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REVIEW

# The Analgesic Mechanism and Recent Clinical Application of Erector Spinae Plane Block: A Narrative Review

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**Abstract:** Now, the erector spinae plane block (ESPB) is widely used in various thoracolumbar surgeries. It has unique advantages: simple and convenient operation, low safety risks, and reduced opioid use. The ESPB is used in thoracic surgery, abdominal surgery, and spinal surgery. There are also relevant research reports on postoperative analgesia during general anesthesia surgery. This article searches the PubMed and Web of Science databases to find and screen relevant studies on ESPB since 2019 and retrospectively summarizes the current indications of ESPB. The methodological quality of the included studies was assessed using the Cochrane bias risk tool. The results showed that the current research on ESPB generally provides low-level clinical evidence. The complex anatomy of the erector spinae muscles is both responsible for its unique advantages and restricts its development. Few anatomical studies have clearly and completely demonstrated the diffusion relationship of local anesthetics among the anatomical structures of the erector spinal muscles. The uncontrollability of the diffusion plane prevents ESPB from being applied on a wider scale with a high level of evidence. To further clarify the scope of application of ESPB and achieve the best analgesic effect, in the future, we should focus on the unique anatomical course and distribution of the erector spinal muscles and their fascia and nerves. It is necessary to combine anatomical, imaging, and histological methods to obtain high-quality evidence to guide clinical application.

**Keywords:** erector spinae plane block, fascial plane block, anatomy, regional anesthesia, pain, nerve block

## Introduction

The erector spinae plane block (ESPB) was first described in 2016 and belongs to the family of fascia plane blocks. It involves injecting local anesthetics into the plane between two layers of fascia to block nerves within that plane or between adjacent tissues.[1,2] Clinical studies have shown that ESPB blocks pain signal transmission in the posterior or anterior branches of spinal nerves, leading to extensive skin sensory analgesia.[3] Compared to the epidural or paravertebral block, ESPB is further away from the pleura and intestinal structures, causing less damage to important nerves, blood vessels, and pleura. The risk of systemic toxicity caused by local anesthetics is lower,[3] and the operation is simple and easy. Numerous clinical research articles have shown that the use of ESPB can reduce the consumption of opioids.[3–8] Therefore, it has aroused widespread concern. A great deal of literature supports its efficacy in many clinical environments and has been used to treat acute and chronic pain in a variety of clinical conditions, including cardiac surgery,[9,10] chest surgery,[1,5,11] chest trauma,[12–15] abdominal surgery and spinal surgery.[1,16–20] Some clinical randomized controlled trials have also reported that ESPB has a significant analgesic effect compared with general anesthesia alone.[21,22] Although a large amount of clinical and anatomical literature has been published in recent years, there is still no consensus on its indications, analgesic mechanism, diffusion plane, and the best analgesic effect in different clinical operations. In particular, how to accurately control the plane of block diffusion is the key to determining the analgesic

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area and surgical indications. This is not only related to the injection but also closely related to the anatomical structure of the erector spine muscle group. This paper reviews the articles on ESPB in the past six years, focuses on the latest progress in the clinical application of ESPB, and explains the mechanism of the horizontal block of erector spine muscle from the point of view of the anatomical structure of the erector spine muscle, in order to provide more treatment basis for doctors when using ESPB.

# Materials and Methods

## Search Strategy

This is a narrative review. The two authors searched the PubMed and Web of Science databases respectively, looking for articles published from January 1, 2019, to March 1, 2024, with the keywords "erector spinae plane block; fascial plane block; regional anesthesia; pain" word article. References cited in reviews or relevant articles were searched for additional eligible articles, and all possible articles were searched independently by two authors. First, the title and abstract of each article were reviewed, irrelevant articles were excluded, and then the remaining articles were subjected to a comprehensive test analysis. Any differences will be discussed in the group until everyone is on the same page.

## Inclusion and Exclusion Criteria

Articles that met the following inclusion criteria were included: (1) patients were older than 18 years old; (2) patients must have undergone ESPB, and visual analog scale (VAS) or numeric rating scale (NSR) or ODI were recorded to evaluate the patients before and after the block degree of pain. (3) It must be a randomized controlled experiment, non-observational experiment, or basic research. In addition, articles must be published in English. Articles were rejected if they met the following exclusion criteria: the article was an editorial, letter, review, conference abstract, conference proceedings, personal communication, and case report; was an animal study; and did not have a VAS or NSR score recorded. A total of 1168 articles were generated from the preliminary search. After eliminating duplicate articles, there were 1063 articles. Upon reviewing the title and abstract, 999 articles were excluded based on inclusion and exclusion criteria, leaving 64 articles. Following a thorough reading of the entire articles, 23 were excluded based on the criteria, and 41 articles were ultimately chosen for inclusion (Figure 1).

## Quality Assessment

Two authors (JHY and YS) evaluated the methodo-logical quality of the trials according to the Cochrane risk-of-bias tool.[23] Each item was categorized as having a "low", "unclear", or "high" risk of bias. Any uncertainty arose were resolve by discussion between two researches until a consensus was achieved.

# Results

The 41 articles ultimately included in this review include: 6 anatomical studies,[24–29] 5 prospective studies,[30–34] and 30 randomized controlled trials.[5–9,17–21,35–52]

## Erector Spinae Anatomy

The erector spinal muscle is a widely distributed muscle in the back, belonging to the composite muscle group. It consists of three muscles: ilia rib muscle, longest muscle, and spinous muscle. Its main function is to keep the body upright. These muscles rise from the back of the sacrum to the back of the occipital bone, filling the deep groove between the spinous process and rib angle.[53] Due to the distribution of the erector spinal muscle on most horizontal planes of the back, this anatomical structure determines that ESPB can be used for chest, waist, and abdominal surgeries. In the chest, the erector spinal muscles from the outside to the inside are the thoracic rib muscle, the longest pectoral muscle, and the thoracic spine muscle.[54] The longissimus thoracis is the largest component of the erector spinae. It is a long muscle made up of many muscle bundles arranged specially. It consists of two parts, the thoracic and lumbar. The lumbar muscle bundles are well developed, and the muscle fibers gradually run outward and downward. The muscle bundles originating from the upper four lumbar vertebrae gradually become a flat tendon and cover the outer edge of the muscle, separating it

