This article has been accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination, and proofreading processes, which may lead to differences between this version and the version of record.

Please cite this article as https://doi.org/10.4097/kja.22138
Anatomical classification and clinical application of thoracic paraspinal blocks

Shin Hyung Kim, M.D., Ph.D.*

Department of Anesthesiology and Pain Medicine, Anesthesia and Pain Research Institute, Translational Research Unit for Anatomy and Analgesia, Yonsei University College of Medicine, Seoul, Republic of Korea

Running title: Thoracic paraspinal blocks

*Corresponding author: Shin Hyung Kim, M.D., Ph.D.

Department of Anesthesiology and Pain Medicine, Yonsei University College of Medicine, 50 Yonsei-ro, Seodaemun-gu, Seoul 03722, Republic of Korea

Telephone: +82-2-2228-7500, Fax: +82-2-364-2951, E-mail: tessar@yuhs.ac

ORCID: https://orcid.org/0000-0003-4058-7697

Conflicts of Interest: No potential conflict of interest relevant to this article was reported.
**Funding:** This work was supported by a grant from the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. 2021R1F1A1045873).

**Acknowledgements:** We are grateful to Jehoon O, Ph.D., Center of Biohealth Convergence and Open Sharing System, Hongik University, Seoul, Republic of Korea, for his help with the illustrations in this review article.
Anatomical classification and clinical application of thoracic paraspinal blocks

Running title: Thoracic paraspinal blocks
Abstract

Many techniques for regional anesthesia and analgesia of the thorax are currently being used in clinical practice. Among them, a recent international consensus anatomically classified paraspinal blocks in the thoracic spine region into four different types: paravertebral block, retrolaminar block, erector spinae plane block, and intertransverse process block. These blocks have different anatomical targets, thus the spreading patterns of the injectate differ. Consequently, they can have different neural blockade characteristics in patients. Paravertebral block directly targets the paravertebral space just outside of the neuraxial region and has comparable analgesic efficacy to epidural block. However, there still remains the potential risks of this technique during the procedure. Retrolaminar and erector spinae plane blocks target the erector spinae plane on the vertebral lamina or transverse process, respectively. In anatomical studies, these two blocks showed different spreading patterns of injectate to the back muscles and fascial plane. Paravertebral spreading occurred but was variable in cadavers. However, numerous clinical reports support potential paravertebral spread when using erector spinae plane blocks. Both techniques reduced postoperative pain compared to the control, but results were inconsistent compared to those obtained with paravertebral block. Intertransverse process block targets the tissue complex posterior to the superior costotransverse ligament. Anatomical studies have revealed that the target area of this block has more direct and closer pathways to the paravertebral space than those of retrolaminar and erector spinae plane blocks. Cadaveric evaluations have consistently shown promising results, but further clinical studies are needed to confirm anatomical findings using this technique.

Keywords: nerve block; pain management; paraspinal block; paravertebral space; paravertebral block; erector spinae plane block; retrolaminar block; intertransverse process block; ultrasonography
**Introduction**

Paravertebral block (PVB) in the thoracic region is a well-established technique for perioperative analgesia and chronic pain management of the thorax [1-3]. PVB directly targets the thoracic paravertebral space (TPVS), which contains the roots of the spinal nerves; PVB is therefore distinct from peripheral nerve blocks [4]. Clinically, successful PVB produces ipsilateral, segmental, somatic, and sympathetic nerve blockade in adjacent dermatomes of the hemi-thorax [3]. This technique was first described by Hugo Sellheim in 1905 [1] and has been modified and improved, but there still remains the potential risk of pneumothorax, neurovascular damage, or unintentional neuraxial injection when performed, even with ultrasound guidance [5-7].

Ultrasound-guided regional anesthesia techniques are fundamental components of multimodal perioperative care [8]. The utility of ultrasound has led to the development of many novel approaches to deliver anesthesia and analgesia, including the concept of interfascial plane block where local anesthesia is injected into a fascial plane to indirectly access target nerves [9]. Since erector spinae plane (ESP) block was first described by Forero et al. in 2016 [10], it has attracted a lot of attention and stimulated an explosion of interest in interfascial plane block. Many block techniques have been introduced since the ESP block, but similar techniques carry different names, and techniques with the same name can have different technical approaches and targets. To standardize this, a recent international consensus anatomically classified paraspinal blocks in the thoracic region into four different types: PVB, ESP block, retrolaminar block (RLB), and intertransverse process (ITP) block [11]. Each paraspinal block is associated with different spreading patterns of injectate following different anatomical target points; consequently, these blocks have different neural blockade characteristics when used clinically.
The purpose of this review is to outline the proposed mechanisms of action of each thoracic paraspinal block based on the available anatomical evidence and to discuss the clinical information reported thus far.

