

# Different Approaches to Ultrasound-guided Thoracic Paravertebral Block

## An Illustrated Review

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### ABSTRACT

Given the fast development and increasing clinical relevance of ultrasound guidance for thoracic paravertebral blockade, this review article strives (1) to provide comprehensive information on thoracic paravertebral space anatomy, tailored to the needs of a regional anesthesia practitioner, (2) to interpret ultrasound images of the thoracic paravertebral space using cross-sectional anatomical images that are matched in location and plane, and (3) to briefly describe and discuss different ultrasound-guided approaches to thoracic paravertebral blockade. To illustrate the pertinent anatomy, high-resolution photographs of anatomical cross-sections are used. By using voxel anatomy, it is possible to visualize the needle pathway of different approaches in the same human specimen. This offers a unique presentation of this complex anatomical region and is inherently more realistic than anatomical drawings. (ANESTHESIOLOGY 2015; 123:459-74)

**T**HORACIC paravertebral (TPV) nerve block produces ipsilateral, segmental, somatic, and sympathetic nerve blockade in contiguous thoracic dermatomes. The technique was first described in 1905 by Sellheim and reintroduced into clinical practice by Eason and Wyatt in 1978.<sup>1</sup> Since then, it has become increasingly popular for treating acute and chronic pain of thorax, abdomen, and pelvis. It can be used unilaterally or bilaterally, with a single injection technique or *via* a catheter.

Different landmark-based techniques exist, with some techniques using electrostimulation guidance or pressure measurement as additional tools.<sup>1-9</sup> With the advent of ultrasound imaging in regional anesthesia, this tool is increasingly used also for TPV blockade, resulting in a rapid development of different ultrasound-guided approaches in recent years.<sup>10-22\*†‡</sup>

Given the fast development and increasing clinical relevance of ultrasound guidance for TPV blockade, this

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\* Vandepitte C, Stopar Pintaric T, Gautier PE: Thoracic paravertebral block. Available at: <http://www.nysora.com/techniques/neuraxial-and-perineuraxial-techniques/ultrasound-guided/3277-thoracic-paravertebral-block.html>. Accessed June 30, 2014.

† Luyet C: Paravertebral nerve block. Available at: <http://www.ultrasoundblock.com/index.php/nerve-block-techniques/nerve-blockother/paravertebral-ultrasound-block>. Accessed June 30, 2014.

‡ Gautier PE: European society of regional anaesthesia and pain medicine 30th annual congress 2011, Web cast. Available at: [http://academy.esraeurope.org/esra/2011/30th/10994/philippe.gautier.intercostal.block.paravertebral.block.html?history\\_id=635072](http://academy.esraeurope.org/esra/2011/30th/10994/philippe.gautier.intercostal.block.paravertebral.block.html?history_id=635072). Accessed June 30, 2014.

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review article strives (1) to provide comprehensive information on TPV anatomy, tailored to the needs of a regional anesthesia practitioner, (2) to interpret ultrasound images of the TPV space using cross-sectional anatomical images that are matched in location and plane, and (3) to briefly describe and discuss different ultrasound-guided approaches to TPV blockade.

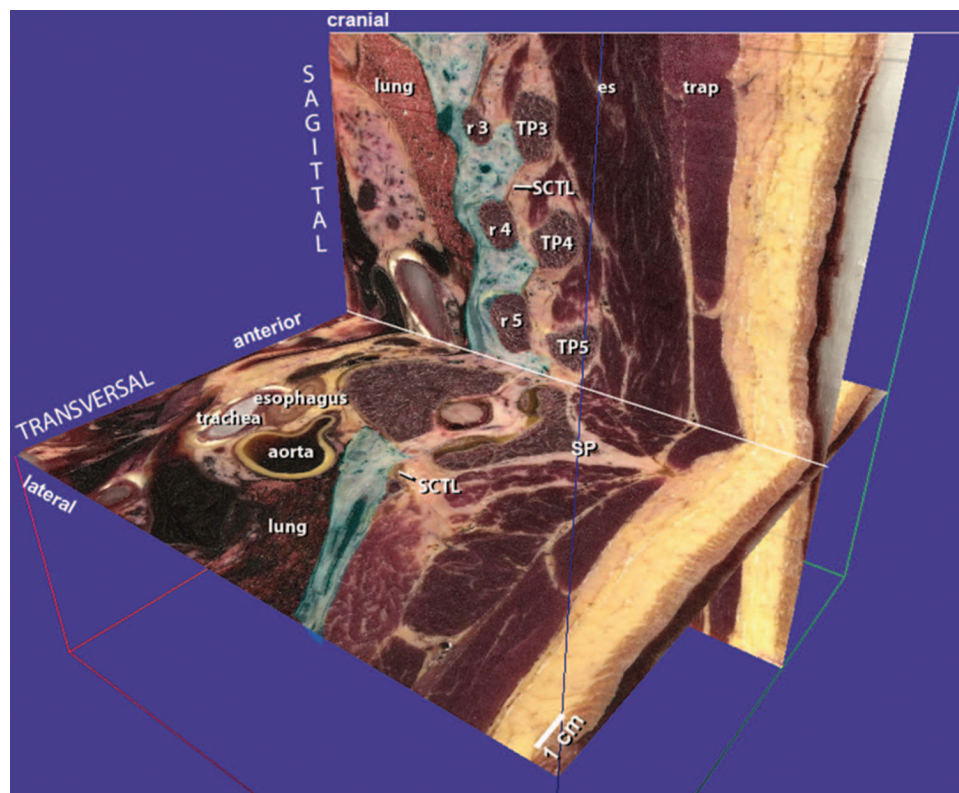
## Images

To illustrate the pertinent anatomy, high-resolution photographs of anatomical cross-sections are used. The anatomical images were obtained by sectioning blocks of tissue containing the spine (T1 to T12) of a human cadaver (male, age 40, body mass index: 24) with a heavy-duty sledge cryomicrotome (PMV, Stockholm, Sweden) at an interval of 78  $\mu$ m. The surface of each section was photographed at high resolution and the resultant photographs were processed with self-developed software (Enhanced Multiplanar Reformatting Along Curves) to digitally reconstruct the three orthogonal planes (sagittal, frontal, and transversal) and oblique cross-sections. The technique is described in detail elsewhere.<sup>23</sup> Tape-mounted histology was also acquired and stained according to a modified Mallory-Cason protocol for large cryosections, which is a general oversight stain.<sup>24</sup>

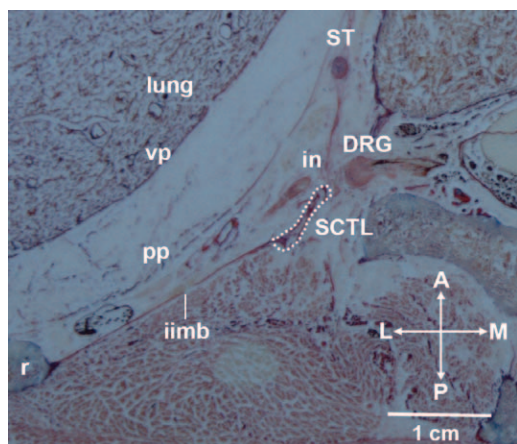
The ultrasound images were collected in healthy volunteers, using either a SonoSite S-serve (USA) or a BK Medical Flex Focus (Denmark) ultrasound platform with a linear-array transducer oscillating at 15 MHz. It should be noted that the anatomy can vary between individuals and that the measurements of distances are only indicative.

## Boundaries and Continuities of the TPV Space

The TPV space is situated directly adjacent to the thoracic spine bilaterally. Its medial boundaries are the vertebral bodies, the intervertebral discs, and the intervertebral foramina where it connects to the epidural space. Laterally, the TPV tapers and continues as intercostal space, a transition that takes place near the costotransverse joint. Superiorly and inferiorly, the TPV space is partially separated from the adjacent levels by the ribs and transverse processes at each thoracic level. However, the adipose tissue at the anteromedial corner of the TPV space is continuous over all thoracic levels, as shown in figure 1. Posteriorly, the TPV space is bounded by the transverse process, the rib and the superior costotransverse ligament (SCTL), as shown in figures 1 to 3. The SCTL runs from the superior border of the neck of the rib to the lower border of the transverse process of the vertebra immediately above (fig. 3, C and D). It can consist of more than one layer and contain gaps.<sup>25–27</sup>



**Fig. 1.** Thoracic paravertebral space at thoracic level T5. The thoracic paravertebral space is highlighted in *turquoise* in both the transversal plane (left side of body) and the sagittal plane (right side of body). es = erector spinae muscle; r = rib; SCTL = superior costotransverse ligament; SP = spinous process; TP = transverse process; trap = trapezius muscle.