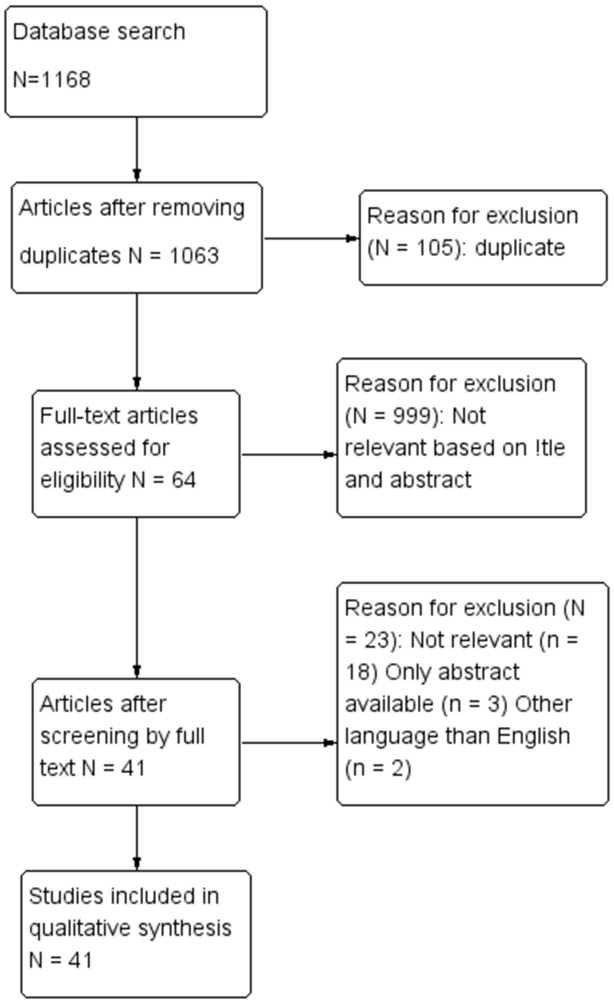


**Figure 1** Process of searching and screening literature.

from the iliocostalis muscle, called the lumbar intermuscular aponeurosis.[54] The thoracolumbar erector spinae are covered by the thoracolumbar fascia.[55] In the lumbar region, the erector spinae are located in the gap between the posterior and medial layers of the thoracolumbar fascia. The multifidus muscle is distributed throughout the spinal region, thickens as it descends to the lumbosacral region, and protrudes to the medial side of the spinous process, covering the posterior part of the sacrum.[56] The erector spinae, together with the transversospinalis muscle group (consisting of semispinalis, multifidus and rotatores) adjacent to the spinous process, form a paraspinal muscle column covering the lamina and transverse process.[54] Normally, the longissimus lumbar and multifidus muscles are separated by a wide fissure filled with fat and veins.[54] It is noteworthy that this wide aperture is composed of smooth tendons on both sides. This is an interesting structure because it is a vertical structure composed of multiple continuous vertebral planes rather than a single horizontal structure. This structure may be an important factor in the extension of local anesthetics to more planes in ESPB.

The anterior and posterior roots of the spinal nerves originate from the spinal cord and merge into one spinal nerve in the intervertebral foramen.[54] Each thoracolumbar spinal nerve divides into an anterior branch and a posterior branch shortly after exiting the intervertebral foramen. The distribution of the posterior branches of spinal nerves is segmental and crisscrossed. It bypasses the transverse processes of the lower vertebrae, then enters and innervates the erector spinal muscles.[57] Its branches continue to ascend to superficial tissues (Figure 2). The posterior branch is divided into lateral and medial branches in the chest and medial, middle, and lateral branches in the lumbosacral part. The erector spinal muscles are innervated by the lateral and medial branches of the posterior ramie of spinal nerves in the lower neck, chest,

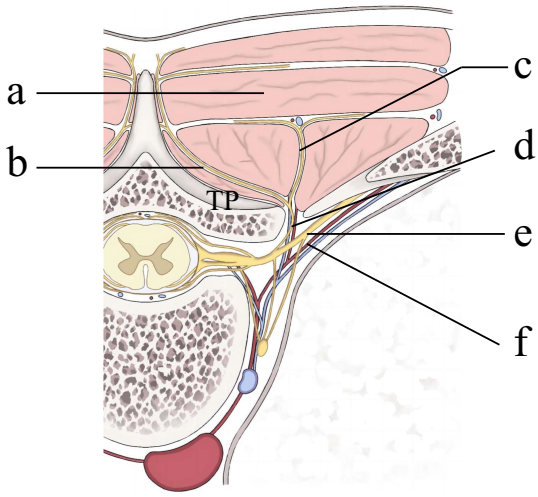


**Figure 2** Distribution of erector spinal muscles in the chest and their innervation. (**a**) erector spinal muscle; (**b**) medial branch of spinal nerve; (**c**) lateral ramus of spinal nerve; (**d**) posterior rami of spinal nerves; (**e**) anterior rami of spinal nerve; (**f**) intercostal arteries;TP, Transverse process.

and lumbar region.[54] The anterior branches of the T1-T12 spinal nerves branch to the ribs to form the intercostal nerves, which run between the intercostal muscles and the external intercostal muscles. There are various muscular branches along the way, and the lateral cutaneous branches originate from the costal angle.[58] The spinal nerves are also connected to the communicating branches of the sympathetic trunk located in front of the vertebral body. Although the anatomical course is complex, the anterior and posterior branches of the spinal nerves and their branches that innervate the fixed area are unavoidable contents in studying the ESPB and determining its diffusion plane.

