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Erector Spinae Plane Block in Children: a Narrative Review

Running Title:
ESPB in children

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Abstract

Erector Spinae Plane block (ESPB) is a novel technique applied both in adult and pediatric patients. Its use on children has been described mostly in perioperative pain management, involving many different surgeries. After its introduction, anesthesiologists started using the ESPB in various surgical settings. Adequate analgesia and very limited complications have been observed, so that great interest rapidly arose on this technique. Many studies have been published, including some randomized controlled trials, leading to the emergence of the numerous clinical indications, and many differences in technical and pharmacological conduct currently evident in literature.

This narrative review aims to analyze the current evidence in order to guide practitioners towards a more homogeneous approach to the ESPB in children, with a major focus on clinical applications, anatomical, technical and pharmacological aspects. ESPB is an efficient, safe and relatively easy technique. A wide range of applications 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 in comparison with other loco-regional techniques. Although the efficacy and safety of the procedure is 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 in the different clinical applications in the pediatric population.

Keywords: ESP block; Children; Anesthesia; Review; Neonates, Regional Anesthesia
Introduction

The Erector Spinae Plane Block (ESPB) was first described by Forero in 2016 [1] for the treatment of thoracic neuropathic pain, and as soon as 2017 was applied in the pediatric population for postoperative pain management [2]. Since then, interest in this technique has rapidly expanded and expertise has increased, finding applications not only in the management of perioperative analgesia, but also in non-surgical pain management in the pediatric population (Table 1).

Despite some more extensive series and observational evidence in current literature, very few rigorous, well-designed trials have been conducted (Table 2). These include some randomized controlled studies, but protocols and indications have been highly variable. The efficacy and safety of the ESPB in perioperative pain management have been explored in many case reports and observational studies and compared to other loco-regional procedures. 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 over the above-mentioned aspects is lacking. The purpose of this narrative review is to give an overview of the state of art of ESPB in children, highlighting critical aspects and future perspectives, in order to guide practitioners towards a more homogeneous approach.
**Clinical Indications:**

The ESPB has been proposed for a wide array of potential uses, 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 obtained in a broad range of anatomical areas, depending on the vertebral level of Local Anesthetic (LA) injection, with extensive craniocaudal spread, providing anesthesia covering multiple dermatomes [3]. Likewise, this technique allows the operator to achieve analgesia in the desired region with an injection remote from the surgical incision area [2].

ESPB could be synergistic with other loco-regional techniques, although thus far it has been mostly reported as an alternative to other approaches. ESPB has been used as an alternative to thoracic epidural, a classic technique for cardiothoracic surgery via midline sternotomy or thoracotomy, as it is considered safer due to its greater distance from important structures such as spinal cord, pleura, vascular structures [4]. Bilateral ESPB at T3-T4 has been shown to provide improved post-operative analgesia in children following cardiac surgery through midline sternotomy as compared to those given no block [5,6].

It may be preferred over other techniques such as the paravertebral block [7] and the retrolaminar block [3] the extensive craniocaudal spread within the fascial plane - most likely meaning more extensive analgesia covering multiple dermatomes.

Several reports are described for body lower sections. The ESPB has been shown to be non-inferior to the quadratus lumborum block for pediatric lower abdominal surgery [8]. Bilateral ESPB can provide superior intra operative and postoperative analgesia when compared to a sham block for splenectomy through a midline incision [9], as well as for lower abdominal surgeries as compared to no block [10].
It has also been shown to provide more effective and longer-lasting postoperative analgesia than an ilioinguinal/iliohypogastric block in unilateral inguinal hernia repair [11].

Despite caudal epidural being one of the most extensively used regional blocks in children undergoing hip procedures and lower abdominal surgery [12,13], no studies comparing it to ESPB in pediatric patients have been reported in literature. Additionally, no evidence is reported about comparison between ESPB and psoas compartment block on hip surgery, for which both techniques have been proven to be effective. [14, 15, 16, 17].

The ESPB has been shown to allow for a reduction in the use of intraoperative and postoperative analgesics for opioid-sparing general anesthesia [9, 5, 6]. Anecdotal evidence, in the form of case studies and small case series, exists for numerous applications of the ESPB as part of a multimodal opioid-sparing analgesia regimen, including thoracotomy, thoracoscopic surgery and thoracic wall surgery [2, 3, 4, 18, 19], sternotomy [20], abdominal surgery [21, 22, 23, 24], hip joint and proximal femur surgery [15, 16, 17].