**Fig. 2.** Transverse cross-section at thoracic level T9. Tape-mounted histology stained according to a modified Mallory-Cason protocol. A = anterior; DRG = dorsal root ganglion; iimb = internal intercostal membrane; in = intercostal nerve; L = lateral; M = medial; P = posterior; pp = parietal pleura; r = rib; SCTL = superior costotransverse ligament (*dotted outline*); ST = sympathetic trunk; vp = visceral pleura.

Posterior to the SCTL lie deep back muscles, that is, the multifidi and the rotatores spinae muscles, and a layer of adipose tissue is frequently present in-between muscles and ligament (fig. 1). Laterally, the SCTL connects with the internal intercostal membrane, that is, the aponeurosis of the internal intercostal muscle that gradually develops into a proper muscle at approximately 4 to 6 cm lateral of the midline (figs. 2 and 3F). Posterior to the internal intercostal membrane, the external intercostal muscle and the levator costarum muscle both pass obliquely downward and lateral to the upper border of the rib, originating from either the rib above (external intercostal muscles) or the transverse process above (levator costarum muscles) (fig. 3E).

Anteriorly, the TPV space is confined either by the parietal pleura (T2 to T10/T11) or the diaphragm (T10/T11 to T12). The endothoracic fascia is part of the anterior border. It is a layer of loose, mesh-like connective tissue of approximately 250- $\mu$ m thickness that lies directly posterior to the pleura and attaches it to the thoracic wall. Medially, the endothoracic fascia merges with the prevertebral fascia.<sup>27–31</sup> Cranially, the high thoracic TPV space lies in close proximity to the adipose tissue of the brachial plexus, phrenic nerve, and cervical sympathetic trunk, which may have consequences for local anesthetic spread. A potential route toward the brachial plexus, the stellate ganglion, and the perivascular nerve plexus of the subclavian artery is shown in figure 4A, but alternative pathways have been reported as well, for example, along Kuntz's nerve.<sup>32</sup>

Caudally, the boundary of the TPV space is subject to debate. Although some cadaver studies showed that the caudal end of the T12 TPV space is effectively sealed off by the origin of the psoas major muscle, other studies observed spread of injectate to the lumbar plexus and the celiac ganglion through the medial and lateral arcuate ligaments of the diaphragm.<sup>33–36</sup> Figure 4, B and C, shows the continuity

of the lower thoracic TPV space toward the retroperitoneal space containing the lumbar plexus, but the clinical significance of this pathway is uncertain.

## Contents of the TPV Space

The TPV space is filled with adipose tissue that contains the intercostal nerve, artery and vein, and the sympathetic trunk. Unlike at the intercostal location, the neurovascular structures are not yet arranged in a standard position (fig. 3). The intercostal nerve comes into the TPV space from medial and gradually assumes a position along the inferior edge of the rib toward lateral. The posterior intercostal artery and vein both enter the TPV space from anteromedial. The artery usually lies in the inferior half of the TPV space, only approaching the inferior border of the rib at 6 to 7 cm from the midline.<sup>37,38</sup> It is quite tortuous, particularly in elderly persons and at high thoracic levels.<sup>37–39</sup>

## Ultrasound-guided TPV Block

For an overview, the various approaches have been categorized, as shown in figure 5. The ultrasound transducer can be oriented in a transversal or sagittal direction, which results in a completely different representation of the TPV space on the ultrasound image. Bony structures, that is, the rib, transverse process, and inferior articular process, constitute the main anatomical landmarks on ultrasound. In this overview, “lateral” approaches are aimed close to the tip of the transversal process or in-between ribs, while “medial” techniques are performed medial to the costotransverse joint. The approaches are furthermore characterized by usage of either an in-plane or out-of-plane technique and the direction of angulation in either the transversal or the sagittal plane.

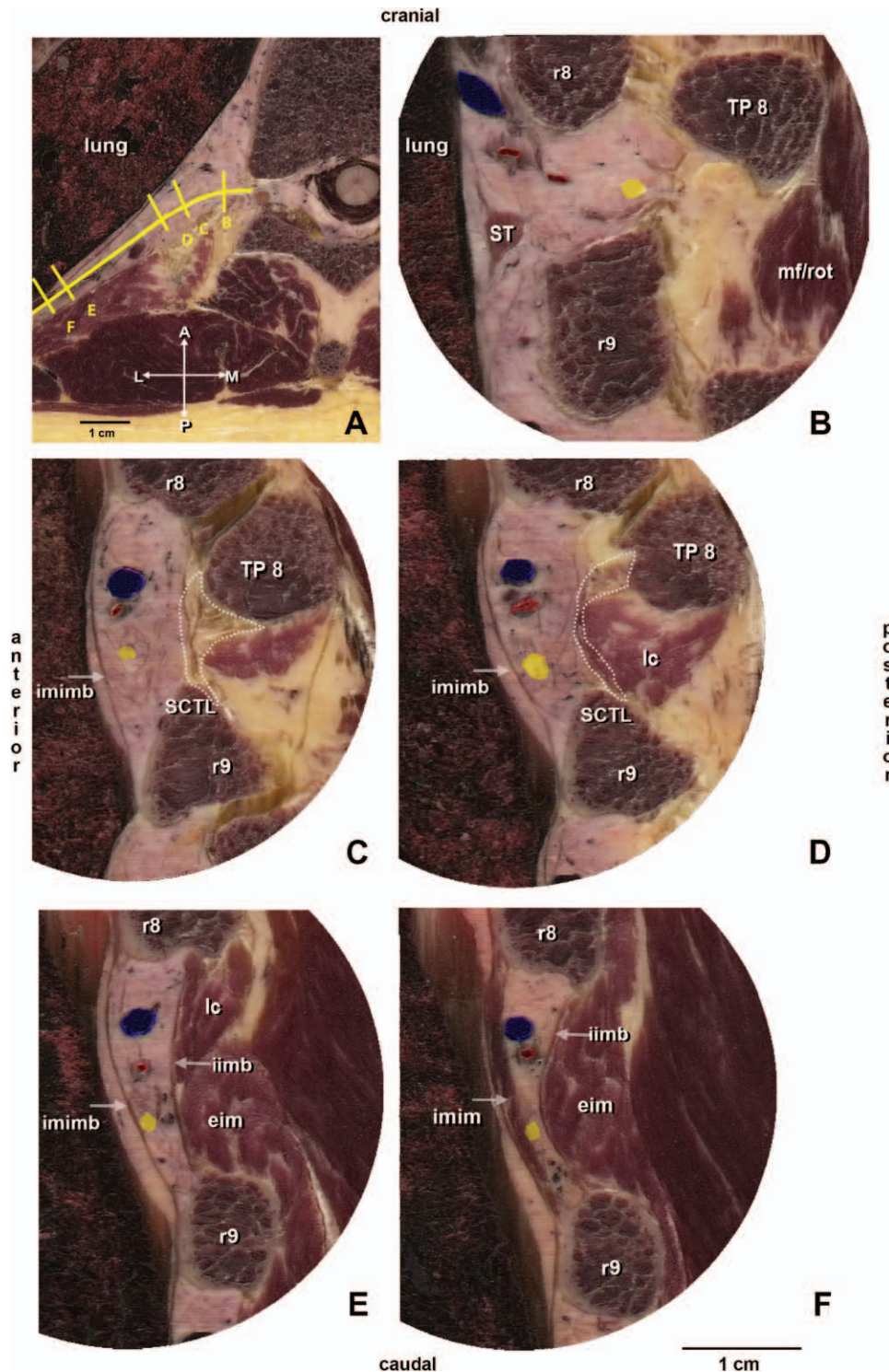
Although there are a variety of approaches, the anatomical landmarks that are used for orientation on the ultrasound image are mostly the same, that is, transverse process, rib, and pleura. Therefore, at first, it is described how these structures can be identified with ultrasound imaging in transversal and sagittal approaches, followed by a brief description of the ultrasound-guided approaches and their differences.

