



Review

Recent Advances in Regional Anesthesia for Thoracic Surgery

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Abstract

For perioperative analgesia in thoracic surgery, epidural anesthesia has long been considered the gold standard. However, as surgical techniques have become less invasive, interest in less invasive analgesic strategies has increased. According to the procedure-specific postoperative pain management (PROSPECT) guidelines published by the European Society of Regional Anesthesia in 2021, epidural anesthesia is no longer recommended as the method of choice for regional anesthesia in video-assisted thoracic surgery (VATS), and thoracic paravertebral block (TPVB) and erector spinae plane block (ESPB) are now recommended. Understanding the effectiveness and limitations of each regional technique is essential to facilitating appropriate anesthetic planning for individual cases. This narrative review summarizes current evidence regarding thoracic epidural anesthesia, TPVB, ESPB, serratus anterior plane block, and emerging intertransverse process block techniques for thoracic surgery.

Keywords: thoracic paravertebral block; erector spinae plane block; serratus anterior plane block; PROSPECT

1. Introduction

Thoracic surgery places unique demands on postoperative pain management because even mild discomfort can interfere with deep breathing and early ambulation. These physiological limitations increase the risk of pulmonary complications, making the selection of an appropriate analgesic strategy clinically important. Moreover, moderate-to-severe acute pain can contribute to the development of persistent postsurgical pain [1]. Although thoracic epidural analgesia has long been regarded as the gold standard, concerns regarding hypotension, urinary retention, and contraindications related to anticoagulation have increased interest in alternative regional anesthesia techniques.

One of the major factors contributing to this shift has been the widespread adoption of minimally invasive surgical approaches. Open thoracic surgery performed under direct visualization has declined, and video-assisted thoracoscopic surgery (VATS) has become the standard approach for many thoracic procedures. The reduced invasiveness of VATS has prompted a reevaluation of perioperative analgesic strategies. This narrative review summarizes current approaches to the selection and effective use of regional anesthesia techniques for perioperative analgesia in thoracic surgery.

This review was based on a structured literature search conducted in the PubMed and Embase databases for studies published between 2000 and 2025. The keywords included “thoracic surgery,” “regional anesthesia,” “thoracic paravertebral block,” “erector spinae plane block,” “intertransverse process block,” and “serratus anterior block.” Additional relevant articles were identified through manual screening of reference lists.



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Studies were selected based on their relevance to perioperative analgesia in thoracic surgery, with priority given to randomized controlled trials, systematic reviews, and high-quality observational studies. Case reports and technical descriptions were included when they provided clinically meaningful insights into emerging techniques. Articles not published in English were excluded.

Although numerous thoracic wall and paraspinal block techniques have been described in recent years—including rhomboid intercostal block and retrolaminar block—the present review focuses on regional anesthesia techniques recommended or discussed in the procedure-specific postoperative pain management (PROSPECT) guidelines for VATS or supported by comparatively robust clinical evidence. These techniques include thoracic paravertebral block (TPVB), erector spinae plane block (ESPB), serratus anterior block, and thoracic epidural anesthesia. The intertransverse process block (ITVB) is included as an emerging modification of ESPB. Other recently proposed techniques were not reviewed in detail because the current evidence base remains limited, and these techniques' clinical roles in VATS analgesia have not yet been clearly established.

2. Current Trends in Perioperative Analgesia

Epidural anesthesia has traditionally been considered the gold standard for perioperative analgesia in thoracic surgery. However, with the increasing use of minimally invasive surgical techniques, interest in less invasive analgesic approaches has grown. The PROSPECT guidelines published by the European Society of Regional Anesthesia and Pain Therapy re-evaluated analgesic priorities for VATS and shifted away from routine epidural use. Instead, these guidelines highlight TPVB and ESPB as preferred options, reflecting a broader trend toward less invasive perioperative management [2].

TPVB and ESPB may provide slightly less potent analgesia than epidural anesthesia. Nevertheless, contemporary perioperative pain management relies on a multimodal approach that combines acetaminophen, nonsteroidal anti-inflammatory drugs, opioids, and regional anesthesia techniques. Compared with TPVB, ESPB generally provides a narrower and less predictable extent of analgesic coverage. In contrast, ESPB is technically easier to perform, requires less time, and is associated with fewer complications. A clear understanding of the advantages and limitations of each regional technique is therefore essential for optimal analgesic planning.