Outside the Operating Room, ESPB has been successfully employed for pain control in pediatric oncological palliative care [26].

Beyond the use of the ESPB as a routine technique in the pediatric anesthesiologist’s arsenal, it has also found applications as a problem-solver for particularly complex cases. It has the advantage that it can exploit craniocaudal spread and be performed at a point remote from the vertebral level of the incision site [27] which may be useful when there is incision site infection, and may be a valid alternative to neuraxial anesthesia in the case of spinal deformities, previous spinal surgery, or neuraxial spread of neoplastic disease [28, 29, 30]. A catheter ESPB has been used successfully when epidural and paravertebral catheters have not been possible due to coagulopathy [31]. The excellent safety profile of the ESPB for hemodynamic impact has further been exploited when clinicians have been reluctant to
utilize epidural anesthesia in patients with heart defects [32]. Analgesia through the perioperative period in emergency laparotomy has been provided even in very low birth weight prematures, despite small size [33].

**Anatomy, technique and diffusion of the anesthetic solution**

An accurate knowledge of pediatric anatomy is mandatory to perform an ESPB and achieve an adequate sensory blockade. Anatomical differences between adult and pediatric patients have to be considered: muscles, fascia and connective tissues under the skin are usually thinner and less rigid. Therefore a neonatal/pediatric probe, a shorter needle and lower volume of drugs should be taken into consideration.

Whatever the vertebral level, the target of this fascial plane block is the so-called erector spinae fasciae plane. This is a virtual space located under the erector spinae muscles, communicating with the paravertebral space, where the dorsal rami of the spinal cord are located (Figure 1).

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 muscle, longissimus dorsi and iliocostalis. These muscles are located posterolaterally to the vertebral column, lying between vertebral spinous processes, medially, and angles of the ribs, laterally.

During sonography, the probe should be initially placed at the midline of the spine with a transverse orientation, in order to visualize the spinous processes. Then a lateral movement allows one to locate the transverse processes. Maintaining a transverse orientation of the probe, an out of plane approach can be used, placing the needle with a cranio-caudal or caudo-cranial 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: trapezius, rhomboid, erector spinae muscle and transverse process of the respective vertebra.

The needle must be advanced to the tip of the transverse process, then local anesthetic can be injected to hydrodissect the plane deep to the erector spinae muscle, in order to verify proper injectate location, before injecting the residual volume. In alternative, should the patient’s weight allow for only very small volumes of LA, normal saline may be used for this initial hydrodissection in order to spare LA allowance.

The distance between the skin and the tip of the transverse process is very small in pediatric patients, with a great variability related to age and BMI. Therefore fine needle skills and a stable position are required to perform the block.

This approach, mostly used in a prone position in children, is similar to the first experiences [1] described in two adult patients in a sitting position. As the technique was applied more and more in the pediatric population and refined for the particular needs of these patients, several other approaches have been developed. In 2018, ESPB in the lateral decubitus position was described, placing the ultrasound probe transversely to get a midline view of the spinous and transverse processes of vertebra and erector spinae muscles, using an out-of-plane technique. [25]

The so-called Aksu approach has also been described, using an in-plane technique in the lateral decubitus position on pediatric patients for lumbar ESPB, thus eliminating the need to turn the anesthetized patient to prone and back to supine position for surgery. [34] The major disadvantage of this approach is the inability to visualize the craniocaudal spread of the local anesthetic, which is only possible upon turning the probe to the sagittal position after the block is applied [35].

Regardless of the technical approach, local anesthetics injected into the erector spinae fascial plane are meant to spread through the paravertebral space, not only at the level of injection site, but also cranially.
and caudally to reach distant dermatomes. However, the exact path of diffusion remains controversial. Dorsal rami emerge from the paravertebral space moving through the intertransverse connective tissue complex. The ventral rami continue from the paravertebral to intercostal space becoming intercostal nerves. The involvement of the ventral rami is a debatable issue, 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 the LA, but still most of them are described in adult patients, whose tissues are much more rigid and stiffer compared to children. Sonography is clearly a limited technique, but is still useful to study the cephalocaudal distribution of the injectate and feasible in the pediatric population. Munoz et al. [2] observed spreading of local anesthetic from T5 to T11 after the injection was performed at T8 with 8 ml solution in a 7-year-old patient. Distribution from T1 to T9 was documented via ultrasound in a 3-year-old patient after ESPB had been performed at T1 with 3.2 ml solution [18]. The same author, in another case report, visualized the spread of 1 ml of solution between T4 and L1 following an ESPB performed at T6 in a two month-old infant [36]. Yet again, a wide distribution between L1 and L4 was observed following the administration of 4.5 ml of solution at L2 in a 4 year-old patient [37].