## Identification of Anatomical Landmarks on Transversal Ultrasound Images

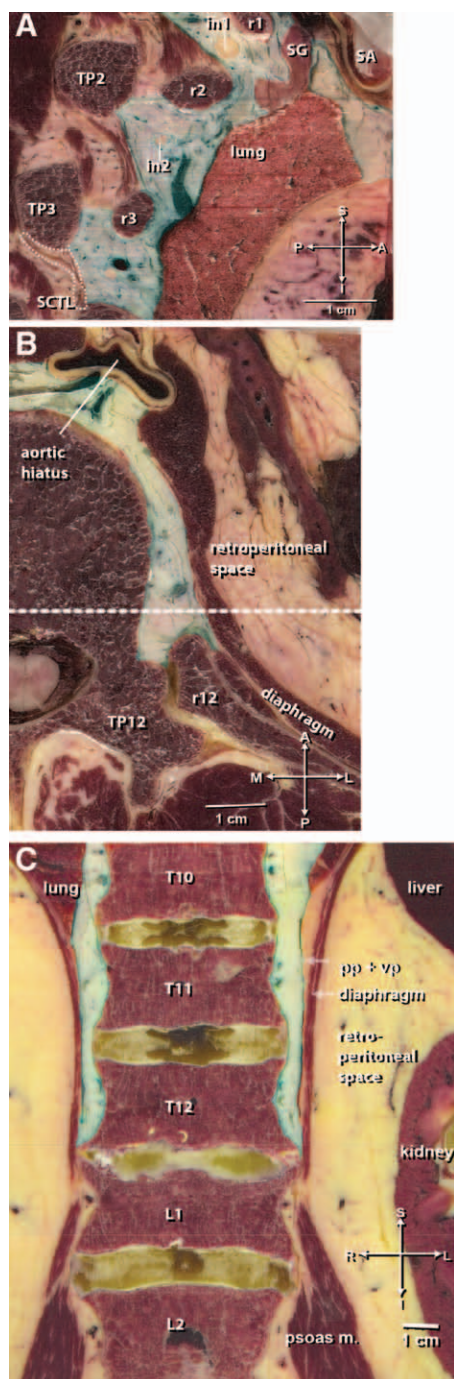
For ultrasound examinations in the transversal plane, the transducer is placed lateral to the spinous process. Tilting and/or sliding the transducer in a craniocaudal direction generates three characteristic views of the TPV space.

Figure 6 shows the rib connecting to its transverse process. Together, they create a large acoustic shadow (fig. 6A). The TPV space is almost completely filled by the rib, leaving only a thin strip of adipose tissue anterior to the head of the rib, which contains the sympathetic trunk (fig. 6, B and C).

Scanning slightly more inferior, figure 7 shows the “thumb-like” contour of the transverse process. The TPV space is situated directly anterior to it but is obscured from



**Fig. 3.** (A–F) Sequence of (oblique) sagittal cross-sections from medial to lateral at thoracic level T8, perpendicular to the trajectory of the eighth intercostal nerve. (A) Transversal cross-section at T8. The yellow line indicates the course of the intercostal nerve, and the position of the (oblique) sagittal cross-sections on B–F is marked. (B) Sagittal cross-section directly lateral to the intervertebral foramen. (C) Oblique sagittal cross-section through the thoracic paravertebral space. (D) Oblique sagittal cross-sections through the thoracic paravertebral space. (E) Oblique sagittal cross-section through the intercostal space. (F) Oblique sagittal cross-section through the intercostal space. A = anterior; eim = external intercostal muscle; iimb = internal intercostal membrane; imim = innermost intercostal muscle; imimb = innermost intercostal muscle membrane; L = lateral; lc = levator costarum muscle; M = medial; mf = multifidus muscle; P = posterior; r = rib; rot = rotator muscle; SCTL = superior costotransverse ligament; ST = sympathetic trunk; TP = transverse process. Red, blue, and yellow indicate artery, vein, and nerve, respectively.



**Fig. 4.** Cranial and caudal boundaries of the thoracic paravertebral (TPV) space. (A) Sagittal cross-section at thoracic levels T2 and T3, 2 cm lateral of the midline. The TPV space is highlighted in turquoise. A = anterior; I = inferior; P = posterior; S = superior. (B) Transversal cross-section at thoracic level T12. The dashed line indicates the location of C. A = anterior; L = lateral; M = medial; P = posterior. (C) Frontal cross-section. The TPV space is highlighted in turquoise. I = inferior; L = left; R = right; S = superior. in = intercostal nerve; pp = parietal pleura; r = rib; SA = subclavian artery; SCTL = superior costotransverse ligament (dotted outline); SG = stellate ganglion; TP = transverse process; vp = visceral pleura.

vision due to the acoustic shadow of the transverse process. What can be visualized is its lateral continuation, the intercostal space. The anterior boundary of the intercostal space is clearly demarcated by the hyperechoic reflection of the pleura. Its posterior boundary is a combined reflection of the internal intercostal membrane and the external intercostal muscle. Inferior to the transverse process, the TPV space is no longer shielded by bone and can now be visualized with ultrasound, as shown in figure 8. The inferior articular process can be visualized at a more medial position than the tip of the transverse process. Its contour and acoustic shadow mark the medial boundary of the TPV space. The bright reflection of the pleura at the lateral side of the image gradually fades toward medial as the pleura bends and reaches almost an acute angle toward the mediastinum. At this level, the SCTL forms the posterior boundary of the TPV space. Connecting rib and the transverse process above it, it has an oblique orientation in two directions, that is, from ventrocaudal to dorsocranial and from ventromedial to dorsolateral. This causes its reflection to diminish toward medial because the ultrasound beams are increasingly nonperpendicular to the ligament. Tilting of the ultrasound transducer increases or decreases its reflection, for example, tilting slightly toward cranial and lateral increases the reflection.

These “characteristic” images apply particularly to thoracic levels T2 to T10. At lower thoracic levels, the diaphragm, not the pleura, forms the anterior boundary of the TPV space that does not display an equally echogenic reflection as the pleura.

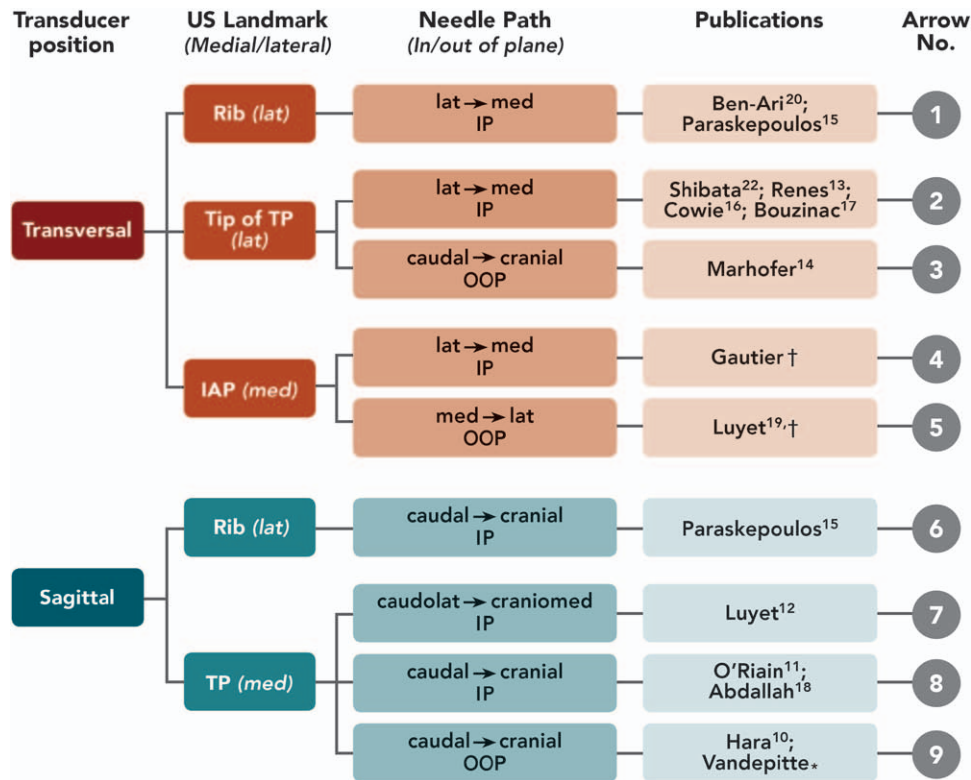
### Ultrasound-guided Techniques Using a Transversal Transducer Position

