative	Unilateral (112) or bilateral (29) single shot T4 to S4 0.25% bupivacaine 0.5 ml/kg (max 20 ml)	None
Munshey et al. 2020 [73]	22	11 months–17 years	Retrospective cohort study	Thoracic, abdominal, hip surgery	Preoperative (postoperative for one patient) followed by intraoperative and postoperative programmed intermittent bolus regimen	Catheter ESPB (17 unilateral, 5 bilateral; 22 thoracic, 5 lumbar) with median loading dose 0.4 ml/kg ropivacaine 0.5%, intraoperative bolus of 0.3 ml/kg/h ropivacaine 0.2%, postoperative programmed intermittent bolus maximum 0.5 mg/kg/h	Local edema and tenderness

ESPB: erector spinae plane block, PIB: programmed intermittent bolus.

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gional procedures (Tables 1 and 2). However, the position, timing, and pharmacological approach are highly variable across operators and no standardized protocols are available.

The level of evidence is still limited, and a general consensus on these aspects is lacking. The purpose of this narrative review is therefore to provide an overview of the state of ESPBs in children, highlighting critical aspects and future perspectives to guide practitioners towards a more homogeneous approach.

Clinical indications

ESPBs have been proposed for a wide variety of potential applications, especially as part of a multimodal perioperative analgesia regimen to promote enhanced recovery after surgery (ERAS) in numerous kinds of procedures, ranging from chest and abdominal to inguinal and lower limb surgeries. In fact, analgesia can be attained in a broad range of anatomical areas depending on the vertebral level of local anesthetic (LA) injection, with extensive craniocaudal spread providing anesthesia coverage to multiple dermatomes [3]. Consequently, this technique allows for the operator to achieve analgesia in the desired region with an injection that is remote from the surgical incision area [2].

While ESPBs could be synergistic with other locoregional techniques, to date, it has mostly been reported as an alternative to other approaches. For example, the ESPB has been used as an alternative to the thoracic epidural, a classic technique for cardiothoracic surgeries involving a midline sternotomy or thoracotomy, as it is considered safer because it is injected farther from important structures, such as the spinal cord, pleura, and vascular structures [4]. Bilateral ESPBs at the T3-T4 level have been shown to provide improved postoperative analgesia compared to no block in children undergoing cardiac surgeries involving a midline sternotomy [5,6].

Several reports have described the use of ESPBs for perioperative pain management during lower body surgeries. The non-inferiority of the ESPB to the quadratus lumborum block in pediatric lower abdominal surgeries has been shown [7]. Bilateral ESPBs can provide superior intraoperative and postoperative analgesia compared to sham blocks for splenectomies involving a midline incision [8] and compared to no block for lower abdominal surgeries [9]. ESPBs have also been shown to provide more effective and longer-lasting postoperative analgesia than ilioinguinal/iliohypogastric blocks in unilateral inguinal hernia repairs [10].

Despite the fact that caudal epidurals are one of the most extensively used regional blocks in children undergoing hip and lower abdominal surgeries [11,12], no studies have compared caudal epidurals to ESPBs in pediatric patients. Additionally, no comparisons between ESPBs and psoas compartment blocks in hip surgery have been conducted, even though the effectiveness of both techniques have been confirmed [13–16].

A reduction in the use of intraoperative and postoperative analgesics for opioid-sparing general anesthesia has also been demonstrated with ESPBs [5,6,8]. Anecdotal evidence in the form of case studies and small case series have been reported for numerous applications of the ESPB as part of a multimodal opioid-sparing analgesia regimen, including for thoracotomy, thoracoscopic surgery, thoracic wall surgery [2,3,4,18–27], sternotomy [28], abdominal surgery [29–37] spinal surgery [38], genital surgery [39] and hip joint and proximal femur surgery [14–16,40].

Outside the operating room, ESPBs have been successfully employed for pain control in pediatric oncological palliative care [41].