**Paravertebral block (PVB)**

1. *Anatomical description*

   PVB is anatomically described as injection in the paravertebral space between the superior costotransverse ligament (SCTL) and parietal pleura in the thoracic region (Fig. 1) [11].

2. *Anatomical considerations*

   The TPVS contains the roots of the spinal nerve and its dorsal and ventral branches and their plexuses, white and gray rami communicantes, the sympathetic ganglion, and the sympathetic chain (Fig. 2) [2,4]. Thus, PVB might be the closest anatomical approach to the concept of ‘paraneuraxial’ nerve block [12]. Even established anatomy textbooks such as Gray’s Anatomy do not use the term ‘paravertebral space’ [13]. The concept underlying TPVS appears to have been shaped by clinical needs, and the TPVS has not been fully elucidated as a clearly delineated space from an anatomical perspective. Posteriorly, the TPVS is bounded by the transverse process, the rib, and the SCTL, and the needle should pass the SCTL to reach the TPVS for conventional PVB [1,2]. In the classic literature, a subtle ‘pop’ or ‘click’ is felt upon the needle piercing the SCTL and loss of resistance is described [1,2]. In the T4-5 region, for example, the SCTL originates from the superior surfaces of the 5th rib (Fig. 2) [14]. Anterior and posterior layers diverge from a common origin of the SCTL on the rib [14]. Anterior and posterior layers of the SCTL are attached to the inferior surfaces of the 4th rib and the transverse process of T4, respectively [14]. Also, the morphology of the SCTL with some anatomical variations seems to be different depending on upper or lower thoracic spinal location [15]. Therefore, although the SCTL is the most important landmark for PVB, the SCTL is
occasionally hard to identify by ultrasonography. The SCTL is located very close to the pleura; the mean distance between the pleura and the attachment of the SCTL was only 7.8 mm in one anatomy report [14]. Furthermore, the posterior intercostal artery and vein within the TPVS are located very close to the pleura. This unique anatomy of the TPVS can explain the risks associated with PVB.

3. Potential risks of block-related complications

Although the reported incidence of procedure-related complications following PVB varies among studies, it appears to be low when using ultrasound [5]. However, a recent meta-analysis reported similar incidence of pneumothorax, pleural puncture, and vascular puncture at 0.3% in ultrasound-guided PVB [7], although this is likely an underestimate due to under-reporting. Indeed, the incidence of procedure-related complication was higher in PVB than other regional techniques for breast surgery. [7]. Previously reported incidences of pneumothorax, pleural puncture, and vascular puncture after PVB with a classic landmark technique were 0.5%, 1.1 %, and 3.8%, respectively [16]. The use of ultrasound might reduce the failure rate of PVB, but clinicians should be aware of the potential risks of PVB during the procedure.

4. Spreading pattern of injectate

In PVB, anteromedial spread of the injectate within the TPVS and lateral intercostal spread are typically observed. PVB with 20 ml of injectate resulted in paravertebral and intercostal spread over approximately 3-4 segments in cadavers [17]. A single injection of PVB with 25 ml of local anesthetic and multiple injection PVB with 5 ml at each of five levels provided similar sensory block over 4-6 dermatomes in patients undergoing unilateral mastectomy [18]. Ventral rami of the spinal nerve and sympathetic ganglion were shown to be involved in successful thoracic PVB, and epidural spread via the intervertebral foramen was often observed [17].