#### *Transversal Intercostal Approach, Lateral to Medial, In-plane*<sup>15,20</sup>

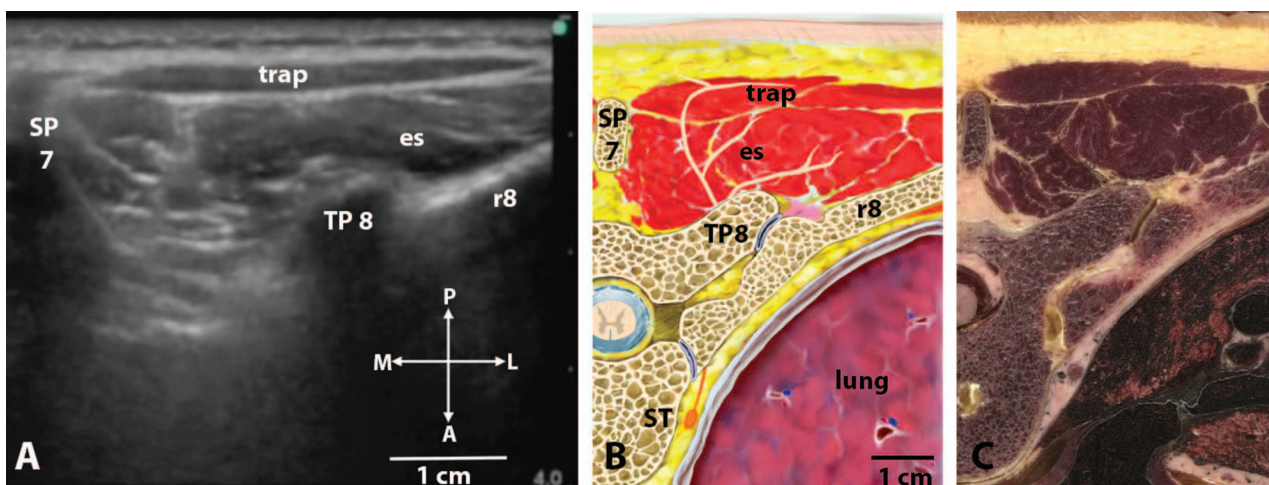
This technique is shown in figure 9 by arrow 1. The transducer is placed transversally at 8 cm lateral to the midline in the sagittal plane. After identification of the rib and the pleura, the transducer is rotated to an oblique transversal position along the long axis of the rib and tilted until the intercostal muscles are visualized. The needle is introduced in-plane at the lateral side of the probe and advanced into the space between the internal and innermost intercostal muscles. This technique technically constitutes an intercostal block and relies on spread of local anesthetic fluid toward the contiguous TPV space medially and from there to adjacent ipsilateral TPV spaces. This distribution of local anesthetic was confirmed in a cadaver study, where 17 of 19 injections of 1 ml methylene blue 1% resulted in spread of dye to the TPV space.<sup>15</sup> In patients, injection of 20 ml lidocaine (15 mg/ml) resulted in a sensory blockade over a median of 5 dermatomes (interquartile range, 4 to 6).<sup>20</sup>

#### *Transversal Technique at the Transverse Process, Lateral to Medial, In-plane*<sup>13,16,17,22</sup>

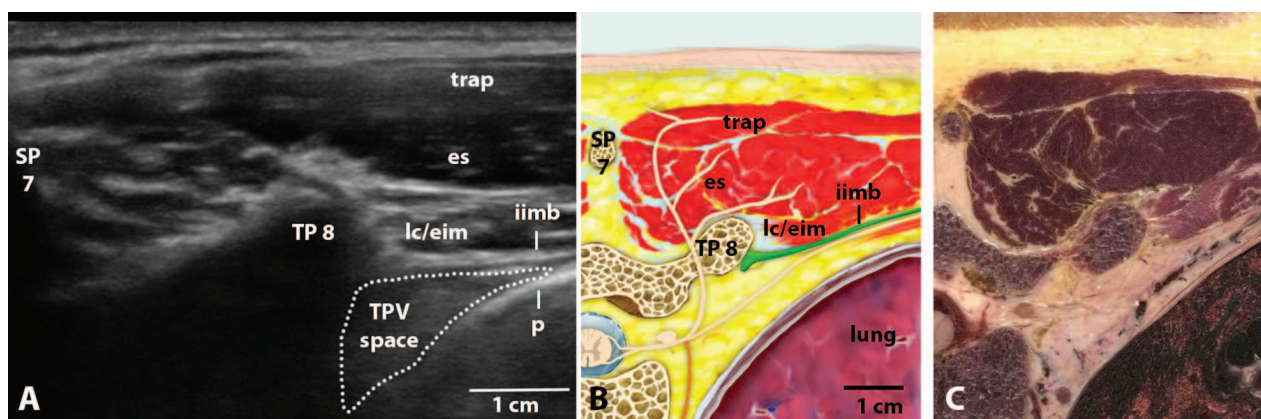
This technique is shown in figure 9 by arrow 2. The reflection of the transverse process is a commonly used landmark



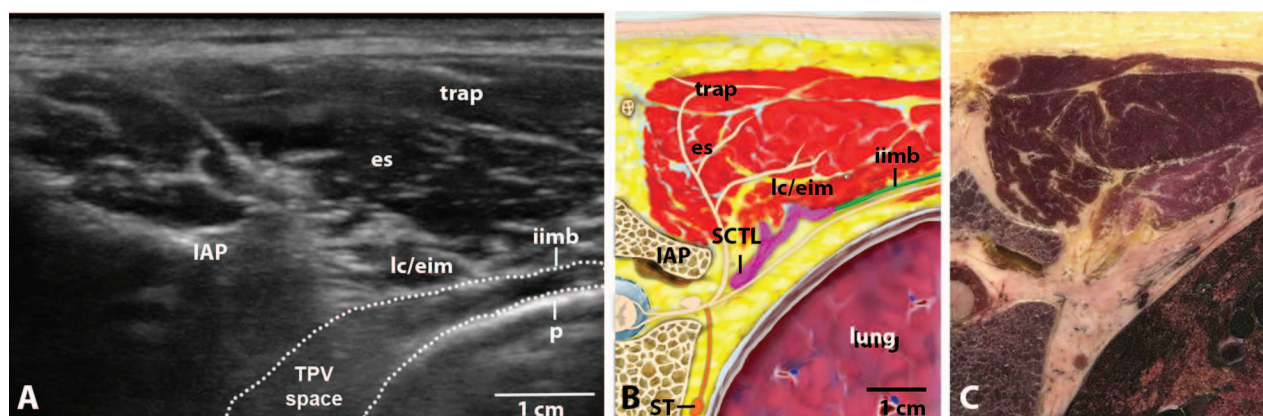
**Fig. 5.** Flow-chart of ultrasound (US)-guided approaches to thoracic paravertebral block. IAP = inferior articular process; IP = in-plane; lat = lateral; med = medial; OOP = out-of-plane; TP = transverse process. The *arrow number* refers to figures 9, 10, 14, 15, and 16. \* Vandepitte C, Stopar Pintaric T, Gautier PE: Thoracic paravertebral block. Available at: <http://www.nysora.com/techniques/neuraxial-and-perineuraxial-techniques/ultrasound-guided/3277-thoracic-paravertebral-block.html>. Accessed June 30, 2014. † Luyet C: Paravertebral nerve block. Available at: <http://www.ultrasoundblock.com/index.php/nerve-block-techniques/nerve-blockother/paravertebral-ultrasound-block>. Accessed June 30, 2014. ‡ Gautier PE: European society of regional anaesthesia and pain medicine 30th annual congress 2011, Web cast. Available at: [http://academy.esraeurope.org/esra/2011/30th/10994/philippe.gautier.intercostal.block.paravertebral.block.html?history\\_id=635072](http://academy.esraeurope.org/esra/2011/30th/10994/philippe.gautier.intercostal.block.paravertebral.block.html?history_id=635072). Accessed June 30, 2014.