3. TPVB

The paravertebral compartment lies immediately lateral to the vertebral column, where the intercostal nerves and sympathetic fibers traverse a narrow anatomical corridor. Injection of a local anesthetic into the paravertebral space produces a predominantly unilateral somatic and sympathetic block (Figure 1). TPVB, in which a local anesthetic is injected into this space, was first described by Eason and Wyatt in 1979 [3]. Initially, the loss-of-resistance technique was used to identify the paravertebral space. Although this technique is relatively simple, it is associated with a risk of complications. The introduction of ultrasound-guided techniques has improved the safety and reliability of TPVB by allowing direct visualization of anatomical structures and needle trajectory [4].

TPVB can be considered a form of unilateral epidural anesthesia. A major advantage of this unilateral approach is a lower incidence of hypotension compared with epidural anesthesia. In addition, because the injection is performed outside the spinal canal, serious complications such as epidural hematoma can be avoided [5]. Given its analgesic efficacy, which is comparable to that of epidural anesthesia, and its more favorable safety profile, TPVB has become a mainstream regional anesthesia technique for thoracic surgery.

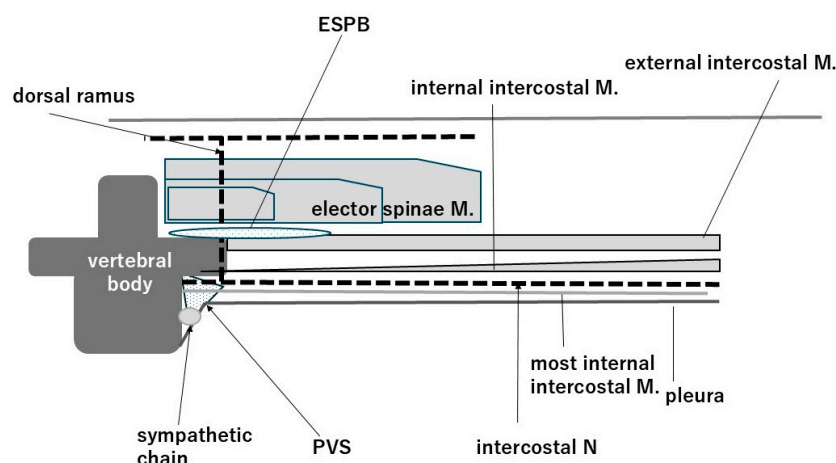


Figure 1. Transverse schematic view of the paravertebral space. PVS: paravertebral space; M: muscle; N: nerve.

Three main ultrasound-guided approaches have been described, depending on whether the needle reaches the paravertebral space laterally (intercostal approach), in a parasagittal orientation (parasagittal approach), or medially (paralaminar approach) [6,7] (Figure 2).

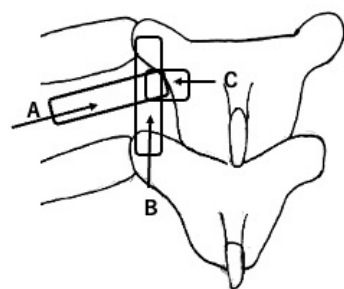


Figure 2. Three ultrasound-guided approaches for paravertebral blocks. Ultrasound probe position and needle insertion direction for the three approaches. A: intercostal; B: parasagittal; C: paralaminar.

The intercostal approach is often considered the most suitable for beginners because of its technical simplicity. In this approach, the ultrasound probe is placed parallel to the ribs to visualize the transverse process, internal intercostal membrane (or muscle), and lateral pleura (Figure 3). A local anesthetic is injected once the needle penetrates the internal intercostal membrane, and ventral displacement of the pleura confirms entry into the paravertebral space.