A cadaver study analyzed the spread of a methylene blue dye solution in two embalmed preterm still born neonates, weighing 1.6 and 0.6 kg. The first cadaver received unilateral injection at T5 level with 0.5 ml of solution and a superficial cephalocaudal diffusion from T2 to T12 was seen, with deeper staining of ventral and dorsal roots and ganglia between T3 and T6. In the second cadaver, where an injection of 0.2 ml was performed at 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 were stained, as well as the dura mater surrounding the spinal cord [38].
CT scanning with multi-slice and 3D technology were used to assess the spread of an iodinated contrast dye in a fresh unembalmed preterm neonatal cadaver weighing 2.7 kg. A first injection with 2.3 ml was performed at T8 level on the right side and a second one on the opposite side at T10 level. A three-dimensional reconstruction revealed a diffusion of the dye from T6 to T9 on the right side and from T9 to T11/T12 on the left side. The contrast dye was seen in the paravertebral space but not in the epidural space, spreading over the costotransverse ligament and reaching the intercostal space. Epidural space sparing could have been explained by in-vivo factors like intrathoracic pressure changes and the absence of muscle tone and tissue tension. The study suggested a 0.3-0.4 ml volume per dermatome, with 3 to 4 dermatomes involved with the ESPB [39].

The paucity of data regarding injectate spread in children leads us to look to studies in adults, while recognizing the great differences which might be encountered between adult and pediatric patterns of diffusion possibly related to multiple factors: developmental formation of the vertebral curvature, the more elastic pediatric spine, and less dense ligaments and cartilaginous laminae [38]. The distribution of the injected drugs in the adult population has been observed with MRI and cadaver examination. These studies suggest different possibilities on the lateral and anterior diffusion of the local anesthetics. Beyond anatomy, the vertebral level [40] and the drug volume [41] are also relevant factors in the spread of injected LA. The analysis of cadaver samples revealed anterior and posterior diffusion of the injectate with different percentages at different vertebral levels, with inconclusive results. Paravertebral, intercostal and epidural spread are described, but these findings are not consistent among the available studies [42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52]. Hence MRI and studies on cadavers furnish uncertain findings on adults, with great variability presumably related to site of injection, volume of solution and physical characteristics of the tissues.
Although the efficacy of the technique is evident from its successful clinical application, the evidence for the precise diffusion of the injected solution in children is still not completely clear, with only two studies on neonatal cadavers and several case series reporting data from sonographic imaging in vivo.

**Choice and dosage of local anesthetics**

The pharmacological approaches described in the current literature are highly inconsistent, as the procedure has multiple applications and specific pharmacological conduct for such a multitude of clinical contexts is variable.

Bupivacaine, Ropivacaine and Levobupivacaine, with quite different concentrations and volumes, have been utilized most commonly in ESPB in pediatric patients, with no great differences in outcomes in terms of postoperative pain management.

The first documented application of the ESPB in children in literature used 0.5% Bupivacaine 14 ml in a seven-year-old boy undergoing surgery for the treatment of a tumor of the 11th rib, with a single shot injection being performed at T8 [2].

Most of the pediatric ESPB currently described in literature are performed with 0.25% Bupivacaine, with volumes ranging from 0.3 to 0.6 ml/kg [37, 53, 54].

A 1:1 solution of 0.25% Bupivacaine and 1% Lidocaine with a total volume of 0.2 ml/kg was utilized in a single shot injection for an ESPB in a 3-year-old girl weighing 16 kg, undergoing surgical resection of dorsal lipoma. The patient was discharged 4 hours after surgery with full pain control [18].

The same solution with a dosage of 0.4 ml/kg was administered in a single shot ESPB in a 2-month-old infant before inguinal hernia repair [36].

The use of levobupivacaine 0.2%, 4 ml, for thoracic surgery in a five-month old female was reported [55] to enhance recovery after surgery.
First continuous ESPB was described in a 3-year-old boy at the end of a thoracotomy, placing the catheter at T9 level with an initial 0.25% Levobupivacaine 8 ml injection. Two hours later a Patient Controlled Analgesia (PCA) pump with 0.1% Levobupivacaine 3 ml/h continuous infusion was started, with the possibility of 1.5mL rescue boluses at 30-minute lockout intervals. At the 4th postoperative day the infusion was stopped, only two 1.5 ml rescue boluses were necessary and no other medications were required to control the pain [32].