**Fig. 6.** Transversal cross-sectional image at thoracic level T8 at the level of the costotransverse junction. (A) Ultrasound image, (B) illustration, and (C) cryosection. A = anterior; es = erector spinae muscle; L = lateral; M = medial; P = posterior; r = rib; SP = spinous process; ST = sympathetic trunk; TP = transverse process; trap = trapezius muscle. This figure was reproduced, with adaptations, with permission from Bigeleisen P, Gofeld M, Orebaugh SE: Ultrasound Guided Regional Anesthesia and Pain Medicine, 2nd edition, Wolters Kluwer, 2015. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.



**Fig. 7.** Transversal cross-sectional image at thoracic level T8 at the level of the transverse process. (A) Ultrasound image, (B) illustration, and (C) cryosection. eim = external intercostal muscle; es = erector spinae muscle; iimb = internal intercostal membrane (green); lc = levator costarum muscle; p = pleura; SP = spinous process; TP = transverse process; TPV space = thoracic paravertebral space (dotted outline); trap = trapezius muscle. This figure was reproduced, with adaptations, with permission from Bigeleisen P, Gofeld M, Orebaugh SE. *Ultrasound Guided Regional Anesthesia and Pain Medicine*, 2nd edition, Wolters Kluwer, 2015. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

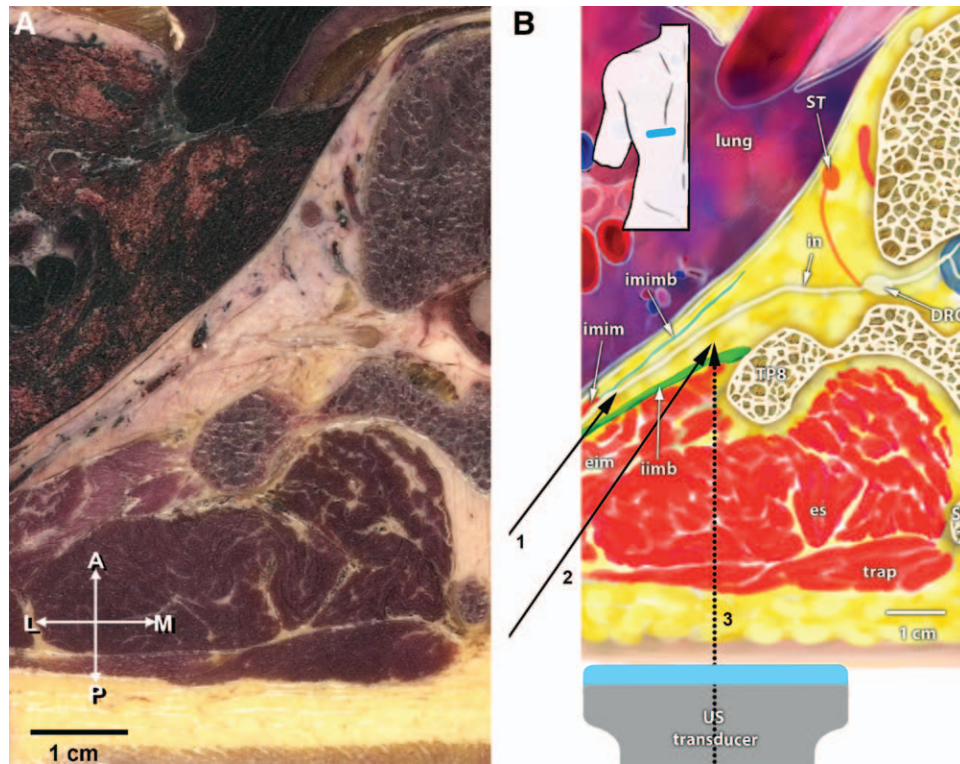


**Fig. 8.** Transversal cross-sectional image at thoracic level T8 at the level of the thoracic paravertebral (TPV) space (dotted outline). (A) Ultrasound image, (B) illustration, and (C) cryosection. eim = external intercostal muscle; es = erector spinae muscle; IAP = inferior articular process; iimb = internal intercostal membrane (green); lc = levator costarum muscle; p = pleura; SCTL = superior costotransverse ligament (pink); ST = sympathetic trunk; trap = trapezius muscle. This figure was reproduced, with adaptations, with permission from Bigeleisen P, Gofeld M, Orebaugh SE: *Ultrasound Guided Regional Anesthesia and Pain Medicine*, 2nd edition, Wolters Kluwer, 2015. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

to determine the target for injection. The needle is inserted in-plane from lateral to medial and advanced until it enters the triangular area in-between the parietal pleura (anterior) and the internal intercostal membrane and intercostal muscles (posterior). The final position of the needle tip is in the transition zone from intercostal to TPV space, just ventrolateral to the tip of the transverse process. In two clinical studies, injection of 20 ml of ropivacaine 0.75% with this approach resulted in sensory blockade over a median of 4 or 6 dermatomes (range, 3 to 7), respectively, whereas a cadaver study observed distribution of 20 ml injected dye over three to four TPV spaces (range, 1 to 10) with 40% incidence of epidural spread.<sup>13,16,17</sup>

#### **Transversal Technique at the Transverse Process, Out-of-plane<sup>14</sup>**

This technique is shown in figure 9 by arrow 3. After identification of the transverse process, the pleura, and the internal intercostal membrane, the needle is inserted out-of plane 1 cm caudal to the ultrasound transducer and advanced in a straight sagittal plane with slight caudocranial angulation until the tip is visualized in a position between the internal intercostal membrane and the pleura. This technique was evaluated in a volunteer study that demonstrated that injecting a total of 20 ml mepivacaine 1% lead to a distribution of local anesthetic over a median of 3.5 to 4 dermatomes (range, 2 to 6) as seen on magnetic resonance images with an incidence of epidural



**Fig. 9.** Ultrasound (US)-guided thoracic paravertebral blocks using a transversal transducer position, lateral techniques. (A) Transversal cross-section at thoracic level T6 at the level of the TP. (B) Illustration depicting transducer position and needle trajectory using lateral to medial angulation (1 and 2) or a strictly sagittal needle pathway (3). The arrow numbers refer to figure 5. A = anterior; DRG = dorsal root ganglion; eim = external intercostal muscle; es = erector spinae muscle; iimb = internal intercostal membrane (green); imim = innermost intercostal muscle; imimb = innermost intercostal muscle membrane; in = intercostal nerve; L = lateral; M = medial; P = posterior; SP = spinous process; ST = sympathetic trunk; TP = transverse process; trap = trapezius muscle.

spread of 25%, while the same volunteers had a sensory blockade over a median of 10 dermatomes (range, 3 to 19).<sup>40</sup>

#### **Transversal Technique at the Inferior Articular Process, Lateral to Medial, In-plane†**

This technique is shown in figure 10 by arrow 4. The inferior articular process is visualized medially and the pleura laterally. The needle is inserted at 4 cm lateral of the midline and advanced in-plane from lateral to medial until bony contact with the posterior border of the inferior articular process is felt. Then the needle is slightly redirected and advanced 1 cm further to a final position lateral to the vertebral body. Because the inferior articular process protrudes further lateral than the intervertebral foramen, and the redirected needle pathway is sufficiently steep, this should prevent the needle tip for inadvertently entering the intervertebral foramen. There are no published reports yet evaluating this technique.