## Clinical Application of ESPB

Interfascial plane blocks are becoming increasingly popular as ultrasound technology is introduced into routine procedures for regional anesthesia and pain management. ESPB quickly became popular due to its relative simplicity, ease of use, safety, and obvious analgesic effect,[6] arousing great clinical and academic interest in many treatments. ESPB was originally used to treat chronic chest pain.[56] Recently, more and more studies have found that the erector spinae fascia extends to the entire spine, and ESPB can block the spinal nerves from the shoulders to the lumbar spine,[5–8,17–19] so its indications have expanded. Since ESPB requires injection of local anesthetic into the ventral aspect of the erector spinal muscles, techniques such as the "sacral" ESPB are not discussed, as it injects local anesthetic into the ventral aspect of the multifidus muscles.[59] Likewise, the newly described "cervical" ESPBs are not discussed because their preliminary description requires further clinical validation.[60] Recent literature suggests that ESPB is effective for both acute and chronic persistent pain. ESPB single-point injection can cover multiple nerve areas and is used for breast,[61–65] chest,[14,66] abdominal surgeries, and even spine-related surgeries,[16–18,20] which has good application prospects. The table below lists the use of ESPB in different surgeries.

## Thoracic Surgery

ESPB allows patients to be in different positions during surgery, and anatomical landmarks can be easily identified using appropriate ultrasound probes. Because the target is far away from the pleura, blood vessels, and nerves, complications of ESPB are rare under proper ultrasonography.[66] ESPB has proven to be particularly valuable in chest trauma,[14] cardiac surgery,[10] and the rescue of high-risk outpatients. Due to its good analgesic effect, it can significantly improve respiratory function,[12] reduce respiratory complications and intensive care hospitalization time,[14] stay away from the spinal cord and major blood vessels, and minimize the risk of nerve damage and fatal bleeding. ESPB can reduce the consumption of opioids and further promote the recovery of postoperative cardiac function.[67] As a result, ESPB is widely used in minimally invasive thoracic surgery to provide anesthesia and pain relief (Table 1).

**Table 1** Application of ESPB in Thoracic Surgery

| aAuthors | Patients | Type of surgery | Analgesic method(s) | Assessment method(s) | Detection time | Results | Conclusions |
|---|---|---|---|---|---|---|---|
| **Meliha 2023**[5] | N=74 | VATS | ESPB, Standard opioid-based balanced anesthesia | VAS, Opioid consumption | 24h | The ESPB group required significantly lower doses of morphine and lower VAS in the first 24 hours after surgery. | ESPB is a promising option for patients undergoing thoracoscopic lobectomy, may reduce the need for postoperative opioids, and improve postoperative pain management. |
| **Wu 2023**[7] | N=150 | Uniportal Thoracoscopic Surgery | ESPB, SAPB | NRS, Opioid consumption | 24h | Compared to the control group, the consumption of sufentanil in both intervention groups was significantly reduced. At 6 hours postoperatively, there were fewer patients with moderate to severe pain in the ESPB group compared to the SAPB group. | Both the ESPB and SAPB demonstrate effective reduction in postoperative opioid consumption and the need for rescue analgesics compared to the control group. |
| **Mo 2023**[8] | N=92 | VATS | ESPB&SAPB(Group S), PVB (Group P) | VAS, QoR-15, Opioid consumption | 1h, 2h, 4h, 8h, 24h | The morphine consumption at postoperative 4 and 8 h and the incidence of ipsilateral shoulder pain were significantly lower in group S than in group P. The QoR-15 questionnaire score at postoperative 24 h was significantly lower in group P than in group S. | ESPB can significantly reduce morphine consumption in the early postoperative period (0–8 h) after thoracoscopy with lower incidence of ISP. It is a simpler and safer operation. |
| **Abdelwahab 2022**[35] | N=90 | PHN | ESPB, PVB | NRS, Pravastatin dosage | 1w, 3w, 4w, 12w, 24w | Compared to the control group, the NRS scores, as well as the usage of pregabalin and acetaminophen, were significantly lower in the ESPB group and PVB group at weeks 3, 4, 12, and 24. Six months later, the incidence of persistent herpes zoster pain in both groups was lower than in the control group. | Both ESB and PVB were effective in controlling acute pain and persistent herpetic pain after 6 months, but ESB is safer. |
| **Moorthy 2022**[36] | N=80 | VATS | ESPB, PVB | QoR-15, Opioid consumption, CPSP | 24h, 48h, 3m | Median (25–75%) QoR-15 at 24 h was higher in ESP compared with PVB: 118 vs 110 and at 48h: 131 vs 120. Incidence of CPSP at 3 months was 12 (34%) for ESP and 11 (31%) for PVB (P=0.7). | Compared with video-assisted, surgeon-placed paravertebral catheter, erector spinae catheter improved overall QoR-15 scores at 24 h and 48 h but without differences in pain or opioid consumption after minimally invasive thoracic surgery. |
| **Armin 2022**[37] | N=50 | Trauma-Associated Chest Wall Pain | ESPB, ICNB | NRS | 1/3h, 1h | Mean values of NRS 0, 20, 60, and disp for the ESPB vs ICNB groups were 8.0 vs 7.4, 5.2 vs 6.1, 4.1 vs 5.4, and 4.3 vs 5.8, respectively. | Ultrasound-guided ESPB was superior to ICNB regarding pain control during the ED stay period of patients with painful chest wall trauma. |
| **Sobhy 2020**[38] | N=60 | Thoracotomy | ESPB | VAS, Opioid consumption | 24h | Postoperative morphine consumption was 22.06 ± 6.24 mg in the ESP group and 30.6 ± 6.23 mg in the control group. | Ultrasound-guided ESPB has a significant analgesic effect in patients undergoing thoracotomy. |
| **Krishna 2019**[9] | N=106 | Heart surgery | ESPB(Group I), Intravenous paracetamol and tramadol(Group II) | NRS | 6h, 8h, 10h, 12h | Compared with patients in group II, patients in group I had significantly lower pain scores at rest after extubation and a longer average duration of postoperative analgesia. | Compared with intravenous paracetamol and tramadol, ESPB may provide safe, better, longer-lasting rest pain relief. |

**Abbreviations**: ESPB, erector spinae plane block; VATS, video-assisted thoracic surgery; CNP, chronic neuropathic pain; TPVB, thoracic paravertebral block; VAS, visual analog scale; NRS, numerical rating scale; GA, general anesthesia; PCA, patient-controlled analgesia; PVB, paravertebral block; CPSP, chronic postsurgical pain; SAPB, serratus anterior plane block; ICNB, intercostal nerve block; PHN, postherpetic neuralgia.