Beyond the use of ESPBs as a routine technique in the pediatric anesthesiologist's arsenal, it has also been applied in the management of particularly complex cases. Due to the craniocaudal spread of ESPBs, it can be injected at a remote point from the vertebral level of the incision site [42], and thus may be used when there is an incision site infection or as a valid alternative to neuraxial anesthesia in the case of spinal deformities, previous spinal surgery, or neuraxial spread of neoplastic disease [43–45]. ESPB catheters have also been used successfully when epidural and paravertebral catheters are not possible due to coagulopathy [46]. The high safety profile of the ESPB in terms of the hemodynamic impact has led to its consideration by clinicians who are reluctant to use epidural anesthesia in patients with heart defects [47]. Additionally, during the perioperative period of an emergency laparotomy, analgesia has been provided by ESPBs even in very low birth weight premature infants, despite their small size [48].

Anatomy, technique, and diffusion of the anesthetic solution

Accurate knowledge of pediatric anatomy is essential for performing an ESPB and achieving an adequate sensory blockade. Anatomical differences between adult and pediatric patients, such as the muscles, fascia, and connective tissues under the skin, which are usually thinner and less rigid in pediatric patients, must be taken into account. Therefore, neonatal/pediatric probe, shorter needle, and lower drug volume should be considered.

Regardless of the vertebral level, the target of this fascial plane block is the erector spinae fasciae plane. This is a virtual space located under the erector spinae muscles that communicates with the paravertebral space where the dorsal rami of the spinal cord is located (Fig. 1).

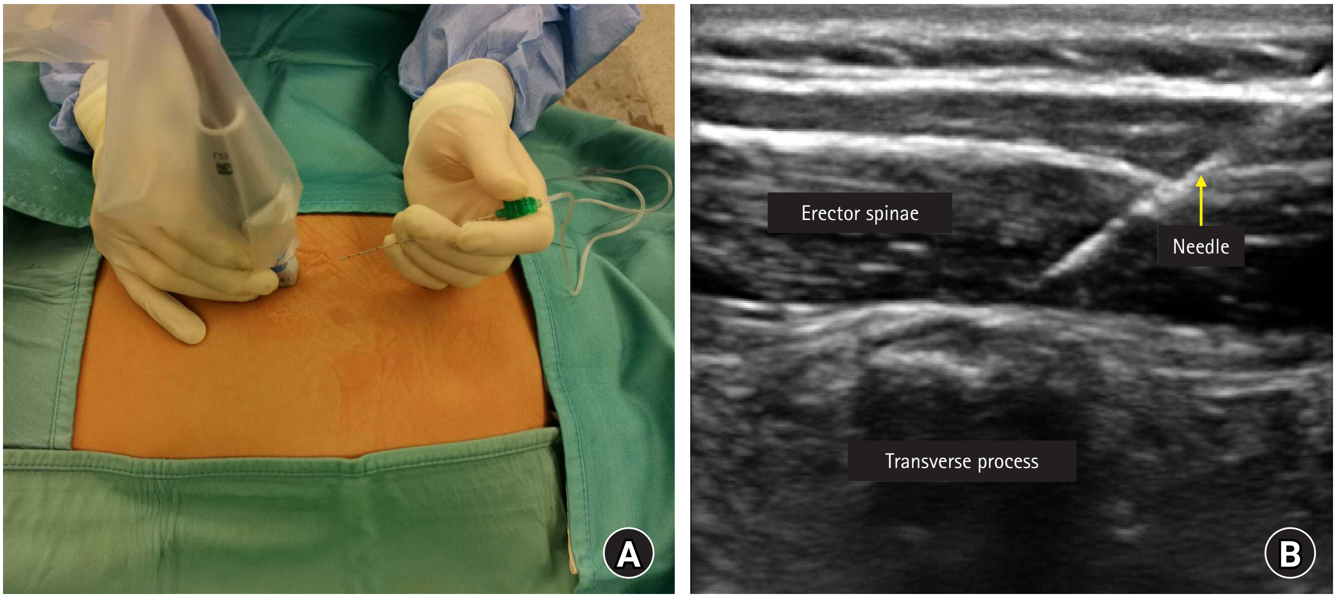

Fig. 1. (A) The ultrasound probe is placed along the midline of the spine and moved laterally to visualize the transverse process. (B) The needle advances to the tip of the transverse process, and LA is injected to dissect the plane deep to the erector spinae muscle.