#### **Transversal Technique at the Inferior Articular Process, Medial to Lateral, Out-of-plane<sup>19†</sup>**

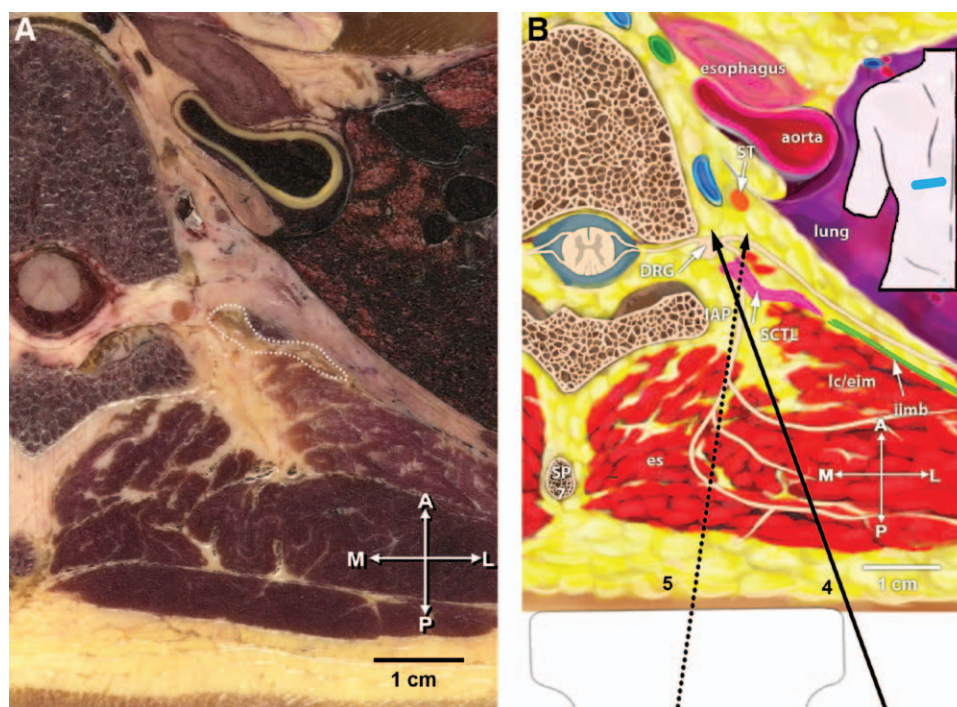
This technique is shown in figure 10 by arrow 5. The inferior articular process is placed at the center of the ultrasound image. The needle is inserted out-of-plane and advanced with slight medial to lateral angulation toward the posterolateral border of the inferior articular process. As visualization of

the SCTL can be difficult to achieve with this technique, the needle tip is walked-off laterally over the edge of the inferior articular process and advanced a few millimeters under direct vision. The correct position of the needle tip is confirmed by injecting 1 to 2 ml of normal saline and visualizing an anterior displacement of the pleura. In a cadaver study, 34 of 36 needle tips were correctly positioned in the TPV with this technique, but subsequently inserted catheters tended to be placed further anterior and medial than the needle tip. Contrast dye (10 ml) injected through the catheters spread not only toward anterior and medial but also toward the intercostal space laterally. Although no catheter tip was located in the epidural space, epidural spread of dye was noted in six instances.<sup>19</sup>

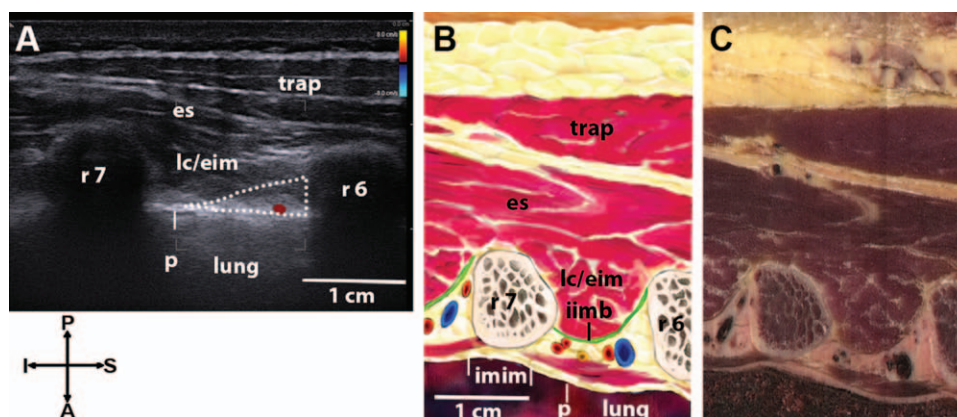
#### **Identification of Anatomical Landmarks on Sagittal Ultrasound Images**

For ultrasound examination in a sagittal orientation, the ultrasound transducer is positioned at approximately 5 cm lateral to the midline and gradually shifted toward medial (Supplemental Digital Content 1, <http://links.lww.com/ALN/B169>, video “Interpreting the Sonoanatomy of the Thoracic Paravertebral Space by Correlating Animated Anatomical and Ultrasound Images”).

Figure 11 shows the intercostal space in-between two adjacent ribs. At this location, directly lateral to the costotransverse



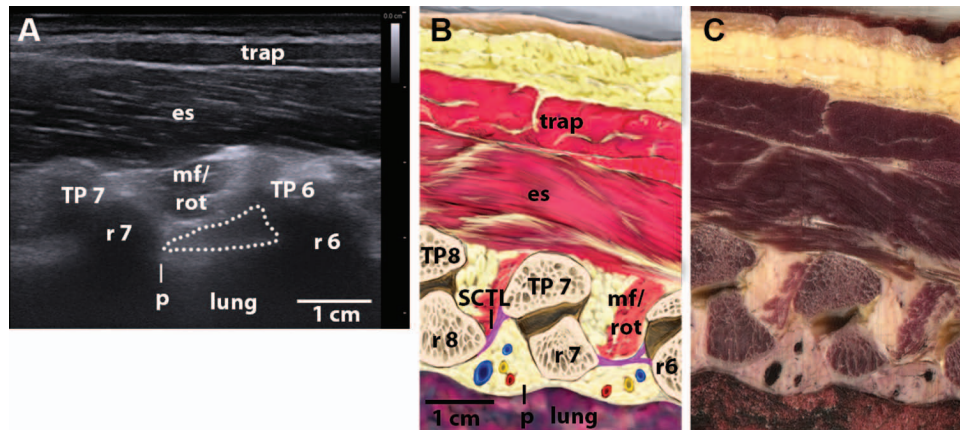
**Fig. 10.** Ultrasound-guided thoracic paravertebral blocks using a transversal transducer position, medial techniques. (A) Transversal cross-section at thoracic level T6 at the level of the inferior articular process (IAP). The superior costotransverse ligament (SCTL, pink) is highlighted by a dotted outline. (B) Illustration depicting transducer position and needle trajectory using lateral to medial (4) or medial to lateral angulation (5). Continuous line = in-plane technique. Dotted line = out-of-plane technique. The arrow numbers refer to figure 5. A = anterior; DRG = dorsal root ganglion; eim = external intercostal muscle; es = erector spinae muscle; iimb = internal intercostal membrane (green); L = lateral; lc = levator costarum muscle; M = medial; P = posterior; SP = spinous process; ST = sympathetic trunk.



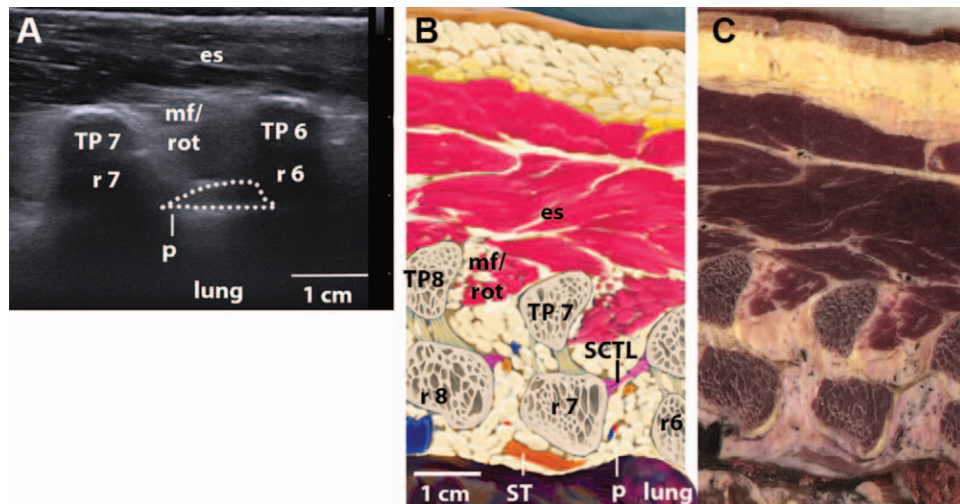
**Fig. 11.** Sagittal cross-sections at thoracic level T6/T7 at the level of the ribs. (A) Ultrasound image, (B) illustration, and (C) cryosection. eim = external intercostal muscle; es = erector spinae muscle; iimb = internal intercostal membrane (green); imim = innermost intercostal muscle; lc = levator costarum muscle; p = pleura; r = rib; trap = trapezius muscle. Red, blue, and yellow indicate artery, vein, and nerve, respectively. Thoracic paravertebral space highlighted by dotted outline. This figure was reproduced, with adaptations, with permission from Bigeleisen P, Gofeld M, Orebaugh SE: Ultrasound Guided Regional Anesthesia and Pain Medicine, 2nd edition, Wolters Kluwer, 2015. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

joint, the posterior border of the TPV space is formed by the external intercostal muscle and the internal intercostal membrane. The innermost intercostal muscle and the pleura form the anterior demarcation. Toward medial, the innermost intercostal muscle is reduced to its membrane. The high

echogenicity of the pleura and its characteristic lung sliding motion make it easily recognizable.<sup>41,42</sup> Identification of the intercostal artery with color Doppler imaging is possible but can be difficult due to its small size and the perpendicular position of the ultrasound probe to the intercostal artery.