A 7-month-old infant received 0.2 % Ropivacaine through a catheter placed at T6 level, 1ml/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 [56].

A retrospective review of a single center described the efficacy of 0.5% Ropivacaine in ESPB in children, with an initial loading dose of 0.4ml/kg, followed by intermittent boluses with 0.2-0.3%, 0.3ml/kg, administered hourly[57].

In any case, pharmacokinetic variability must be accepted in all fascial plane blocks. As opposed to peripheral nerve blocks, where anesthetics are precisely deposited around a specific nerve, a consistent intensity of sensory blockade cannot be expected in a fascial plane block. Moreover, a different tissue laxity in pediatric patients could contribute to increase such variability. As a result, the same sensory block in different children is difficult to replicate, even with the same practitioner.

More studies are necessary to guide type, dosage and duration of administration of local anesthetic and adjuvants, in order to create specific protocols for pediatric ESPB in different clinical applications.

**Safety profile and Adverse events**

Regional anesthesia is considered to be generally safe in the pediatric population, although caution must be exercised especially when applying these techniques in infants [58]. Furthermore, these techniques may be safely utilized under general anesthesia [59]. The ESPB in particular appears to be
very 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. It is widely accepted that the ESPB may even be conducted safely on patients with coagulopathy [31].

While the standard contraindications and possible complications of any peripheral block, including Local Anesthetic Systemic Toxicity (LAST), allergic reactions, or motor block, may potentially be a risk of the ESPB, the available literature documents a promising safety profile in children, with most studies documenting no adverse events or complications. It does not pose the risk for epidural hematoma which may be encountered in neuraxial blocks.

Some minor adverse events, such as catheter occlusion, displacement or unintentional removal have been reported [6, 57]. Rare cases of bradycardia or possible LAST have been reported, but quickly reversed [60, 61]. While injection site infection may be a contraindication to peripheral nerve blocks, the possibility to inject local anesthetic in a site distant to the target in a fascial plane block may allow operators to safely implement the ESPB even in cases of surgical site infection. It has been suggested that pneumothorax may be a possible complication of the ESPB [62, 63], however literature search yielded no documented episodes, and experienced operators hold that ultrasound guidance, fine needle skills, and preventative techniques can minimize this risk [25].

**Conclusions**

Despite significant interest in the ESPB in the pediatric anesthesia community due to its versatility, simplicity, and safety, available evidence is still anecdotal and dishomogeneous with few rigorous trials, yielding low-quality evidence and no clear protocol to apply.

When considered together, available data suggests that the ESPB 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 considered this procedure a valid alternative to
other loco-regional techniques and to epidural anesthesia. The choice of local anesthetic is quite variable among different practitioners, with single shot or continuous infusion being described in different surgeries. Furthermore, the distribution of the injected solution remains controversial.

Hence more well-designed controlled randomized trials are needed to clarify specific approaches in performing ESPB in different clinical applications in the pediatric population.
**List of abbreviations:**

BMI (Body Mass Index)
ERAS (Enhanced Recovery After Surgery)
ESPB (Erector Spinae Plane Block)
FLACC (Face, Legs, Activity, Cry, and Consolability)
IIHB (Ilioinguinal/iliohypogastric Nerve Block)
LA (Local Anesthetic)
LAST (Local Anesthetic Systemic Toxicity)
NRS (Numeric Rating Scale)
MRI (Magnetic Resonance Imaging)
PCA Patient Controlled Analgesia
PIB (Programmed intermittent bolus)
QLB (Quadratus Lumborum block)
VAS (Visual analogue scale)
References