## Abdominal Surgery

Many clinical studies have demonstrated the effectiveness of ESPB in various abdominal surgeries (Table 2). First, ESPB allows precise localization of relevant thoracoabdominal spinal nerves: the upper abdominal incision is injected at T7-T8, and the lower abdominal incision is injected at T9-T10. Secondly, the paravertebral distribution of local anesthetic covers the intercostal nerves that innervate the ventral wall, blocking the sympathetic chain and producing visceral analgesia. Third, the catheter can be inserted before or after surgery and left in place long-term to achieve long-lasting pain relief.

**Table 2** Application of ESPB in Abdominal Surgery

| Authors | Patients | Type of Surgery | Analgesic Method(s) | Assessment Method(s) | Detection Time | Results | Conclusions |
|---|---|---|---|---|---|---|---|
| **Dubilet 2023**[17] | N=100 | Surgery to remove abdominal tumors | ESPB | VAS, Opioid consumption | 1h, 4h, 8h, 12h | Accordingly, patients in the ESP group required less morphine from 60 minutes to 12 hours after surgery, but they required increased non-opioid postoperative analgesia management at 4, 8, and 12 hours after surgery compared to the control group. | ESPB is a safe, technically simple, and effective treatment for postoperative pain management after elective oncologic abdominal procedures. |
| **Dubilet 2023**[17] | N=100 | Surgery to remove abdominal tumors | ESPB | VAS, Opioid consumption | 1h, 4h, 8h, 12h | Patients who received preoperative ESPB had significantly lower VAS and less morphine consumption at 60 minutes, 4, 8, and 12 hours postoperative compared to controls | ESPB can be used to treat postoperative pain after surgery for elective abdominal tumors. |
| **Guan 2023**[39] | N=102 | Pediatric Inguinal Hernia Repair | ESPB, Caudal Block | Time to the First Rescue Analgesia | 24h | The median time to the first rescue analgesia was longer in the erector spinae plane block group than in the caudal block group.Additionally, the area under the curve of the pain scores over time was lower in the ESPB group than in the caudal block group. | Erector spinae plane block provided superior postoperative analgesia compared to caudal block in children undergoing inguinal hernia repair. |
| **Hamed 2023**[40] | N=100 | Open abdominal hysterectomy | ESPB, Saline Injection | VAS, Fentanyl consumption | 24h | The intraoperative and postoperative fentanyl consumption in the ESPB group was significantly lower than that in the control group, and VAS was significantly reduced within 24 hours after surgery. | Patients undergoing open hysterectomy under general anesthesia use bilateral ESPB as an adjunct method, which is effective and safe. |
| **Mostafa 2023**[41] | N=60 | Open liver resection | ESPB, TAPB | NRS, Opioid consumption | 24h | The ESPB group consumed less morphine after surgery and the time to first morphine requirement was longer. | ESPB provided superior analgesic properties than subcostal TAPB. |
| **Park 2023**[42] | N=57 | LCS | ESPB | Opioid consumption, Pain level | 24h | The ESPB group used less fentanyl during the initial 24 h after surgery and experienced less pain than the control group. The time to the first ambulation and the length of hospital stay were shorter in the ESPB group than in the control group. | ESPB could promote early recovery by reducing opioid consumption and pain intensity in patients receiving LCS. |
| **Lu 2023**[43] | N=197 | LC | ESPB, Saline Injection | VAS, Fentanyl consumption | 12h | At postoperative 12h, ESPB group observed less patients with moderate pain (0% vs 8.91%) and severe pain (0% vs 0.99%) than the control group ($P < 0.001$). Moreover, ESPB group found less dose of additional sufentanil and less adverse reactions(5.21% vs 17.82%). | ESPB was followed by better postoperative analgesia and less opioid consumption. |
| **Xin 2022**[44] | N=50 | Laparoscopic hepatectomy | ESPB, PCIA | VAS, Opioid consumption | 3h, 6h, 12h, 16h, 20h, 24h, 48h, 72 h | The ESPB group showed lower resting VAS scores at 3h postoperatively, 2.0 (0.5) vs 4.3 (0.7), $P<0.001$, and significantly lower scores at rest and during movement at 6–24h postoperatively. None of the ESPB subjects showed ESPB-related complications. | Compared with patient-controlled intravenous analgesia only, preoperative ultrasound-guided erector spinae plane block can improve postoperative analgesia, reduce opioid demand. |

## Spinal Surgery

Due to the special anatomy of the erector spine muscles and their fascia, ESPB can be performed at all segments of the spine and provides analgesia to most areas of the body. It is widely used in spine surgery (Table 3). But there is now no systematic evaluation to determine the effect of lumbar ESPB. It is unclear whether the use of different drug doses, needle insertion methods, and injection sites during lumbar ESPB will produce different regional analgesic effects. A large number of prospective studies are needed in the future.[68]

## General Anesthesia Surgery

Several randomized controlled trials have shown that ESPB provides effective postoperative analgesia for patients undergoing surgery under general anesthesia (Table 4). Table 4 mainly summarizes the effects of ESPB before general anesthesia on postoperative pain scores, opioid consumption, and other factors in thoracic and spinal surgery. Patient-controlled intravenous analgesia is often used after surgery. Several results have shown that compared with general anesthesia alone, ESPB combined with general anesthesia can reduce opioid consumption and the number of patients requiring postoperative analgesia within 24 hours after surgery,[51] shorten ICU stay,[69] reduce pain scores,[70] prolong the time to first need for analgesia.[71] However, as shown in the table, the type, concentration, and dose of local anesthetic injected during ESPB are different for different types of surgery, and the injection plane is also different. Therefore, when ESPB is used in different surgeries, how to determine the block segment and correctly and reasonably use local anesthetics to cooperate with general anesthesia to achieve the best postoperative analgesia effect remains to be studied.