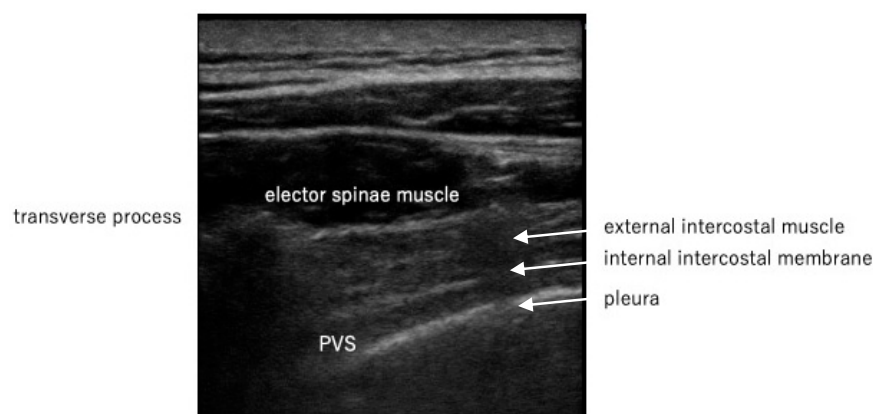


Figure 3. Ultrasound image of the intercostal approach. PVS: paravertebral space.

4. Continuous TPVB

A single injection of a local anesthetic for TPVB typically provides analgesia for up to 10 h. In more invasive procedures, a continuous paravertebral block using an indwelling catheter may be beneficial. In minimally invasive VATS, however, a single-injection block combined with intravenous patient-controlled analgesia using opioids provides sufficient postoperative analgesia in many cases [8]. Therefore, the need for catheter placement should be assessed on an individual basis.

Several technical considerations are important when inserting a paravertebral catheter. The paravertebral space is anatomically adjacent to the pleura. The catheter may inadvertently penetrate the pleura and enter the thoracic cavity or migrate into the intervertebral foramen. Lekhak et al. reported a case of total spinal anesthesia caused by inadvertent placement of a paravertebral catheter into the subarachnoid space [9]. These potentially life-threatening complications underscore the need for meticulous technique. For safer catheter placement, the catheter should generally be advanced approximately 2 cm beyond the needle tip to minimize the risk of migration. After catheter insertion, injection of saline containing air under ultrasound guidance can help confirm correct catheter placement within the paravertebral space.

For continuous TPVB, an initial bolus of 10–20 mL of local anesthetic is typically administered, followed by a continuous infusion at a rate of 5–10 mL/h. The analgesic effect usually extends over approximately three vertebral segments and is influenced by the catheter tip location and the method of administration [10].

Takeda et al. compared TPVB performed using the intercostal and paralaminar approaches in patients undergoing VATS [11]. Both groups received an initial bolus of 20 mL of 0.5% ropivacaine, followed by a continuous infusion of 0.2% ropivacaine at 5 mL/h. Analgesic efficacy was superior with the paralaminar approach, providing sensory blockade over four vertebral segments compared with three segments with the intercostal approach. These findings suggest that a more medial catheter position results in a broader distribution of local anesthetic within the paravertebral space.

Programmed intermittent bolus (PIB) administration has been proposed as another strategy to enhance the extent of analgesia. Whereas conventional syringe pumps deliver local anesthetics at a constant rate, some patient-controlled analgesia pumps allow PIB administration. Takeda et al. compared continuous infusion at 5 mL/h with PIB administration of 15 mL every 3 h [12]. Although postoperative opioid consumption and pain scores did not differ between the groups, the sensory block extended over a greater number of vertebral segments in the PIB group. Similar findings were reported by Hida et al. and Chen et al. [13,14]. These results suggest that PIB administration may be advantageous when broader analgesic coverage is required.

Despite these strategies, continuous TPVB typically provides analgesia over no more than four vertebral segments. When more extensive analgesia is required, multiple blocks may be considered. However, multiple blocks increase procedural time and the risk of complications. In most VATS procedures, a single TPVB provides sufficient analgesia [15].

When multiple continuous blocks are planned, catheter placement should be carefully considered preoperatively. The risk of local anesthetic systemic toxicity increases with the cumulative dose required for multiple continuous infusions, particularly when higher total volumes of long-acting local anesthetics are administered.

5. ESPB

Although TPVB provides excellent analgesia for thoracic surgery, it is technically demanding. The ESPB is a fascial plane block classified as a paraspinal peripheral nerve block technique. It involves ultrasound-guided injection of a local anesthetic into the plane

deep to the erector spinae muscle and superficial to the transverse processes of the vertebrae (Figure 4).