The endothoracic fascia seems to be significantly involved in the variability of injectate spreading patterns following thoracic PVB. The endothoracic fascia, which is the deep fascia of the
The endothoracic fascia, a fibroelastic structure that lines the inside of the thoracic cage, is interposed between the parietal pleura and the innermost intercostal muscle in the chest wall and between the parietal pleura and the SCTL or transverse process in the TPVS [19]. The endothoracic fascia appears to divide the TPVS into two potential fascial compartments: an anterior (extrapleural) and a posterior (subendothoracic) compartment [2, 19]. The sympathetic ganglion is contained in the extrapleural compartment, whereas the spinal nerve is positioned in the subendothoracic compartment [2, 19]. This anatomy was confirmed by electron-microscopic findings in rats [20]. However, it seems difficult to observe the endothoracic fascia using dissection technique in human tissues because it is very thin fascia and indistinguishable from parietal pleura [21]. An extrapleural compartment injection may produce the extensive longitudinal, prevertebral, and contralateral diffusion of the injectate with sympathetic blockade [19, 20]. On the contrary, injections made subendothoracic compartment of TPVS may result in a cloud-like spreading pattern, with only limited distribution over adjacent segments but with a greater chance for epidural spreading [19, 20]. Superiorly, the endothoracic fascia is continuous with the suprapleural membrane (Sibson’s fascia) that is attached to the inner border of the first rib and costal cartilage anteriorly, C7 transverse process posteriorly and to the mediastinal pleura medially [19]. Inferiorly, the endothoracic fascia is continuous with the abdominal transversalis fascia [21, 22]. This continuity occurs dorsal to the diaphragm through the lumbocostal arches and the aortic hiatus [19]. The transversalis fascia blends medially with the fascia of the anterior layer of the quadratus lumborum and the psoas fascia [22]. Anatomically, an injection into the subendothoracic compartment of TPVS at the lower thoracic levels can spread caudally via the medial and lateral arcuate ligament to the retroperitoneal space in the abdomen [22]. Such spread can affect peripheral nerves originating from the lumbar plexus [19-21].

5. Clinical evidence
PVB is the oldest paraspinal block technique, and there are numerous clinical reports of PVB in surgical patients and chronic pain patients. PVB can be used for surgical anesthesia. Historically, PVB was designed to replace spinal anesthesia and was usually performed to control pain during abdominal surgery [1]. In data from six randomized controlled trials, thoracic PVB for surgical anesthesia was associated with lower pain intensity during the immediate postoperative period, as well as less postoperative nausea and vomiting, shorter length of hospital stay, and greater patient satisfaction than was general anesthesia in patients undergoing breast surgery [23]. PVB has similar postoperative pain control effectiveness after thoracic surgery to thoracic epidural analgesia [24,25]. Moreover, contraindications to thoracic epidural analgesia do not preclude paravertebral block in most cases. For thoracic surgery such as thoracotomy, PVB provides better postoperative analgesia and lower opioid consumption than do ESP block and RLB [26-28]. Although conflicting results have been reported for breast cancer surgery [29], the analgesic efficacy of PVB was superior to that of ESP block and other truncal blocks [7]. PVB was recommended as the first-choice regional analgesic technique for major breast surgery in recently published guidelines [30].

Retrolaminar block (RLB)

1. Anatomical description

RLB is anatomically described as injection in the plane between the erector spinae muscles and the lamina (Fig. 1) [11].

2. Anatomical considerations

The concept of RLB, also known as the ‘lamina technique,’ was introduced much earlier than ESP block. This technique was first described by Pfeiffer in 2006 as the landmark (blind) technique [31]. Main advantage of this technique is that it is a very easy and simple procedure to perform that requires either a single injection or use of a catheter. Furthermore, it can be performed in the
cervical and lumbar regions for a wide range of clinical indications. The target injection point for RLB is the posterior surface of the vertebral lamina [32], while ESP block targets the fascial plane deep to the erector spinae muscle at the tip of the transverse process (Fig. 3) [10], which is more laterally located than the target point of RLB. Although the injection locations for these two techniques differ, anatomical similarities exist because the anterior fascia of the erector spinae muscle group adheres to both the lamina and the transverse process.

3. **Spreading pattern of injectate**

Some anatomical studies have demonstrated injectate spread to the TPVS, epidural space, intercostal space, and intervertebral foramina in RLB, but this spreading pattern appears to be quite variable [33,34]. In comparison to conventional PVB, injectate spread to the TPVS is much more limited in RLB [33]. The spinous process, lamina and facet joint capsule can act as anatomical barriers between the retrolaminar space and TPVS [34]. The lateral tip of the transverse process is directly and indirectly connected to the two layers of the thoracolumbar fascia [35]. ESP block directly placed injectate into the fascial space of the thoracolumbar fascia. RLB placed the injectate into a plane that is continuous with the facial space of the thoracolumbar fascia. Thus, in both techniques, the injectate can spread directly and indirectly into the posterior layer of the thoracolumbar fascia or into the posterior fascia of the erector spinae [34]. However, RLB and ESP blocks had distinct spreading patterns of injectate in a cadaveric evaluation [34]. ESP block, which involved direct injection into the fascial plane, made the dye spread more laterally, while RLB made the dye spread vertically along the posterior surface of the lamina [34]. RLB resulted in an intensely stained retrolaminar plane beneath the transversospinalis muscles and erector spinae muscles, with wide vertical spread, which may indicate adequate blockade of the dorsal rami at the affected spinal level [34].