## ESPB Block Plane

Due to the continuity of the anatomical distribution of the erector spinal muscles and fascia in the vertical plane of the entire spine and the complexity of their distribution in different areas of the back, when selecting different block sites in different surgeries, the diffusion planes of anesthetics injecting into the local fascial plane are wide but different, resulting in a wide range of analgesic effects in different areas, and have been widely used in various types of surgeries. However, due to the uncertainty of the anesthetic diffusion plane, it is still difficult to determine the best indications and analgesic plane of ESPB. ESPB is a type of interfascial plane block used in different clinical conditions. This is a new analgesic technology that injects local anesthetic at the tip of the transverse process under ultrasound guidance, and the liquid spreads in the deep fascial plane,[72,73] thus blocking the pain signal transmission of the posterior and anterior branches of the thoracolumbar spinal nerves (Figure 3).

## The Analgesic Mechanism of ESPB

The analgesic mechanisms of ESPB may include nerve blockade and central depression. Allow direct diffusion of fluid into the paravertebral space or epidural space;[74,75] block ascending posterior spinal nerve rami;[72] lateral spread of local anesthetic can block lateral cutaneous nerve branches, anterior rami, and intercostal nerves, and achieve visceral analgesia through the communicating branch and sympathetic chain;[1,76] analgesia mediated by increased plasma concentration of local anesthetics; immune system regulation caused by local anesthetics; sensory blockade of fascia.[2] The most likely main mechanism is that the local anesthetic penetrates deeply into the erector spinal muscles and adjacent tissues, blocking the nerves within the fascial plane.[2]

The diffusion of anesthetics after ESPB may follow different pathways, different needle placement angles, different anesthetic doses, and different vertebral segments, all leading to different sensory block areas.[77] Recently, there have been many cadaveric studies on dye injections and imaging studies on patients (Table 5).

All anatomical studies have reported a widespread distribution of dye along the posterior rami of spinal nerves.[26–29,33,34] TMost of the early attention on ESPB focused on blocking the anterior rami of spinal nerves, resulting in analgesia in the corresponding area. However, a large number of studies now show that the spread of local anesthetics associated with ESPB also blocks the posterior rami of spinal nerves and their branches.[26–29,33,34] These nerves innervate the spine and surrounding muscles, explaining the analgesia of ESPB in spine and back surgeries. Effect. Nerves run between interconnected fat muscles, providing a potential pathway for local anesthetic diffusion after lumbar ESPB

**Table 3** Application of ESPB in Spinal Surgery

| Authors | Patients | Type of surgery | Analgesic method(s) | Types of liquid | Blocking level | Assessment method(s) | Detection time | Results | Conclusions |
|---|---|---|---|---|---|---|---|---|---|
| **Zhang 2023**[20] | N=60 | Posterior lumbar interbody fusion surgery | ESPB,Wound infiltration | 20 mL 0.375% ropivacaine | — | Opioid consumption, The proportion given rescue analgesia | 24h, 48h | Sufentanil consumption at 24 hours was lower in the ESPB group and the proportion of patients receiving analgesia within 48 hours was lower. | Bilateral ESPB provides similar analgesia to patients after lumbar fusion compared with wound infiltration. |
| **Zheng 2023**[18] | N=80 | Posterior lumbar interbody fusion | ESPB | 25 mL 0.3% ropivacaine | L1-L5 | VAS, Opioid consumption | 24h | The rate of sensory block covered by double-segment ESPB surgery was significantly higher than that of single-segment block. | Double vertebral segment ESPB provides higher sensory block coverage without increasing the incidence of complications. |
| **Flaviano 2023**[19] | N=60 | Total hip arthroplasty | ESPB, FIB | 40 mL 0.5% ropivacaine | L3-L5 | VAS, Opioid consumption, Exercise intensity | 24h | Compared to FIBs, quadriceps exercise intensity was better preserved in the ESPB group. | ESPB may be a promising postoperative analgesic alternative to FIB. |
| **Bellantonio 2023**[45] | N=30 | Thoracic and lumbar spinal fusion | ESPB; Receive opioid analgesia only | 20mL 0.4% ropivacaine | T11-S1 | NRS, Opioid consumption | 2h, 6h, 12h, 24h, 48h | Morphine consumption was significantly lower in the ESPB group at 48 hours after surgery. 2, 6, 12, 24 and 36h NRS are lower. | ESPB is a safe and effective pain control technique after spinal fusion. |
| **Bellantonio 2023**[45] | N=30 | Lower-Thoracic and Lumbar Spinal Fusion | ESPB; Receive opioid analgesia only | 20mL 0.4% ropivacaine | — | NRS, Opioid consumption | 2h, 6h, 12h, 24h, 48h, 36 h | The ESPB group showed significantly lower morphine consumption at 48 h postoperatively, lower need for intraoperative fentanyl, lower NRS score, and higher satisfaction rates of patients. | Erector spinae plane block is a safe and efficient opioid-sparing technique for postoperative pain control after spinal fusion surgery. |
| **Gișì 2023**[46] | N=42 | Spinal Fusion Surgery | ESPB | — | — | NRS, Opioid consumption | 12h, 24h | The 24-hour morphine consumption level of the ESPB group was significantly lower than that of the control group, and the postoperative pain intensity evaluated by NRS was significantly reduced. | Ultrasound-guided bilateral ESPB in multilevel spinal fusion surgery with instrumentation alleviates severe postoperative pain and reduces opioid consumption. |
| **Barsa 2023**[47] | N=52 | TPED | G1(IS+LIA) G2(IS+ESPB) | — | — | Volume of Fentanyl and Propofol | 2h, 6h, 12h, 24h, 48h | Volume of fentanyl, propofol, and level of postoperative sedation was significantly lower in G2. There were no adverse events in G2 | ESP reduced the volume of intraoperative fentanyl and propofol, thereby reducing the adverse effects of sedation |
| **Asar 2022**[48] | N=78 | Lumbosacral spine surgery | ESPB | — | — | NRS, Opioid consumption | 6h, 12h, 24h | Total opioid consumption as morphine equivalent was higher in the control group than the ESPB group. The numeric rating scale scores were lower in the ESPB group at the 6th, 12th, and 24th hours ($p < 0.05$). | ESPB is adequate for postoperative analgesia in patients undergoing lumbar spine surgery and can reduce opioid consumption. |

**Abbreviations**: ESPB, erector spinae plane block; VAS, visual analog scale; FIB, fascia iliaca block; NRS, numerical rating scale; TPED, transforaminal percutaneous endoscopic discectomy; IS, intravenous sedation; LIA, local infiltration anesthesia.