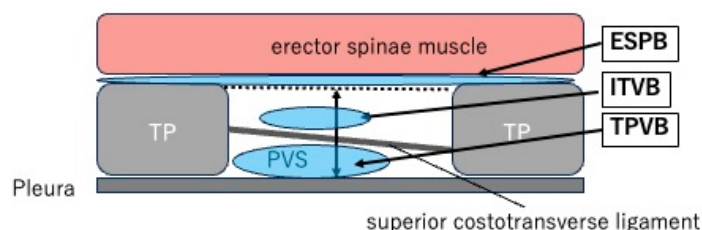


Figure 4. Sagittal schematic view of ESPB and ITVB. PVS: paravertebral space; ESPB: erector spinae plane block; ITVB: intertransverse process block; TPVB: thoracic paravertebral block.

The proposed mechanism of ESPB involves blockade of the dorsal rami and, in some cases, the ventral rami of the intercostal nerves. Anterior spread of the local anesthetic toward the paravertebral space has been demonstrated in anatomical and imaging studies, potentially affecting the sympathetic chain and intercostal nerves. However, the extent and consistency of this anterior spread remain variable, which may contribute to differences in clinical analgesic efficacy.

However, although ESPB is widely used, its pharmacodynamic behavior is still being elucidated. Imaging and cadaveric studies have shown that the injectate may reach the paravertebral region in some—but not all—cases, suggesting that its clinical effect depends on anatomical and technical factors. Whereas some anatomical and imaging studies have demonstrated anterior spread of local anesthetic into the paravertebral space, others have reported limited or inconsistent spread beyond the erector spinae plane. This variability may be influenced by factors such as the injection level, the volume of local anesthetic, and individual anatomical differences.

As a result, the extent to which ESPB reliably blocks the ventral rami and sympathetic chain remains uncertain. This inconsistency in paravertebral spread is considered a key factor underlying variability in its clinical analgesic efficacy.

ESPB has increasingly been used as an alternative to TPVB. The characteristics and mechanisms of ESPB were previously summarized [16]. Although its analgesic effect is generally weaker and less predictable than that of TPVB, ESPB is easier to perform, requires less time, and is associated with fewer complications [17,18]. Consequently, ESPB is recommended alongside TPVB in the PROSPECT guidelines for VATS. It should be emphasized that the PROSPECT guidelines also recommend systemic analgesics, including acetaminophen, nonsteroidal anti-inflammatory drugs, and opioids. Therefore, ESPB should be regarded as one component of a multimodal analgesic strategy.

Findings from randomized controlled trials are generally consistent with these observations. In a randomized study of patients undergoing VATS, TPVB provided significantly better early postoperative pain control than ESPB, although overall analgesic outcomes were similar over time.

A recent meta-analysis including more than 1800 patients demonstrated that TPVB was associated with lower pain scores within the first 6 h after surgery and reduced early opioid consumption compared with ESPB, although the differences diminished at 24–48 h [19].

Taken together, current evidence suggests that although ESPB offers a simpler and safer technique with broadly comparable overall analgesia, TPVB may provide more reliable and stronger early postoperative pain relief. Therefore, the choice between these techniques should be individualized based on clinical priorities, including the need for greater early analgesic intensity, technical feasibility, and patient-specific risk factors.

ESPB may be considered when TPVB is contraindicated or technically difficult, such as in patients receiving anticoagulation therapy [20]. As with TPVB, a catheter can be inserted

to provide continuous ESPB. PIB administration may also be effective [21]; however, clinical studies directly comparing continuous infusion with PIB administration for ESPB are currently lacking.

To increase the extent of analgesic coverage, multiple ESPB injections may be considered. The combined use of TPVB and ESPB has also been reported [22]. In such cases, TPVB may be used for the most invasive surgical areas, with ESPB applied to additional regions.

6. ITVB

The ITVB is a relatively recent addition to the spectrum of paraspinal regional anesthesia techniques for thoracic surgery. ITVB is a collective term encompassing several techniques, including the mid-point transverse process-to-pleural block [23] and the costotransverse foramen block [24], in which a local anesthetic is administered in deeper paraspinal planes between ESPB and TPVB [25] (Figure 4).

In ITVB, a local anesthetic is injected posterior to the superior costotransverse ligament. This region is referred to as the retro-superior costotransverse ligament (SCTL) space [26]. Anatomical and imaging studies have demonstrated that injection of local anesthetic into the retro-SCTL space may facilitate more reliable spread toward the paravertebral space and produce variable sensory blockade of the ipsilateral anterior hemithorax. ITVB can be considered a modified technique of ESPB that more reliably targets the paravertebral space.