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<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Age range</th>
<th>Indication</th>
<th>Timing</th>
<th>Intervention</th>
<th>Block Related Adverse Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakshi, 2020</td>
<td>[30]</td>
<td>2 3 years</td>
<td>inginal hernia repair</td>
<td>Preoperative</td>
<td>Single-shot T5 0.2 mL/kg bupivacaine 0.25% 0.2 mL/kg lidocaine 1%</td>
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<td>Matee, 2017</td>
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<td>Single-shot T5 1 mL bupivacaine 0.5% with epinephrine 5 mcg/mL</td>
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<td>[25]</td>
<td>2 11 years</td>
<td>Abdominal surgery</td>
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<td>Single-shot T11 bilateral 0.25% bupivacaine 0.5 mL/kg</td>
<td>None</td>
</tr>
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<td>Aksu, 2018</td>
<td>[53]</td>
<td>2 5 months</td>
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<td>Single-shot T12 0.5 mL/kg 0.25% bupivacaine</td>
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</tr>
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<td>De la Cuadra-Fontaine, 2018</td>
<td>[32]</td>
<td>1 3 years</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Single-shot T10 0.5 mL 0.25% bupivacaine; Continuous infusion 0.1% bupivacaine 3 mL/h + PCA 1.5 mL with lockout 30min</td>
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<td>[37]</td>
<td>1 4 years</td>
<td>hip surgery</td>
<td>Preoperative</td>
<td>Single-shot L2 0.3 mL/kg 0.25% bupivacaine</td>
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<td>Hernandez, 2018</td>
<td>[18]</td>
<td>3 1 year</td>
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<td>Single-shot T1 0.1 mL/kg bupivacaine 0.25% 0.1 mL/kg lidocaine 1%</td>
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<td>Kaplan, 2018</td>
<td>[56]</td>
<td>1 7 months</td>
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<td>Preoperative</td>
<td>Single-shot levobupivacaine 0.2 mL of 0.25% for hydrodissection and catheter placement, then continuous infusion through catheter 0.2% bupivacaine 1 mL/h Catheter removed at 72 h</td>
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<td>[21]</td>
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<td>Preoperative</td>
<td>Bilateral catheters T8-T10 0.5 mL 0.25% bupivacaine followed by 0.5 mL/kg 0.25% bupivacaine intrathecal. Postoperative 0.5 mL/kg 0.25% bupivacaine until catheter removal 72h postop.</td>
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<td>Munthesy, 2018</td>
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<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Catheter tip T8 Bupiv 0.3 mL/kg 0.25% bupivacaine 0.2% every hour during surgery, then 0.5 mL/kg bupivacaine 0.5% at end of surgery. Catheter removed at 48h.</td>
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<td>Thomas, 2018</td>
<td>[23]</td>
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<td>Single-shot Bilateral T9 0.25% bupivacaine 0.5 mL/kg (x2)</td>
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<td>1 17 years</td>
<td>Cardiac surgery</td>
<td>Preoperative</td>
<td>Bilateral catheter tip T10 0.5 mL 0.75% bupivacaine (x2) prophylactic, then postoperative alternating catheter bupivacaine 0.1 mL/kg every 60 min. Catheter removal at 72h.</td>
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<td>Adler, 2019</td>
<td>[4]</td>
<td>1 3 weeks</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Initial postoperative bolus through catheter T6 (non dilution q30 min) bupivacaine 0.5% (0.25mg/kg/h) in solution for 48h Catheter removed after 48h</td>
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<td>[68]</td>
<td>1 8, 11, 13 years</td>
<td>Laparoscopy</td>
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<td>Single-shot bilateral T7; 0.5 mL/kg 0.25% bupivacaine (max 20ml) (x2)</td>