4. **Clinical evidence**
RLB has been reported to be clinically effective in patients with rib fracture or those undergoing breast surgery [32,36,37]; however, clinical data regarding RLB are more limited than the data available for ESP block. In a previous report, the analgesic efficacy of continuous RLB was inferior to that of continuous PVB in the first 24-hour period after mastectomy [38]. Furthermore, single injection of RLB produced an analgesic duration of only 2 to 3 hours after breast surgery, which is much shorter than that reported for PVB [39]. In thoracoscopic surgery, PVB provided better analgesia and resulted in less nausea than did RLB [28].

**Erector spinae plane (ESP) block**

1. **Anatomical description**

   ESP block is anatomically described as injection in the plane between the erector spinae muscles and the transverse process (Fig. 1) [11].

2. **Proposed mechanisms of action**

   ESP block has gained popularity as a simpler and safer technique to perform than traditional PVB, and placement of a catheter is also feasible. However, its exact mechanisms of action have been debated. Some proposed mechanisms of action are analgesia mediated by elevated local anesthetic plasma concentrations due to systemic absorption, immunomodulatory analgesic effect via the lymphatic system, or an analgesic effect mediated through nerve innervation of the thoracolumbar fascia [40]. However, these seem to be inconclusive and require further investigations [40]. The most controversial topic is whether ESP block produces neural blockade from direct spread of local anesthetic to the TPVS. Paravertebral spread was originally proposed as the primary mechanism of action of ESP block [10]. However, the results of anatomical studies are inconsistent. Some previous cadaver studies revealed limited or even no paravertebral spread in the ESP block, accompanied with more predominantly posterior back muscle or fascia spread [34,41].
Nevertheless, the weight of available evidence shows that paravertebral spread can and does occur. Magnetic resonance imaging (MRI) in living subjects demonstrated contrast medium spread into the paravertebral and even epidural spaces across multisegmental levels in ESP block [42,43].

3. Limitation of cadaver studies

Some limitations of cadaver studies should be taken into account when interpreting the findings of these studies. Condition of the cadavers such as whether they have been embalmed or their freeze-thaw status can affect the results. Furthermore, due to the nature of cadaveric studies, sample size is limited, and descriptive results are mostly reported. Postmortem changes in muscle, fascia, and ligamentous tissue can significantly affect diffusion of injectate. More importantly, cadaver study cannot reflect delayed diffusion after ESP block as would occur with respiratory movement in living subjects.

4. Clinical evidence

When ESP block was first introduced, there was some controversy regarding its anatomical similarity to RLB [44,45]. However, RLB and ESP block show different spreading patterns in cadavers in addition to block efficacy in patients [34,46]. Although there are no clear clinical comparisons and more clinical data regarding RLB are needed, the clinical efficacy of single-shot RLB is controversial, while ESP block results in significantly lower postoperative pain [47-49]. To date, 5-6 years after ESP block was first introduced, a large number of randomized-controlled trials to investigate the analgesic efficacy of ESP block in almost all types of surgeries performed on the human torso has been published [50]. Overall, ESP block provided better pain relief and lower opioid consumption after various surgeries, such as breast surgery, laparoscopic cholecystectomy, and thoracotomy, than did sham or no block [47-54]. However, it is uncertain whether ESP block can replace conventional PVB, which afforded better pain relief after thoracotomy and breast surgeries in several studies [7,27,53-55], although there were some conflicting results [29, 54].
Furthermore, block reproducibility with consistent results is a major concern in clinical practice. Therefore, more controlled studies are needed to compare ESP blocks and robust multimodal analgesic regimens. Dermatomal sensory blockade data in ESP block should be evaluated according to injected volume and spinal level. Considering the difference in anatomical basis between ESP block and PVB, it is reasonable to assume that these approaches differ in terms of their specific clinical indications and risk–benefit ratio. Thus, future clinical studies should endeavor to compare ESP block and other truncal nerve blocks.