**Table 4** Application of ESPB in General Anesthesia Surgery

| aAuthors | Patients | Type of surgery | Analgesic method(s) | Types of liquid | Assessment method(s) | Detection time | Results | Conclusions |
|---|---|---|---|---|---|---|---|---|
| **Zhang 2023**[49] | N=94 | TL | GA+PCIA (Group A), ESPB+GA +PCIA (Group B) | 30 mL 0.375% ropivacaine | NRS, Frequency of PCIA | 2h, 6h, 12h, 24h, 48h, 3m, 6m | Compared with group A, group B had lower frequencies of postoperative NRS and postoperative PCIA use and lower incidences of postoperative nausea and vomiting at any follow-up time point. | ESPB reduces acute postoperative pain and chronic pain in patients undergoing lobectomy. |
| **Subbiah 2023**[21] | N=76 | Lumbar and Thoracolumbar spinal surgery | GA, SA +GA, ESPB +GA | 20mL 0.25% bupivacaine | Muscle relaxation, Surgical field of, Hemodynamic parameters | 24h | Compared with GA, GA+RA was significantly better in terms of muscle relaxation and postoperative analgesia, with no difference between GA+SA and GA+ESPB (p>0.05). | The combination of general anesthesia and ESPB may be a viable alternative to anesthesia. |
| **Zheng 2023**[50] | N=77 | Posterior lumbar surgery | Bilateral 2-level ESPB+GA +PCIA (group E), GA+PCIA (group C) | 25mL 0.3% ropivacaine | The time of the first flatus after surgery, VAS, Opioid consumption | 24h, 48h | Patients in group E had a significantly shorter time to first flatus, earlier liquid intake, earlier food intake, and first off-bed activity. Patients in group E had less pain and total sufentanil consumption within 24 hours after surgery. | Bilateral 2-level erector spinae plane block can accelerate gastrointestinal function recovery and shorten the length of hospital stay in patients undergoing open posterior lumbar surgery. |
| **Yao 2020**[51] | N=75 | VATS | ESPB+GA +PCIA, Inject saline solution +GA+PCIA | 25mL 0.5% ropivacaine | QOR-40, Opioid consumption | 0.5h, 1h, 2h, 4h, 8h, 24h, 48h | The global QoR-40 score at postoperative day 1 was significantly higher in the ESPB group than the control group. Compared with the control group, single-injection of ESPB reduced PACU discharge time, acute postoperative pain, and cumulative opioid consumption. | Preoperative single-injection thoracic ESPB with ropivacaine improves QoR, postoperative analgesia, and patient satisfaction after VATS. |
| **Singh 2020**[52] | N=40 | Lumbar spine surgery | ESPB+GA, GA | 20mL 0.5% bupivacaine | 11-point Numerical Rating Scale, Morphine consumption | 6h, 24h | Postoperative morphine consumption, pain scores immediately after surgery and at 6 hours after surgery were lower in the ESP block group compared with those in the control group. Patient satisfaction scores were more favorable in the block group. | US-guided ESP block reduces postoperative opioid requirement and improves patient satisfaction compared with standard analgesia in lumbar spine surgery patients. |

**Abbreviations**: ESPB, erector spinae plane blocesia; SA, spinal anesthesia; GA, general anesthanesthesia; RA, regional anesthesia; PCIA, patient controlled intravenous analgesia;TL,thoracoscopic lobectomy; QoR, quality of recovery; VAS, visual analog scale; NRS, numerical rating scale;VATS,video-assisted thoracic surgery.

surgery. Interestingly, both the interspace of the psoas major muscle and the epidural space is filled with adipose tissue and contain the spinal nerve roots and lumbar plexus, communicating with the adipose spaces surrounding the erector spinae muscle. Therefore, after injecting a local anesthetic into the plane between the erector spinal muscle and the tip of the transverse process, some fluid may pass forward through the channel in the connective tissue complex between the transverse processes and enter the paravertebral space, or may enter the epidural space through the intervertebral foramen. The fluid is spread along the fascia beneath the erector spinal muscles, often across multiple vertebral levels, and the pain relief is broad. The lateral spread of local anesthetic usually reaches only the lateral border of the thoracolumbar fascia. However, the studies in Table 5 have different opinions on the liquid diffusion plane. Sørenstua et al[31] and Schwartzmann et al[33] found that local anesthetics diffused into the intercostal spaces on MRI in healthy volunteers and patients, respectively. Bonvicini et al[25] injected black dye into two fresh frozen cadavers and found that fluid could pass through the costotransverse foramen to the anterior paravertebral space and infiltrate the intercostal nerves, but other studies did not find that fluid could diffuse into the intercostal spaces.[27–29,34] Considering that the above

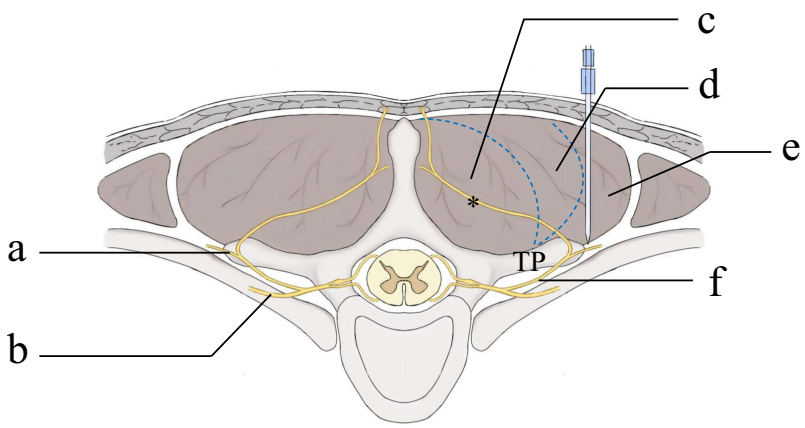


**Figure 3** Schematic diagram of the erector spinal muscle plane block, which shows the distribution of the erector spinae muscle and nerve walking; (**a**) Posterior lateral branch of spinal nerve; (**b**)Anterior branch; (**c**) Spinatus; (**d**) Longissimus; (**e**) Iliocostalis; (**f**) Posterior branch of the spinal nerve; "*" stands for the medial branch of the posterior ramus of the spinal nerve; TP,Transverse Process.

studies used different methods, different specific block segments, and especially the opposite physiological activity states of the subjects, whether local anesthetics can diffuse into the intercostal spaces during ESPB still needs further study.