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<tr>
<td>Aksu, 2019</td>
<td>[34]</td>
<td>2 2 years</td>
<td>Thoracic surgery</td>
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<td>Single-shot lumbar ESPB 0.25% bupivacaine 0.5 mL/kg (does not specify vertebral level)</td>
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<td>Altunparmak, 2019</td>
<td>[69]</td>
<td>1 1 days</td>
<td>inginal hernia repair</td>
<td>Preoperative</td>
<td>Single-shot T4 T6 0.5 mL, 0.25% bupivacaine (x2)</td>
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<td>Balaban, 2019</td>
<td>[16]</td>
<td>1 6 years</td>
<td>Femur fixation</td>
<td>Postoperative</td>
<td>Single-shot T3 20 mL 0.25% Bupivacaine</td>
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<tr>
<td>Cesar, 2019</td>
<td>[18]</td>
<td>3 5-12 years</td>
<td>inginal hernia repair</td>
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<td>Single-shot 0.25% bupivacaine with a volume of 0.5 mL/kg (vertebral level not specified)</td>
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<td>[15]</td>
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<td>iliac crest autograft</td>
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<td>Single-shot catheter tip at L2 1.5 mL 0.3% Bupivacaine intraoperative. 11ml 0.2% ropivacaine qph postoperative days 0-5.</td>
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<td>Single-shot T4 5 mL bupivacaine 0.25%</td>
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<td>Single-shot 0.5% bupivacaine + Dexamethasone (1 bilateral)</td>
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<td>[72]</td>
<td>1 4 years</td>
<td>Hip surgery</td>
<td>Preoperative</td>
<td>Single-shot L4 ESPB in combination with percutaneous nerve block 0.25% bupivacaine total 20ml (0.25% bupivacaine)</td>
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<td>Ince, 2019</td>
<td>[73]</td>
<td>1 13 years</td>
<td>Abdominal surgery</td>
<td>Preoperative</td>
<td>Single-shot Bilateral L2-3; 4A not specified</td>
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<td>Karaca, 2019</td>
<td>[67]</td>
<td>4 10-14 years</td>
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<td>Bilateral single-shot T7 with total 2.5mg/kg bupivacaine</td>
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<td>[55]</td>
<td>1 5 months</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Single-shot T4 (nurse); 6ml, 0.3% levobupivacaine after induction, 4ml, 0.1% levobupivacaine before emergence</td>
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<tr>
<td>Patel, 2019</td>
<td>[31]</td>
<td>1 6 years</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Single-shot T5; 10 mL 0.5% Bupivacaine; Continuous infusion through catheter 0.2mg/kg/h Ropivacaine. Catheter removed at 96h.</td>
<td>None reported</td>
</tr>
<tr>
<td>Tan, 2019</td>
<td>[74]</td>
<td>1 16 years</td>
<td>Spinal surgery</td>
<td>Intraoperative surgical</td>
<td>Bilateral catheters tip at T8; At end of surgery 20 mL lidocaine 0.5% (x2). Postoperative 20-22ml 0.5% lidocaine alternating right and left side every 60 minutes. Catheter removed at 48h.</td>
<td>None reported</td>
</tr>
<tr>
<td>Bac, 2019</td>
<td>[26]</td>
<td>1 15 years</td>
<td>Palliative Pain</td>
<td>Catheter placed under general anesthesia in hospital before release to home care</td>
<td>Bilateral tunneled catheters T12 (advanced to T12) Single-shot 1cc 0.3% ropivacaine PIB 10 mL 0.2% bupivacaine every 2h alternating sides; Catheter removal after 7 days</td>
<td>None</td>
</tr>
<tr>
<td>Wyatt, 2019</td>
<td>[75]</td>
<td>1 17 years</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Single-shot T5 with catheter placement, 25ml 0.5% ropivacaine; Continuous infusion through catheter 0.2% bupivacaine 4ml/h during surgery, 0.1% ropivacaine 10ml/h postoperative. Rescue bolus 4ml ropivacaine 0.25% mixed + 1ml lidocaine 2% upon arrival in ICU Catheter removed at 96h.</td>