5. Spreading pattern of injectate

A significant amount of injectate spread following ESP injection was observed in the back muscles and fascial layer in previous anatomical evaluations [34,41]. This spread pattern clearly supports multisegmental involvement of the dorsal rami of spinal nerves in ESP block. Certainly, this characteristic of ESP block, as well as RLB, can result in good analgesia in surgical procedures involving the spine or back [52,56]. However, for blockade of the ventral rami of the spinal nerve or sympathetic ganglion, local anesthetic should spread into the TPVS. The fascia structure is highly permeable to macromolecules, including local anesthetic agents [40]. At the microscopic level, gaps in its largely acellular architecture of interlinked collagen fibers readily permit rapid diffusion [40, 57]. The SCTL has a slit structure on both medial and lateral ends, and its medial slit is corresponding to the well-known anatomical ‘costotransverse foramen’ (Fig. 4). Thus, TPVS is not an anatomically isolated compartment or closed space and communicates with the outside posteriorly via slits of the SCTL [14]. Additionally, some microroutes involving muscular branches of the dorsal rami and intercostal nerve and vessels or through the intercostal membrane could contribute to injectate spread to the TPVS in ESP block [40]. Indeed, there is considerable clinical evidence, although it has been reported sporadically or described as a side effect, that ESP block can involve the ventral rami and sympathetic nerves, yielding analgesia in visceral pain and
complex regional pain syndrome, some sympathetically-mediated symptoms (Harlequin syndrome, priapism, hypotension), and even motor blockade [58-65].

6. Clinical considerations

Interfascial plane block is generally regarded as a volume-dependent block [66]. The underlying principle is that a volume of local anesthetic is injected into a fascial plane remote from the intended sites of action [9]. There are a few reports of local anesthetic systemic toxicity following ESP block with large volume of local anesthetic [67,68]. However, safe dose ranges of local anesthetics for ESP blocks have not been specifically evaluated by serum concentration. It is difficult to predict what volume of the injectate spreads to the TPVS anteriorly or back muscles and fascial layer posteriorly in ESP block. A previous cadaver study showed that continually increasing the volume of injectate for ESP blocks did not guarantee an increase in extent of paravertebral spread [69]. Therefore, for safe and effective ESP block, clinical data regarding optimal dose-volume regimens that consider patient condition, injection site, and types of local anesthetic should be gathered [70].

Intertransverse process (ITP) block

1. Anatomical description

ITP block is anatomically described as injection in the tissue between two transverse processes, posterior to the superior costotransverse ligament or halfway between the posterior aspect of the transverse process and the pleura (Fig. 1) [11].

2. Anatomical considerations

ITP block, recently named by international consensus [11], is a collective name for several reported block techniques, including mid-point transverse process to pleura block [71], multiple injection costotransverse block [72], subtransverse process interligamentary block [73], and
costotransverse foramen block [74]. The concept of an ITP block was first introduced as a mid-point transverse process to pleura block by Costache et al. in 2017 [71]. The target area for ITP block is tissue, which is clearly different from that of a fascial plane for an ESP block or RLB. Thus, an ITP block is not an interfascial plane block. The complex area posterior to the SCTL was first described as the ‘intertransverse tissue complex (ITTC)’ and comprises the intertransverse ligament, fatty tissue, the intertransverse and levatores costarum muscles, and the SCTL that borders the TPVS [72]. While the ITTC has been designated from an anatomical perspective, ultrasound images cannot show its complicated details. The proposed term ‘retro-SCTL space’ [14], the space posterior to the SCTL, might clinically represent the appropriate target area of an anatomically intricate tissue complex for ITP block. The erector spinae fascia, SCTL, the pleura that demarcates the erector spinae muscle compartment, the retro-SCTL space, and the TPVS are important landmarks used during ultrasound-guided ITP block (Fig. 3) [75]. Recent micro-computed tomography images provided a three-dimensional detailed anatomy of the TPVS and retro-SCTL space within cadavers (Supplemental video 1) [14,75].