The erector spinae muscles constitute the intermediate layer of the deep muscles of the vertebral column, arising from the posterior part of the iliac crest, sacrum, and lumbar spinous processes. It encompasses the spinalis, longissimus dorsi, and iliocostalis muscles. These muscles are located posterolaterally to the vertebral column, lying between the vertebral spinous processes medially and angles of the ribs laterally.

During sonography, the probe should initially be placed at the midline of the spine with a transverse orientation to visualize the spinous processes. Moving laterally, the transverse processes can then be located. Maintaining the probe in a transverse orientation, an out-of-plane approach can be used, with the needle placed in a craniocaudal or caudocranial direction. Otherwise, after a 90° rotation of the probe, an in-plane approach is also possible.

The structures are visualized from superficial to deep as follows: the trapezius, rhomboid, and erector spinae muscles and the transverse process of the respective vertebra.

The needle must be advanced to the tip of the transverse process, after which the LA can be injected to hydrodissect the plane deep to the erector spinae muscle to verify the proper injectate location before injecting the residual volume. Alternatively, if the patient's weight allows for only very small volumes of LA, normal saline may be used for this initial hydrodissection to spare the LA allowance.

The distance between the skin and tip of the transverse process is very small in pediatric patients and can vary considerably according to age and body mass index. Therefore, small-sized needle devices and a stable position are required to perform the block.

The above mentioned approach, which is mostly conducted in the prone position in children, is similar to that used in the first reports of ESPBs conducted on two adult patients in the sitting position [1]. As this technique has been increasingly applied in the pediatric population and refined for the particular needs of these patients, several other approaches have been developed. In 2018, an ESPB administered with the patient in the lateral decubitus position was described by placing the ultrasound probe transversely to obtain a midline view of the spinous and transverse processes of the vertebral and erector spinae muscles, using an out-of-plane technique [49].

The Aksu approach for lumbar ESPBs has also been described in pediatric patients, in which an in-plane technique in the lateral decubitus position is applied, thus eliminating the need to turn the anesthetized patient prone and then back to a supine position for surgery [50]. The major disadvantage of this approach is the inability to visualize the craniocaudal spread of the LA, which is only possible when the probe is turned to the sagittal position after the block is performed [51].

Regardless of the technical approach, LAs injected into the erector spinae fascial plane are meant to spread through the paravertebral space, not only at the level of the injection site but also cranially and caudally to reach distant dermatomes.

However, the exact diffusion pathway remains controversial. The dorsal rami emerges from the paravertebral space and moves through the inter-transverse connective tissue complex. The ven-

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tral rami continues from the paravertebral to the intercostal space, becoming the intercostal nerves. The involvement of the ventral rami is contested since no solid evidence is available on the actual route of spread of the injected drugs.

Different methods have been adopted to study the spread of LAs; however, most are described in adult patients whose tissues are much more rigid and stiffer than those of children. Sonography, while clearly a limited technique, is useful for studying the cephalocaudal distribution of the injectate and is feasible in the pediatric population. Munoz et al. [2] observed the spread of LA from T5 to T11 after an 8-ml injection of solution was performed at T8 in a 7-year-old patient. Additionally, the distribution of a 3.2-ml solution from T1 to T9 was documented via ultrasound in a 3-year-old patient after an ESPB was performed at T1 [17]. In another case report, the same author visualized the spread of 1 ml of solution between T4 and L1 following an ESPB performed at T6 in a 2-month-old infant [52]. A wide distribution was also observed between L1 and L4 following the administration of 4.5 ml of solution at L2 in a 4-year-old patient [53].