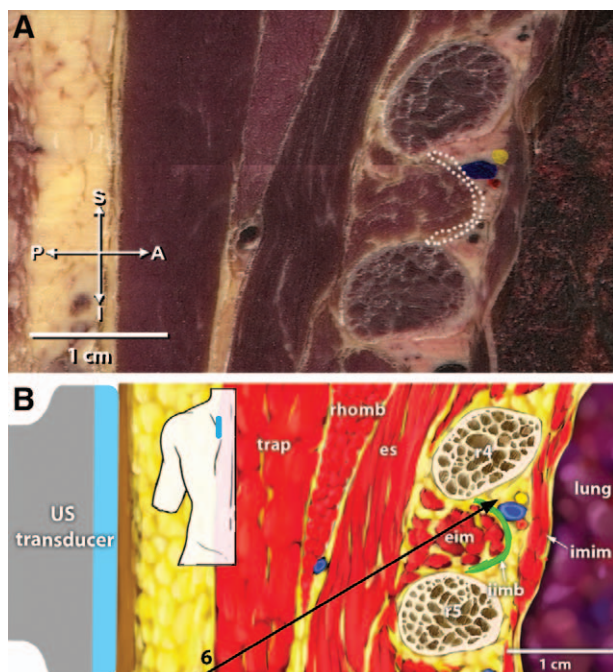
**Fig. 12.** Sagittal cross-sections at thoracic level T6/T7 at the costotransverse junction. (A) Ultrasound image, (B) illustration, and (C) cryosection. es = erector spinae muscle; mf = multifidus muscle; p = pleura; r = rib; rot = rotator muscle; SCTL = superior costotransverse ligament (pink); TP = transverse process; trap = trapezius muscle. Red, blue, and yellow indicate artery, vein, and nerve, respectively. Thoracic paravertebral space highlighted by dotted outline. This figure was reproduced, with adaptations, with permission from Bigeleisen P, Gofeld M, Orebaugh SE: *Ultrasound Guided Regional Anesthesia and Pain Medicine*, 2nd edition, Wolters Kluwer, 2015. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.



**Fig. 13.** Sagittal cross-sections at thoracic level T6/T7 at the thoracic paravertebral space. (A) Ultrasound image, (B) illustration, and (C) cryosection. es = erector spinae muscle; mf = multifidus muscle; p = pleura; r = rib; rot = rotator muscle; SCTL = superior costotransverse ligament (pink); ST = sympathetic trunk; TP = transverse process. Red, blue, and yellow indicate artery, vein, and nerve, respectively. Thoracic paravertebral space highlighted by dotted outline. This figure was reproduced, with adaptations, with permission from Bigeleisen P, Gofeld M, Orebaugh SE: *Ultrasound Guided Regional Anesthesia and Pain Medicine*, 2nd edition, Wolters Kluwer, 2015. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

Further medial, the contour of the reflection changes when rib and transverse process form the costotransverse joint (approximately 3 to 4 cm from the midline), as shown in figure 12. It is characterized by a compound reflection of the transverse process (postero-caudal) and the rib (ventro-caudal). The TPV space lies anterior to the SCTL. Due to its oblique orientation, the ligament is nonperpendicular to the ultrasound beams impeding clear visualization. The view may be improved by tilting the transducer slightly toward lateral.<sup>43</sup>

Again, further medial, the rib can be completely masked by the transverse process, as shown in figure 13. The acoustic windows between bony structures are narrow, causing scattering of ultrasound beams that hampers clear visualization of structures. The adipose tissue in-between the deep back muscles and the SCTL is variable in amount, and the acoustic interface between muscles and adipose tissue can be mistaken for the SCTL, which in fact lies further anterior. The reflection of the pleura gradually fades when the transducer is approaching the midline because



**Fig. 14.** Ultrasound (US)-guided thoracic paravertebral blocks using a sagittal transducer. (A) Sagittal cross-section at thoracic level T4/T5 at approximately 5 cm lateral of the midline. (B) Illustration depicting transducer position and needle trajectory for a lateral technique targeting in-between ribs (6). The arrow number refers to figure 5. A = anterior; eim = external intercostal muscle; es = erector spinae muscle; I = inferior; iimb = internal intercostal membrane (light green); imim = innermost intercostal muscle; P = posterior; r = rib; rhomb = rhomboid muscle; S = superior; trap = trapezius muscle. Red, blue, and yellow indicate artery, vein, and nerve, respectively.

the pleura becomes more sagittally oriented and is replaced by the shadow of the mediastinal structures and spine.

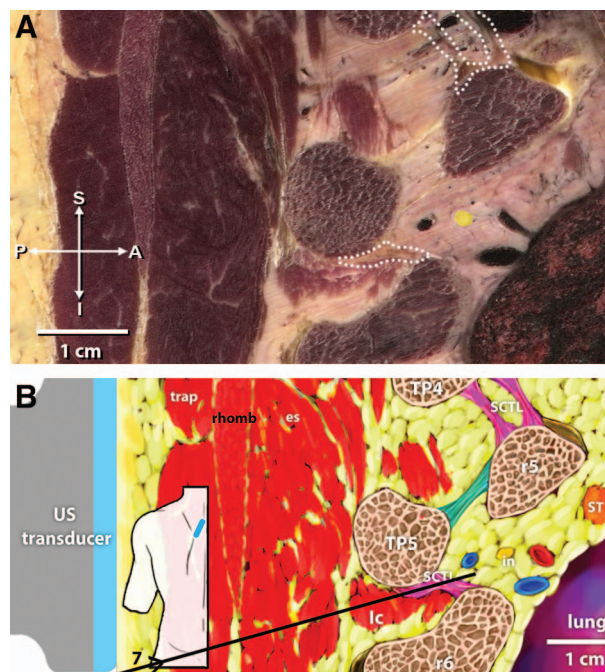
## Ultrasound-guided Techniques Using a Sagittal Transducer Position

### *Sagittal Technique at the Rib, In-plane<sup>15</sup>*

This technique is shown in figure 14 by arrow 6. At 5 cm lateral to the midline, the transducer is placed sagittally over the ribs. The needle is inserted in-plane at the inferior side of the transducer and advanced in a cephalad direction. It is guided toward a location in-between the internal intercostal membrane and the pleura. In a cadaver study, 13 of 14 injections of 1 ml methylene blue 1% resulted in spread of dye to the TPV space. The same study also evaluated a transversal in-plane intercostal approach (fig. 9, arrow no. 1) and found that more attempts were required to successfully place the needle with the sagittal technique compared with the transversal technique: two (range, 1 to 4) and four (range, 1 to 7), respectively.<sup>15</sup>

### *Oblique Sagittal Technique at the Transverse Process, Lateral to Medial, In-plane<sup>12</sup>*

This technique is shown in figure 15 by arrow 7. The transducer is positioned at approximately 3 to 4 cm lateral of the