## Complications and Risks of ESPB

Regarding complications of ESPB, the overall incidence appears to be low. Tsui et al[47] detected only 1 pneumothorax among 242 pooled cases. Likewise, ESPB appears to be safe for children. Holland et al[78] reported no complications in 164 pediatric patients. A retrospective study also showed that complications of ESPB were rare, with only 5 cases of hematoma and infection reported. ESPB can be used safely even in the setting of anticoagulation and coagulopathy, but prospective data from large cohorts are needed.[79] Bellantonio et al[45] did not observe complications related to ESPB in perioperative pain management during thoracolumbar fusion.

# Discussion

Overall, the erector spinae plane block is widely used in various clinical surgeries and outpatient emergencies due to its simple, safe, and effective characteristics.[80] Ultrasound-guided ESPB achieves pain relief by moving the needle tip towards the transverse process, injecting local anesthetic, expanding the deep fascia plane, allowing the fluid to spread within the fascia plane, and blocking the transmission of pain signals from nerves in surrounding tissues.

The use of opioids during or after surgery may lead to delayed recovery, prolonged hospital stays, and increased risk of death.[81] Due to the unique anatomical structure of the erector spinal muscle group and its fascia, a large number of randomized controlled studies have shown that ESPB can effectively alleviate postoperative pain in various surgeries, with a wide range of pain relief,[5,16,82–84] and can reduce perioperative opioid use,[82–85] away from the spinal canal and important blood vessels, Reduce the incidence of postoperative adverse reactions,[82,83] improve postoperative lumbar function,[82] shorten hospital stay,[69,82] reduce postoperative nausea and vomiting,[85] and improve patient satisfaction. Due to the many advantages mentioned above, ESPB has been widely used for perioperative analgesia in thoracic, abdominal, and spinal surgeries. In spinal surgery, there may be differences in the onset of action of thoracic and lumbar ESPB. Chung et al[86] found that under the same local anesthetic formula, the onset time of lumbar ESPB and the time to reach the maximum analgesic effect were much later than that of thoracic ESPB. It is possible that because the sensory anatomy of the lower abdomen and lower extremities is more complex than that of the thorax and abdomen, the lumbar ESPB plane is deeper and more difficult to visualize with ultrasound than the thorax, and local anesthetic injected in the lumbar fascial plane has more limited craniocaudal diffusion.[3] However, once the lumbar ESPB takes effect, it can still produce a significant Analgesic effect. When applying lumbar ESPB during the perioperative period, the local anesthetic formula and injection timing should be adjusted to make the analgesic onset consistent with immediate postoperative pain.[86] In addition, ESPB has also been proven to have good analgesic effects in departments such as obstetrics and

**Table 5** Extent of Fluid Diffusion When Erector Spinal Plane Block is Applied in Different Situations

| Authors | Research object | Blocking level | Blocking side(s) | Types of liquid | Liquid volume | Detection method(s) | Diffusion range |
|---|---|---|---|---|---|---|---|
| **Breidenbach 2023**[24] | A fresh, unembalmed corpse | L4 | Bilateral | Methylene blue and 0.25% bupivacaine | 20mL | Autopsy | Staining is most common in L2 and extends to the sacrococcygeal part to subsacrum, where it is confined to the posterior part of the spine rather than to the nerve roots on both sides. |
| **Hong 2023**[30] | 175 patients | L4 | Bilateral | 0.1% ropivacaine mixture | 10mL(5mL contrast medium)、20mL(7mL contrast medium) | X-ray | The contrast agent distribution of ESPB in the 20mL group was more extensive than that in the 10mL group, and the total number of diffused lumbar vertebral segments was significantly higher than that in the 10mL group. |
| **Sørenstua 2023**[31] | 10 volunteers | T7 | Unilateral | 2.5mg/mL ropivacaine | 30mL(0.3mL gadolinium) | MRI; The loss of sensation to cold and pinprick | MRI showed anesthetic spread in the intercostal spaces in all volunteers, 9/10 to the paravertebral space, 8/10 to the intervertebral foramen, and 4/10 to the epidural space. |
| **Bonvicini 2021**[25] | 2 fresh, frozen corpses | T5 | Bilateral | Diluted black tissue marking dye | 20mL | Autopsy | T2/3 to T10/11 dorsally of the chest, extending transversely up to 10 cm, and ventral T2/3-T9/10 of the thorax, spreading along the posterior branches and blood vessels of the spinal nerve and passing through the costotransverse foramen to the anterior paravertebral space and the intercostal nerves. |
| **Zhang 2021**[32] | 28 patients | T12 | Bilateral | 0.4% ropivacaine hydrochloride and 2 mg of dexamethasone | 25mL | The cold-warm method | The effective longitudinal plane of T12 ESPB was mainly distributed in the dorsal cutaneous branch of T9-L5, and the blockade area distribution was safe and stable |
| **Azevedo 2021**[26] | 7 fresh corpses | L4 | Bilateral、Unilateral | 0.1% methylene blue solution | 20、30、40mL | Autopsy | When injecting 20 mL of anesthetic in small doses, it can effectively reach the posterior branch of the lumbar spinal nerve; Using a larger volume of solution (30–40 mL) can diffuse to the anterior ramus or paravertebral space. |
| **Harbell 2020**[27] | 5 unembalmed corpses | L4 | Bilateral、Unilateral | 0.166% methylene blue solution | 20mL | Autopsy | Methylene blue can spread persistently to the posterior ramus of the spinal nerve, but not anteriorly to the anterior ramus or paravertebral space. |