A cadaveric study that analyzed the spread of a methylene blue dye solution in two embalmed preterm stillborn neonates weighing 1.6 and 0.6 kg was also conducted. The first cadaver received a unilateral 0.5-ml injection of solution at the T5 level, and superficial cephalocaudal diffusion from T2 to T12 was observed, with deeper staining of the ventral and dorsal roots and ganglia between T3 and T6. In the second cadaver, in which a 0.2-ml injection was performed at the T8 level, superficial staining spread from T7 to L1 and dorsal and ventral roots/ganglions were involved from T7 to T11. In both cases, the paravertebral and epidural spaces as well as the dura mater surrounding the spinal cord were stained [54].

CT scanning with multi-slice and three-dimensional (3D) technology has been used to assess the spread of iodinated contrast dye in a fresh unembalmed preterm neonatal cadaver weighing 2.7 kg. The first injection (2.3 ml) was performed at the T8 level on the right side and a second injection (2.3 ml) on the opposite side was performed at the T10 level. 3D reconstruction revealed diffusion of the dye from T6 to T9 on the right side and from T9 to T11/T12 on the left side. Contrast dye was seen in the paravertebral space but not in the epidural space, spreading over the costotransverse ligament and reaching the intercostal space. The lack of spread to the epidural space could be explained by in vivo factors, such as intrathoracic pressure changes and the absence of muscle tone and tissue tension. The study suggested a volume of 0.3–0.4 ml per dermatome, with involvement of 3 to 4 dermatomes with the ESPB [55].

The paucity of data available regarding injectate spread in children requires that adult studies be referenced. However, considerable differences in diffusion patterns in adult and pediatric patients must be recognized in relation to multiple factors, such as the developmental formation of the vertebral curvature, more elastic pediatric spine, and less dense ligaments and cartilaginous laminae [54]. Drug distribution in the adult population has been observed in MRI and cadaveric studies, which suggest different possibilities for lateral and anterior diffusion of LAs. Beyond anatomy, the vertebral level [56] and drug volume [57] are also relevant factors in the spread of injected LA. Analyses of cadaveric samples have revealed anterior and posterior diffusion of the injectate with different percentages at different vertebral levels, with inconclusive results. Paravertebral, intercostal, and epidural spread have been described, but these findings are not consistent among the available studies [56–68]. Given these variabilities in adult MRI and cadaveric studies, the results are inconclusive and presumably related to the site of injection, volume of solution, and physical characteristics of the tissues.

Although this technique is clearly effective, given its many successful clinical applications, evidence regarding the precise diffusion of the injected solution in children is not entirely clear, with only two studies on neonatal cadavers [54,55] and several case series reporting data from in vivo sonographic imaging.

Choice and dosage of local anesthetics

The pharmacological approaches described in the current literature are highly inconsistent, as the procedure has multiple applications and the specific pharmacological approach associated with the variety of clinical contexts is variable.

Bupivacaine, ropivacaine, and levobupivacaine at different concentrations and volumes have been most commonly used for ESPBs in pediatric patients, with no significant differences in postoperative pain management between them.

In the first documented application of the ESPB in children in the literature, a single shot injection of 14 ml of 0.5% bupivacaine performed at T8 was administered to a 7-year-old boy undergoing surgery for the treatment of a tumor of the eleventh rib [2].

Most of the pediatric ESPBs currently described in the literature are performed with 0.25% bupivacaine, with volumes ranging from 0.3 to 0.6 ml/kg [19,20,25,30,31,33,36,69,70].

A 1 : 1 solution of 0.25% bupivacaine and 1% lidocaine with a total volume of 0.2 ml/kg was administered via ESPB as a single shot injection to a 3-year-old girl weighing 16 kg undergoing surgical resection of dorsal lipoma. The patient was discharged 4 h after surgery with full pain control [17]. The same solution at a dosage of 0.4 ml/kg was administered as a single shot ESPB in a

2-month-old infant before inguinal hernia repair [53].