Cadaveric studies also suggest that deeper paraspinal injections may achieve more consistent paravertebral spread than ESPB while maintaining a more favorable safety profile compared with TPVB [27].

ITVB is performed by injecting a local anesthetic posterior to the SCTL in the retro-SCTL space, which is anatomically closer to the paravertebral space than the ESPB injection plane. This deeper injection site may facilitate more consistent anterior spread of the local anesthetic toward the paravertebral space. As a result, ITVB is hypothesized to provide a balance between the safety and technical simplicity of ESPB and the more reliable analgesic effect of TPVB.

Despite these promising anatomical and mechanistic considerations, the current clinical evidence supporting ITVB remains limited. Most available data are derived from cadaveric and imaging studies demonstrating the spread of the injectate toward the paravertebral space. Clinical evidence is largely restricted to small observational studies and case series, with few randomized controlled trials directly comparing ITVB with established techniques such as TPVB and ESPB.

Therefore, at present, ITVB should be considered an emerging technique rather than a standard regional anesthesia option. Although it may offer theoretical advantages, its clinical role remains to be established, and further validation through high-quality randomized controlled trials is required.

7. Serratus Anterior Block

The serratus anterior block is recommended as a second-line regional anesthesia technique for VATS in the PROSPECT guidelines [2]. This block targets the lateral cutaneous branches of the intercostal nerves by injecting a local anesthetic either superficially or deep to the serratus anterior muscle (Figure 5). Consequently, anesthetic coverage is limited to the lateral chest wall. When VATS port sites are located predominantly on the anterior chest wall and other regional techniques are difficult to perform, the serratus anterior block may be considered [28]. In fact, a recent meta-analysis has shown that, in terms of postoperative analgesia following VATS, the serratus anterior block is superior to local infiltration anesthesia but inferior to paravertebral blocks and ESPB [29].

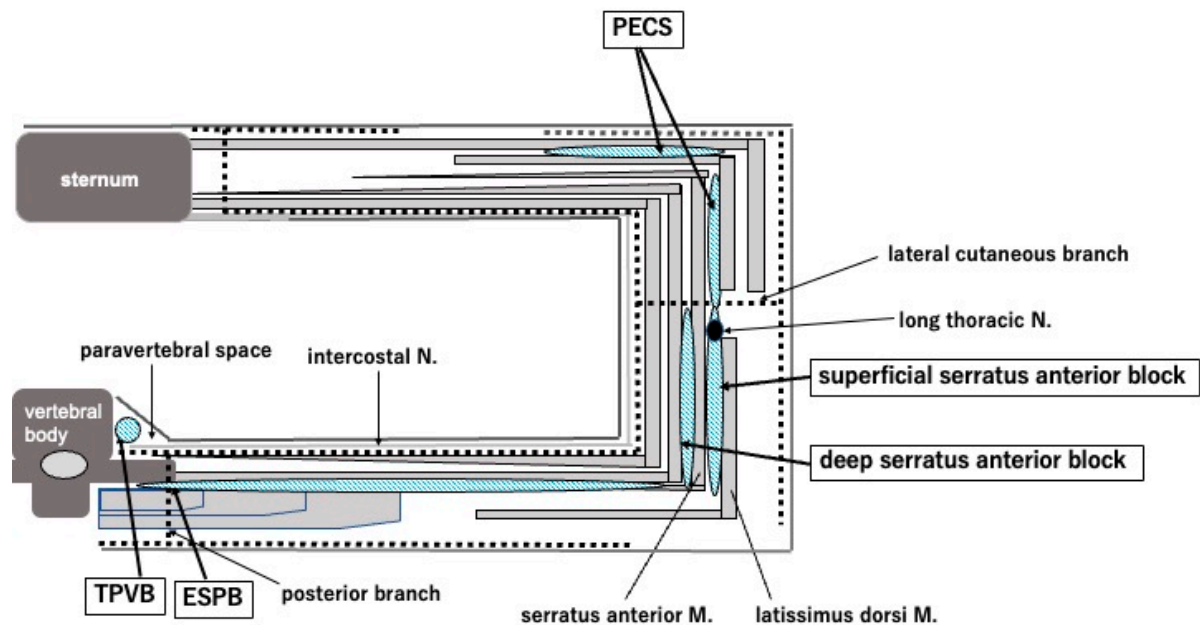


Figure 5. Transverse schematic view of thoracic blocks. ESPB: erector spinae plane block; TPVB: thoracic paravertebral block; PECS: pectoral nerve block; M: muscle; N: nerve.