<td>None reported</td>
</tr>
<tr>
<td>Agiri, 2020</td>
<td>[75]</td>
<td>1 9 months</td>
<td>Abdominal surgery</td>
<td>Postoperative</td>
<td>Single-shot T10 + T11 Bupivacaine 0.25% (3ml T10 + 3ml T11)</td>
<td>None</td>
</tr>
<tr>
<td>Aksu, 2020</td>
<td>[77]</td>
<td>1 6 months</td>
<td>General surgery</td>
<td>Preoperative</td>
<td>Single-shot Midazol anesthetic; 8 mL of 0.25% Bupivacaine</td>
<td>None</td>
</tr>
<tr>
<td>Ayubak, 2020</td>
<td>[78]</td>
<td>1 5 years</td>
<td>chest tube insertion</td>
<td>Preoperative</td>
<td>Single-shot T6-7 T7; 0.5 mL, 0.25% bupivacaine</td>
<td>None reported</td>
</tr>
<tr>
<td>Baidi, 2020</td>
<td>[30]</td>
<td>2 3 years</td>
<td>Thoracic surgery</td>
<td>Preoperative, postoperative</td>
<td>Intermittent bolus 6ml 0.25% bupivacaine every 4h for 4d; Intermittent bolus of 5cc 0.25% bupivacaine every 8h for 4d.</td>
<td>None</td>
</tr>
<tr>
<td>Buourn, 2020</td>
<td>[33]</td>
<td>1 3 days</td>
<td>Abdominal surgery</td>
<td>Preoperative</td>
<td>Single-shot Bilateral T7 0.5 mL, 0.25% bupivacaine (x2)</td>
<td>None reported</td>
</tr>
<tr>
<td>Author</td>
<td>Year</td>
<td>Age</td>
<td>Diagnosis</td>
<td>Intervention</td>
<td>Local Anesthetic Details</td>
<td>Adverse Events</td>
</tr>
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</tr>
<tr>
<td>Çiftçi, 2020</td>
<td>79</td>
<td>12 years</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Single-shot T3; 18mL, 0.25% bupivacaine</td>
<td>None reported</td>
</tr>
<tr>
<td>Ekinci, 2020</td>
<td>80</td>
<td>2 years</td>
<td>Shock wave lithotripsy</td>
<td>Preoperative</td>
<td>Single shot T10; 6mL, 0.25% bupivacaine</td>
<td>None reported</td>
</tr>
<tr>
<td>Gupta, 2020</td>
<td>81</td>
<td>2 years</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Single-shot T5; 8mL, 0.375% ropivacaine + 10 mcg clonidine</td>
<td>None reported</td>
</tr>
<tr>
<td>Le, 2020</td>
<td>28</td>
<td>17 years</td>
<td>Renal procedure</td>
<td>Preoperative</td>
<td>Bilateral catheter T5; 20mL 0.2% ropivacaine, preoperative. Continuous inf- 6-8mL/6hr ropivacaine 0.15%, Raneu bupivacaine 0.15% on each side on postoperative day 3. Catheters removed at 72h.</td>
<td>None reported</td>
</tr>
<tr>
<td>Swanson, 2020</td>
<td>82</td>
<td>2 days</td>
<td>Thoracic surgery</td>
<td>Preoperative</td>
<td>Single-shot T5-T6 with hydrodissection + 2mL 3% chloroprocaine. At the surgery: 1mL 0.1%; Continuous infusion: 1.5% chloroprocaine at 0.25mL/hour. Catheter removed at 140h.</td>
<td>None reported</td>
</tr>
<tr>
<td>Uysal, 2020</td>
<td>83</td>
<td>5 months</td>
<td>Diaphragmatic hernia</td>
<td>Postoperative</td>
<td>Single-shot (twice): T6-T10 0.5mL/kg 0.25% bupivacaine.</td>
<td>None reported</td>
</tr>
<tr>
<td>Bonfiglio, 2021</td>
<td>89</td>
<td>19 years</td>
<td>Thoracoscopy</td>
<td>Preoperative</td>
<td>Single-shot T4; 10 mL of 0.25% levobupivacaine + 30 μg of dexmedetomidine Continuous infusion 0.125% levobupivacaine 10 mL + PCI 3 mL with lidocain 60 min; Catheter removed on postoperative day 3.</td>
<td>None reported</td>
</tr>
<tr>
<td>Bosimic, 2021</td>
<td>17</td>
<td>2 years</td>
<td>Hip surgery</td>
<td>Preoperative</td>
<td>Single-shot T4 Lidocaine 2% 2mL 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/hour via infusion pump. Catheter removed at 72h.</td>
<td>None reported</td>
</tr>
<tr>
<td>Garbis, 2021</td>
<td>60</td>
<td>1 day 25 days</td>
<td>Thoro-abdominal surgery</td>
<td>Postoperative; preoperative</td>
<td>Single-shot T4; T8 0.75 mL 0.2% bupivacaine. Bradycardia 10 min after block (treated with atropine) in 1 case.</td>
<td>None reported</td>
</tr>
<tr>
<td>Karuppiah, 2021</td>
<td>84</td>
<td>not specified</td>
<td>Thoracic surgery</td>
<td>not specified</td>
<td>Single shot 0.25% bupivacaine with epinephrine 1:200,000 up to 1mL/kg.</td>
<td>None reported</td>
</tr>
<tr>
<td>Kopši, 2021</td>
<td>27</td>
<td>2-10 years</td>