The use of levobupivacaine 0.2% (4 ml) for thoracic surgery in a 5-month-old female was also reported [71] to enhance recovery after surgery.

The first continuous ESPB in the literature was administered to a 3-year-old boy, who received an 8-ml initial injection of 0.25% levobupivacaine through a catheter placed at the T9 level at the end of a thoracotomy. Two hours later, a patient-controlled analgesia pump with 0.1% levobupivacaine (3 ml/h continuous infusion) was started, with a standing order of 1.5-ml rescue boluses at 30-min lockout intervals. On the fourth postoperative day, the infusion was stopped. Only two 1.5-ml rescue boluses were administered and no other medications were required to control pain [47].

A 7-month-old infant received 0.2% ropivacaine through a catheter placed at the T6 level (1 ml/h) prior to an upper lobectomy for a congenital pulmonary airway malformation. The catheter was removed on the third postoperative day, and pain scores showed adequate analgesia [72].

A retrospective review of a single center on various surgeries described the efficacy of ESPBs with 0.5% ropivacaine in children, with an initial loading dose of 0.4 ml/kg followed by intermittent boluses of 0.2%–0.3% at 0.3 ml/kg administered hourly [73].

Pharmacokinetic variability must be taken into account for all fascial plane blocks. In contrast to peripheral nerve blocks, where anesthetics are precisely deposited around a specific nerve, a consistent level of intensity of the sensory blockade cannot be expected for fascial plane blocks. Moreover, differences in tissue laxity in pediatric patients could contribute to increased variability. Consequently, it is difficult to replicate the same sensory block in different children, even when administered by the same practitioner.

More studies are thus necessary to guide the type, dosage, and duration of LA and adjuvant administrations to create specific protocols for the various clinical applications of pediatric ESPBs.

Safety profile and adverse events

Regional anesthesia is generally considered safe in the pediatric population, although caution must be exercised, especially when applying these techniques to infants [74]. Furthermore, these techniques can be safely utilized under general anesthesia [75]. In particular, ESPBs appear to be exceptionally safe, as the injection site is very superficial and ultrasound guidance allows for visualization of vital structures such as the neuraxis, pleura, and vascular structures as the needle is inserted. Additionally, it is widely accepted that ESPBs can be conducted safely in patients with coagulopathy [46]. While the standard contraindications and possible complications of any peripheral block, including LA systemic toxicity (LAST), allergic reactions, or motor block, may occur with ESPBs, the available literature documents a promising safety profile in children, with most studies reporting no adverse events or complications such as epidural hematoma, which may occur with neuraxial blocks.

Some minor adverse events such as catheter occlusion, displacement, and unintentional removal have been reported [6,73]. Rare cases of bradycardia or possible LAST have also been reported, but quickly reversed [76,77]. While injection site infections may be a contraindication to peripheral nerve blocks, the possibility of injecting LAs at a site distant from the target in a fascial plane block may allow operators to safely implement ESPBs even in cases of surgical site infection. One other potential complication of ESPBs is a pneumothorax [78]; however, a literature search yielded no documented episodes, and experienced operators hold that ultrasound guidance, fine needle skills, and preventative techniques can minimize this risk [49].

Conclusions

Despite significant interest in ESPBs in the pediatric anesthesia community due to its versatility, low learning curve and safety profile, the available evidence is still anecdotal and non-homogeneous with few rigorous trials, yielding low-quality evidence and no clear protocol to follow. Taken together, the available data suggest that ESPBs may be a valid technique to improve intra- and postoperative pain control and reduce opioid use in pediatric thoracic, abdominal, inguinal, hip, and femur surgeries. Additionally, multiple authors have considered this procedure a valid alternative to other loco-regional techniques and epidural anesthesia. The choice of LA is quite variable among practitioners, with reports of single shot or continuous infusions for different surgeries, and the distribution of injected solutions remains controversial. Hence, more well-designed randomized controlled trials are needed to clarify specific approaches for performing ESPBs for different clinical procedures in the pediatric population.

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