Injection superficial to the serratus anterior muscle is referred to as the superficial serratus anterior plane block, whereas injection deep to the muscle is termed the deep serratus anterior plane block. At present, there is insufficient evidence to determine which approach provides superior analgesia. Therefore, when interpreting studies on the serratus anterior block, it is important to note the precise injection plane used.

Multiple injections or continuous catheter techniques may be employed to increase the extent and duration of analgesia. However, in thoracic surgery, catheter placement should be performed with caution because of its anatomical proximity to the surgical field.

8. Thoracic Epidural Anesthesia

Thoracic epidural anesthesia is no longer the first-line regional technique for minimally invasive VATS. Nevertheless, epidural anesthesia remains valuable in open thoracic surgery involving rib resection. In fact, the PROSPECT guidelines recommend thoracic epidural anesthesia and TPVB equally for open thoracic procedures [30]. Open thoracotomy continues to require a more aggressive analgesic strategy because of its substantially greater pain burden. Therefore, although the present review focuses primarily on minimally invasive surgery, it is important to recognize that epidural anesthesia retains a central role in open thoracotomy, and its use should be individualized based on surgical invasiveness and patient-specific factors.

In clinical practice, thoracic epidural anesthesia remains a useful option, particularly in settings in which ultrasound equipment is unavailable or practitioner expertise favors epidural techniques. It should be recognized that epidural anesthesia is not universally the gold standard for postoperative analgesia and that the choice of technique should depend on institutional resources and the anesthesiologist's experience.

9. Conclusions

This narrative review summarizes current approaches to the selection and effective use of regional anesthesia techniques for perioperative analgesia in thoracic surgery (Table 1).

Table 1. Comparison of thoracic regional anesthesia techniques. VATS: video-assisted thoracoscopic surgery; SCTL: superior costotransverse ligament.

Technique	Indication	Mechanism	Advantages	Limitations
Epidural anesthesia	Open thoracotomy	Epidural spread blocking the spinal nerves and sympathetic chain	Reliable analgesia	Hypotension, urinary retention, contraindicated with anticoagulation
Paravertebral block	VATS	Injection into the paravertebral space blocking the ventral rami and sympathetic chain	Reliable unilateral analgesia, fewer systemic effects than epidural anesthesia	Technically demanding, risk of pneumothorax
Erector spinae plane block (ESPB)	VATS	Blockade of the dorsal rami with indirect spread to the paravertebral space	Easy to perform, low complication rate	Less reliable analgesia
Intertransverse process block (ITVB)	Emerging option in thoracic surgery	Injection into the retro-SCTL space with potential spread to the paravertebral space	More consistent paravertebral spread than ESPB	Limited clinical evidence
Serratus anterior block	VATS (lateral chest wall procedures)	Blockade of the lateral cutaneous branches of the intercostal nerves	Simple technique, useful for lateral chest wall pain	Limited dermatomal coverage

In current clinical practice, the choice of regional anesthesia technique should be individualized. TPVB may be preferred when strong and reliable early postoperative analgesia is required, particularly for more invasive procedures. In contrast, the ESPB may be considered when technical simplicity and safety are prioritized, such as in patients receiving anticoagulation therapy or those at higher procedural risk. The serratus anterior plane block may serve as a useful adjunct for lateral chest wall analgesia, whereas thoracic epidural anesthesia remains an important option in open thoracic surgery.

Emerging techniques such as the ITVB may offer a potential balance between efficacy and safety; however, their clinical role remains to be fully established. Current evidence is limited and heterogeneous, and high-quality randomized controlled trials directly comparing these techniques with established approaches are needed.

Future research should focus not only on comparative effectiveness but also on standardizing nomenclature, clarifying mechanisms of action, and identifying procedure-specific analgesic approaches. Given the diversity of thoracic procedures and patient characteristics, no single regional technique is universally optimal. An individualized strategy that integrates procedural invasiveness, patient comorbidities, and institutional expertise is likely to provide the greatest overall clinical benefit.

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