3. Spreading pattern of injectate

In contrast with ESP block or RLB, anatomical studies have consistently demonstrated paravertebral spread with sympathetic involvement, a very similar pattern to PVB, in ITP block (Fig. 5) [71,72,74,75]. The retro-SCTL space appears to directly communicate with the TPVS via the slit structure of the SCTL, namely the costotransverse foramen, and via the costotransverse space, the space between the TP and the rib (Fig. 2) [14,75]. The costotransverse space is connected to the roof and base of the retro-SCTL space and its base was incompletely covered by a part of the SCTL and the radiate ligament [75]. Also, histologic examination revealed that the costotransverse space was mostly occupied by adipose and loose connective tissues [75]. In a cadaveric evaluation, the costotransverse foramen and the costotransverse space served as anatomical conduits for anterior
and intersegmental paravertebral spread of the ITP block, respectively [75]. Indeed, on real-time ultrasound images, anterior pleural displacement was observed in most ITP block injections [71, 74, 75]. However, some spreading of the injectate to the erector spinae fascia was observed on real-time ultrasound images, indicating posterior spread [71, 74, 75]. Dye infiltration to the back muscles and fascia following ITP block, which is similar to the spreading pattern of ESP block, was observed in most cadaver studies [71, 72, 74, 75]. Although this spread can contribute to blockade of the dorsal rami of the spinal nerve, it could result in loss of injectate volume for paravertebral spread. A needle replacement technique to minimize this posterior spread until adequate anterior spread was visualized by ultrasonography was proposed previously [74]. In terms of paravertebral spread, recent reports have suggested that ITP block, involving injection into the retro-SCTL space that has direct and close pathways to the TPVS, can be anatomically more advantageous than ESP block or RLB [71, 72, 74, 75]. Local anesthetics take a longer pathway to reach the TPVS, through both the erector spinae fascia and retro-SCTL space, in RLB and ESP block. The bottom line is that ITP block seems to have characteristics that fall somewhere between those of PVB and ESP block.

4. Clinical evidence

Indeed, despite limited sample sizes, ITP blocks were shown to have excellent analgesic efficacy with intense sensory block in patients who underwent breast surgery or thoracotomy [71-74]. However, more data are required concerning the effectiveness of ITP block compared to ESP block or RLB. The clinical potential and efficacy of ITP block should be evaluated in further clinical studies and compared to those of thoracic paraspinal blocks or truncal nerve blocks.

Conclusions

A precise anatomical understanding of the TPVS is essential for successful and safe performance of thoracic paraspinal blocks. Despite some potential risks, PVB is a well-established
technique with a wealth of clinical data available and comparable analgesic efficacy to epidural block. Thus, education and training regarding performance of thoracic PVB in clinical practice should continue. ESP block and RLB, more superficial blocks, do not approach the pleura and neurovascular structures, and their procedure-related risks are lower than those of PVB. Furthermore, ESP block and RLB can be performed in difficult situations or in cervical/lumbar regions for a wide range of clinical indications. However, it is uncertain whether ESP block has the same analgesic efficacy as conventional PVB. ITP block targets the retro-SCTL space, which has direct and closer pathways to the TPVS, and appears to be anatomically more advantageous than ESP block or RLB. Further clinical studies are needed to confirm this anatomical finding for ITP block.

Each type of thoracic paraspinal block has a different anatomical basis, resulting in differing spreading patterns of injectate. Consequently, intrinsic characters of the neural blockade differ between techniques. Understanding the proposed mechanisms of action of each paraspinal block could assist clinicians in further investigating and refining block performance, with the ultimate goal of optimizing analgesic efficacy and improving patient outcomes.
References


72. Nielsen MV, Moriggl B, Hoermann R, Nielsen TD, Bendtsen TF, Børglum J. Are single-
injection erector spinae plane block and multiple-injection costotransverse block equivalent

73. Kilicaslan A, Sarkilar G, Altınok T, Tulgar S. A novel ultrasound-guided technique in peri-
paravertebral area: Subtransverse process interligamentary (STIL) plane block: The game

74. Shibata Y, Kampitak W, Tansatit T. The Novel Costotransverse Foramen Block Technique:
Distribution Characteristics of Injectate Compared with Erector Spinae Plane Block. Pain

thoracic intertransverse process (ITP) block: Micro-computed tomography findings and
**Figure legends**

**Fig. 1.** Anatomical targets of paraspinal blocks at the mid-thoracic region on sectional images of micro-computed tomography.