<td>Multiple surgery</td>
<td>Preoperative</td>
<td>Single shot preoperative upon catheter placement, 0.25% levobupivacaine 0.6-1mL/kg. Then postoperative continuous infusion through perineural catheter T1-T5 for thoracotomy; T3 for bronchoscopy; T12-L2 for appendectomy and inguinal hernia; L1-L2 for orthopedic and urologic; and L4 for hip surgery. Catheters removed within 24h after surgery.</td>
<td>None reported</td>
</tr>
<tr>
<td>Pts</td>
<td>Age range</td>
<td>Study Design</td>
<td>Indication</td>
<td>Timing</td>
<td>Intervention</td>
<td>Block Related Adverse Events</td>
</tr>
<tr>
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<tr>
<td>Aksu, 2019 [8]</td>
<td>57</td>
<td>1-7 years</td>
<td>Prospective double blind randomized trial</td>
<td>Pelvic Small Surgery</td>
<td>Preoperative</td>
<td>Single shot L1 ESPB vs. Single shot Quadratus Lumborum block 0.5ml/kg 0.25% bupivacaine</td>
</tr>
<tr>
<td>Aksu, 2019 [64]</td>
<td>141</td>
<td>0.25-17 years</td>
<td>Retrospective cohort study</td>
<td>Thoracic, abdominal and pelvic surgery</td>
<td>Preoperative</td>
<td>Unilateral (112) or bilateral (29) single shot T4 to S4 0.25% bupivacaine 0.5ml/kg (max 20ml)</td>
</tr>
<tr>
<td>Eldousm, 2019 [11]</td>
<td>60</td>
<td>6 months-3 years</td>
<td>Prospective randomized control trial</td>
<td>Unilateral inguinal hernia repair</td>
<td>Preoperative</td>
<td>Single shot L1 level ESPB vs. Inguinal iliopsoas nerve block 0.5ml/kg 0.125% bupivacaine + fentanyl 1mg/ml, regimen</td>
</tr>
<tr>
<td>Holland, 2019 [65]</td>
<td>154</td>
<td>2 days-19 years</td>
<td>Retrospective case series</td>
<td>Thoracic, abdominal and pelvic surgery</td>
<td>Preoperative</td>
<td>Single shot ESPB (125 unilateral, 39 bilateral) 0.25% - 0.5% bupivacaine with 1:200 000 epinephrine for placement (83%); Mean: 0.3 ml/kg for monolateral block and 0.3 ml/kg(x2) for bilateral block</td>
</tr>
<tr>
<td>Kaushal, 2019 [5]</td>
<td>60</td>
<td>mean age 28.5 months</td>
<td>Prospective double blind comparative trial</td>
<td>Cardiac surgery</td>
<td>Preoperative</td>
<td>Single shot Bilateral T3 1.5mg/kg 0.2% ropivacaine (x2) vs. no block</td>
</tr>
<tr>
<td>Mostafa, 2019 [9]</td>
<td>60</td>
<td>3-10 years</td>
<td>Prospective randomized control trial</td>
<td>Open splenectomy</td>
<td>Preoperative</td>
<td>Single shot Bilateral T7 0.3 ml/kg 0.25% bupivacaine (x2) vs. bilateral sham ESPB 0.3 ml/kg normal saline (x2)</td>
</tr>
<tr>
<td>Jambotkar, 2020 [65]</td>
<td>30</td>
<td>1-12 years</td>
<td>Prospective observational study</td>
<td>Thoracoectomy</td>
<td>Preoperative</td>
<td>Single shot T4 0.25% bupivacaine 0.5ml/kg</td>
</tr>
<tr>
<td>Macaire, 2020 [6]</td>
<td>50</td>
<td>mean age 25 mo</td>
<td>Prospective randomized double blind controlled trial</td>
<td>Cardiac surgery</td>
<td>Preoperative followed by postoperative programmed intermittent bolus regimen</td>
<td>Catheter ESPB (17 unilateral, 5 bilateral, 22 thoracic, 5 lumbar) initial loading dose 0.4ml/kg ropivacaine 0.3%, postoperative bolus of 0.2ml/kg ropivacaine 0.2%, postoperative programmed intermittent bolus maximum 0.5mg/kg/h</td>
</tr>
<tr>
<td>Munoz, 2020 [57]</td>
<td>22</td>
<td>11 months-17 years</td>
<td>Retrospective cohort study</td>
<td>Thoracic, abdominal, hip surgery</td>
<td>Preoperative (1 pt postoperative) followed by postoperative programmed intermittent bolus regimen</td>
<td>Catheter ESPB (17 unilateral, 5 bilateral, 22 thoracic, 5 lumbar) initial loading dose 0.4ml/kg ropivacaine 0.3%, intrathecal bolus of 0.2ml/kg ropivacaine 0.2%, postoperative programmed intermittent bolus maximum 0.5mg/kg/h</td>
</tr>
<tr>
<td>Singh, 2020 [10]</td>
<td>40</td>
<td>2-10 years</td>
<td>Prospective randomized control trial</td>
<td>Lower abdominal surgery</td>
<td>Preoperative</td>
<td>Single shot Bilateral L1 0.5ml/kg 0.25% bupivacaine (x2) vs. no block</td>
</tr>
</tbody>
</table>
Figure 1. ESPB visual explanation