(*Continued*)


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**Table 5** (Continued).

| Authors | Research object | Blocking level | Blocking side(s) | Types of liquid | Liquid volume | Detection method(s) | Diffusion range |
|---|---|---|---|---|---|---|---|
| **Schwartzmann 2020**[33] | 6 patients | T10 | Unilateral | 0.25% bupivacaine mixed | 30mL(0.3mL gadolinium) | MRI | Persistent spread to the posterior ramus of the spinal nerve, intervertebral foramen, and intercostal spaces, causing anterior and posterior chest and abdominal wall blockade, but varying degrees of spread to the intervertebral foramen and intercostal spaces. |
| **Zhang 2020**[34] | 12 volunteers | T5 | Unilateral | 0.5% ropivacaine | 20mL | Cold stimulation measures the cutaneous sensory loss area and cutaneous sensory declination area | Loss of cold sensation is concentrated in T6-T9; The decline area is mainly concentrated in T4-T11. The left side does not cross the posterior axillary line, and the right side reaches the posterior median line. extensive cutaneous sensory blockade in the posterior chest that does not reach the anterior chest, lateral chest, or abdominal wall; The posterior branch is widely blocked. |
| **Aponte 2019**[28] | 4 fresh corpses | T7 | Bilateral, Unilateral | Radioactive contrast agent dye mixture | 20mL | Autopsy<br>CT | Dorsal regions of T1-T11 were observed to spread the dye in the cephalocaudal region and extend transversely towards the costoverte region, covering a wide range of posterior spinal nerve innervation, without spreading to the paravertebral space or involving the anterior branch of the spinal nerve. |
| **Gonzalez 2019**[29] | 6 fresh corpses | L4 | Bilateral | Contrast solution | 20mL | Autopsy<br>Cryosection | Diffuses from L2 to L5, reaches the medial facet joints and lateral thoracolumbar fascia, always acts on the posterior branch of the spinal nerve, rarely to the paravertebral space. In 33% of the samples, the solution did not diffuse before the transverse process; In 51% of the sample, the degree of diffusion was small; 16% spread widely, reaching the corresponding spinal nerves. |

gynecology, breast surgery, and urology surgery. Ultrasound-guided bilateral ESPB provides adequate postoperative analgesia for cesarean section patients, reduces postoperative fentanyl consumption, and lasts longer than neuraxial anesthesia alone. After breast surgery, postoperative pain after resection and reconstruction is often reported, and ESPB at T4-T5 levels may be a feasible choice for postoperative pain relief in patients undergoing breast surgery.[65] In breast reduction surgery, a single preoperative ESPB can reduce perioperative opioid consumption compared to the use of systemic analgesics alone, and provide enough pain relief within 24 hours after surgery.[87] Due to the different physiological characteristics of obese patients and their high sensitivity to opioid drugs, postoperative pain management after weight loss surgery is difficult. According to reports, the combination of ESPB and multimodal analgesia can help with postoperative analgesia in patients undergoing weight loss surgery. Cesur et al[88] performed bilateral or unilateral ESPB at the T8 level on 90 patients who underwent laparoscopic cholecystectomy and found that bilateral ESPB provided more effective analgesia than unilateral ESPB and reduced opioid consumption and the incidence of post-operative shoulder pain.

Numerous studies have reported that single or continuous ESPB may replace paravertebral block or high-level epidural anesthesia in the future. A study involving 13 kidney disease patients showed that continuous ESPB can provide effective pain relief after kidney transplantation.[89] A report on rib fractures also reflects that continuous ESPB using indwelling catheter technology may provide more long-term effective pain relief than a single ESPB.[58] Initial injection of local anesthetic will expand the appropriate fascia plane, making it easier to place the catheter.[72] When the catheter cannot be placed, ESPB combined with other intraoperative pain relief methods can also prolong the pain relief time and improve the quality of pain relief, but higher quality control trials are still needed to verify in the future. The modified ESPB technique reported by Hu et al[90] minimizes the total amount of local anesthetic injected, allowing the application of higher concentrations of local anesthetic and extending the duration of analgesia.

Although many clinical studies indicate that ESPB can reduce opioid consumption, there are still some studies that do not find this result. Hoogma et al[91] found that adding ESPB to a standard multimodal analgesia regimen did not reduce opioid consumption and pain scores after robotically-assisted minimally invasive direct coronary artery bypass surgery. Moorthy et al[36] also found no difference in pain or opioid consumption after minimally invasive thoracic surgery with ESPB compared with video-assisted, surgeon-placed paravertebral catheter.

As erector spinae plane block is increasingly used in various surgical procedures, it has shown various advantages in intraoperative and postoperative analgesia. However, there is currently no study that has clearly pointed out the best indications for ESPB. It is impossible to clarify the diffusion plane of local anesthetics in the erector spinae muscle group fascia, and thus its analgesic area cannot be determined, which may limit the application scope of ESPB to a certain extent. The key to solving the above problems lies in clarifying the anatomical course of the erector spinal muscles, their fascia, and nerves. Some studies have shown that using a relatively shallow needle trajectory close to the distal transverse process can avoid damage to surrounding important anatomical structures.[72]

## Conclusion

Compared with other fascial plane blocks, ESPB is safer, more effective, has fewer complications, and can produce good intraoperative and postoperative analgesia. At present, it has outstanding performance in intraoperative analgesia in thoracic surgery, abdominal surgery, and spinal surgery, as well as postoperative analgesia under general anesthesia. However, the diffusion plane and pain block area of local anesthetics are not clear enough. The key lies in clarifying the anatomical structure of the erector spinal muscles and their fascia. Therefore, to explore and determine the best indications for ESPB, the focus, and direction of future research is to overcome the complex anatomical course of the erector spinal muscles, their fascia, and internal nerves.

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## Disclosure

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