A. A cross-sectional image at the transverse process level.

B. A cross-sectional image at the intertransverse process region.

C. A sagittal-sectional image at the intertransverse process region.

Arrows indicate each paraspinal block techniques (PVB, paravertebral block; RLB, retrolaminar block; ESP, erector spinae plane block; ITP, intertransverse process block). Arrowheads indicate the superior costotransverse ligament (SCTL). Asterisk indicates the costotransverse space between the rib (R) and the transverse process (TP). Red-dotted lines indicate erector spinae fascial plane.

SP, spinous process; L, vertebral lamina; P, pleura; CTJ, costotransverse joint; CVJ, costovertebral joint; ES, erector spinae muscles; IAP, inferior articular process; DRG, dorsal root ganglion; ICN, intercostal nerve.
Fig. 2. Paravertebral space and adjacent anatomical structures at the mid-thoracic region.

A. Illustrated diagram of a transverse sectional view of the intertransverse/intercostal region.

B. Micro-computed tomography image corresponding to illustration A.\textsuperscript{14}

C. Illustrated diagram of a sagittal sectional view of the intertransverse process region.

D. Micro-computed tomography image corresponding to illustration C.\textsuperscript{14}

Arrow indicates the costotransverse foramen, and arrowheads indicate the anterior and posterior layer of the superior costotransverse ligament (SCTL). Asterisks indicate the costotransverse space between the rib (R) and the transverse process (TP).

ES, erector spinae muscles; IAP, inferior articular process; ITL, intertransverse ligament; DRG, dorsal root ganglion; DR, dorsal rami; VR, ventral rami; ICN, intercostal nerve; SG, sympathetic ganglion; P, pleura; TPVS, thoracic paravertebral space (bluish area); RS, retro-SCTL space (greenish area).
Fig. 3. Ultrasound images of the paravertebral space and relevant anatomical structures for paraspinal block at the mid-thoracic region.

A. A transverse scan to identify bony landmarks.

B. A transverse scan to perform paravertebral block (PVB).

C. A parasagittal scan to perform retrolaminar block (RLB).

D. A parasagittal scan of the intertransverse process (ITP) region.

Illustrations in the right corner show the probe location for each ultrasound image. Arrows indicate the erector spinae fascial plane (ESP), and arrowheads indicate the superior costotransverse ligament (SCTL). In Fig. 4D, ESP block targets the erector spinae fascial plane. ITP block targets the tissue complex posterior to the SCTL (retro-SCTL space). PVB directly targets the TPVS.

ES, erector spinae muscles; L, vertebral lamina; ICM, intercostal muscles; TP, transverse process; SP, spinous process; P, pleura; TPVS, thoracic paravertebral space; RS, retro-SCTL space.
Fig. 4. Costotransverse foramen (CTF) at the mid-thoracic region.

A. The erector spinae muscles were removed. The dorsal rami of spinal nerve (DR) emerge from the medial slit of superior costotransverse ligament (SCTL), corresponding to the CTF (blue-dotted line), beneath the vertebral lamina (L).

B. In the intrathoracic view, the CTFs are clearly revealed after removal of the pleura and vessels. The ventral rami of spinal nerve (ICN, intercostal nerve) pass through the CTFs (blue-dotted line).

TP, transverse process; ITL, intertransverse ligament; R, rib; RC, rami communicantes; SC, sympathetic chain.
Fig. 5. Dye spreading pattern following intertransverse process (ITP) block.

A. A cross-sectional cut of a non-embalmed cadaver after injection of dye solution into the tissue complex posterior to the superior costotransverse ligament (SCTL), retro-SCTL space, for ITP block at the T4–T5 level. 

B. Anatomical structure annotations corresponding to Fig. 3A

Arrow indicates the costotransverse foramen (CTF, medial slit of the SCTL), and arrowheads indicate the SCTL. Multi-directional spread of the dye from the injection site (retro-SCTL space) was observed as the dye spread into the paravertebral space through the CTF, the intercostal space, and erector spinae (ES) compartment. The dye fully surrounded the dorsal (DR) and ventral (VR) rami of the spinal nerve and the sympathetic ganglion (SG).

DRG; dorsal root ganglion; IIM, intercostal membrane; ICM, intercostal muscles

Supplementary video 1. Serial three-dimensional images at T4-T5 level are shown in cross and sagittal sections.