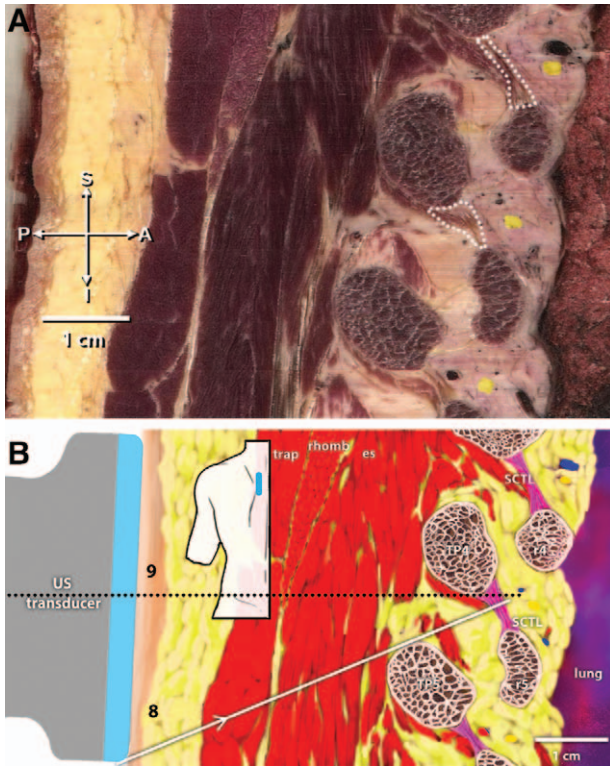


**Fig. 15.** Ultrasound (US)-guided thoracic paravertebral blocks using a sagittal transducer. (A) Oblique sagittal cross-section at thoracic level T4/T5 at approximately 5 cm lateral of the midline. The superior costotransverse ligament (SCTL) (pink) is highlighted by a dotted outline. (B) Illustration depicting transducer position and needle trajectory for a medial technique with caudolateral to craniomedial angulation (7). The arrow number refers to figure 5. A = anterior; es = erector spinae muscle; I = inferior; in = intercostal nerve; lc = levator costarum muscle; P = posterior; r = rib; rhomb = rhomboid muscle; S = superior; ST = sympathetic trunk; TP = transverse process; trap = trapezius muscle; turquoise = costo-transverse ligament. Red, blue, and yellow indicate artery, vein, and nerve, respectively.

midline between two transverse processes in an oblique sagittal position with a slight amount of angulation from craniomedial to caudolateral. After identification of the parietal pleura and the SCTL, the needle is inserted at the caudal border of the transducer and advanced using an in-plane technique into the TPV space. An anterior displacement of the pleura upon injection confirms correct needle placement. This technique was evaluated in a cadaver study, in which needle insertion was successfully achieved, but subsequent insertion of catheters through the needle was found to be difficult or impossible in 6 of 20 catheters placed, and a high variability in spread of injectate occurred, including 30% epidural spread.<sup>12</sup> In a subsequent study by the same authors, this approach has been substituted by a transversal technique at the inferior articular process (fig. 10, arrow no. 5).<sup>19</sup>

### *Sagittal Technique at the Transverse Process, In-plane<sup>11,18</sup>*

This technique is shown in figure 16 by arrow 8. The transducer is placed approximately 2.5 cm lateral to the midline in a sagittal orientation. The midpoint of the transducer



**Fig. 16.** Ultrasound (US)-guided thoracic paravertebral blocks using a sagittal transducer. (A) Sagittal cross-section at thoracic level T4/T5 at approximately 3cm lateral of the midline. (B) Illustration depicting transducer position and needle trajectory for a medial technique with caudal to cranial angulation (8 and 9). *Continuous line* = in-plane technique; *dotted line* = out-of-plane technique. The *arrow numbers* refer to figure 5. A = anterior; es = erector spinae muscle; I = inferior; P = posterior; r = rib; rhomb = rhomboid muscle; S = superior; SCTL = superior costotransverse ligament (pink); TP = transverse process; trap = trapezius muscle. Red, blue, and yellow indicate artery, vein, and nerve, respectively.

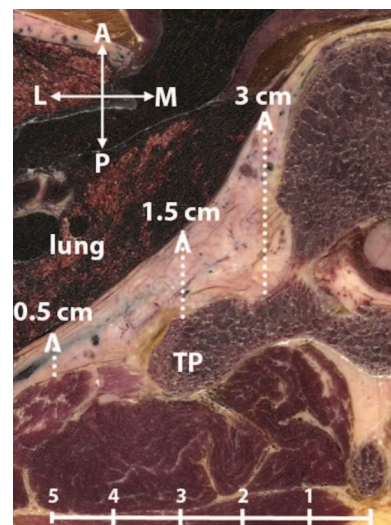
is aligned in-between two adjacent transverse processes, thereby placing the target TPV space at the center of the ultrasound image.<sup>11</sup> Alternatively, the transducer can be moved cranially to place the TPV space at the caudal border of the ultrasound image.<sup>18</sup> With the latter modification, the needle is inserted at a steeper angle, thereby reducing the length of the needle pathway. The needle is inserted in-plane at the lower border of the transducer and advanced in a straight sagittal direction to cranial and anterior. It is also possible to insert the needle at the cranial border of the transducer and advance in a caudal direction. Entering the TPV space through the SCTL may lead to a loss of resistance, but visualization of an anterior displacement of the pleura upon injection confirms correct needle placement. Although considerable clinical experience with this technique is reported,<sup>18</sup> publications describing injectate spread and sensory distribution of block in patients are currently lacking.

### Sagittal Technique at the Transverse Process, Out-of-plane<sup>10\*</sup>

This technique is shown in figure 16 by arrow 9. The transducer is placed sagittally over a transverse process, placing it at the center of the ultrasound image.<sup>10</sup> Alternatively, the space in-between two adjacent transverse processes may be positioned at the center.\* The needle is inserted using an out-of-plane technique and advanced until the central transverse process is contacted, or else the cranial of the two, with no or minimal angulation in the sagittal plane or the transversal plane. Subsequently, the needle is walked off the transverse process into the TPV space and advanced 1 to 1.5 cm beyond the transverse process without further visualizing the needle tip on ultrasound. Entering of the needle tip into the TPV space can result in a loss of resistance to normal saline and by visualizing anterior displacement of the pleura upon injection. As with the previous technique, little data are available on injectate spread and sensory distribution of block in patients.

### Considerations Regarding the Choice of Ultrasound-guided Approach

The field of ultrasound-guided regional anesthesia is moving fast. For TPV blockade, this has resulted in at least nine different ultrasound-guided approaches that have been described in the past 5 yr and are part of this review article. Quite possibly, this number will increase with growing clinical experience leading to modifications to these approaches. However, some approaches will lose relevance for exactly the same reason. From this review, it is already apparent that some experts have adapted their technique over time.<sup>12,19\*</sup> As there are currently no comparative studies, the choice between approaches involves personally weighing a number of factors relating to the ease, success, and safety of block



**Fig. 17.** Transversal cross-sectional image at thoracic level T8. The *dashed arrows* indicate the anteroposterior diameter of the thoracic paravertebral space. The respective measurement is noted at the *arrowhead*. A = anterior; L = lateral; M = medial; P = posterior; TP = transverse process.

performance. In the following section, these factors are discussed in context of the categories used in figure 5.

### **Transversal or Sagittal Transducer Position**

With some practice, the relevant anatomical landmarks can be identified on the ultrasound image with both a transversal or a sagittal transducer position and it can in fact be helpful to use both viewing planes during a scout scan before needle insertion. With a sagittal transducer position, it can be challenging to find an acoustic window between bony structures that is large enough to enable clear visualization of the underlying TPV space. With a transversal transducer position, an ultrasound image with minimal interference of bones can be obtained when the transducer is positioned in-between transverse processes. However, both the pleura and the SCTL have an oblique anteromedial to posterolateral course that places them at a nonperpendicular angle to the ultrasound beams on transversal ultrasound images, which reduces their visibility toward medial. This is not the case in sagittal views, in which, by tilting the ultrasound transducer slightly toward lateral, the ultrasound beams are more perpendicular to pleura and SCTL, which improves their visibility at a medial position.<sup>43</sup>

### **Choice of Ultrasound Landmark, Medial or Lateral Target for Needle Tip**

The closer to the midline, the narrower are the acoustic windows for ultrasound imaging and the deeper lies the TPV space relative to the skin. Consequently, image quality is higher at a lateral position and insertion of the needle is easier because it is more superficial.

However, the anteroposterior diameter of the TPV space decreases from medial to lateral, as shown in figure 17. At 1 to 2 cm lateral of the midline, the TPV space expands up to 2.0 to 2.5 cm beyond the anterior edge of the transverse process to the pleura. This decreases to approximately 1.0 to 1.5 cm at 2 to 4 cm lateral of the midline. Further lateral, at the intercostal location, the anteroposterior diameter is only approximately 0.5 cm. From this, it can be concluded that

the “safety margin” to avoid pleural puncture for straight sagittal needle advancement is larger at a medial insertion point than at a lateral insertion point. In addition, it should be noted that the anteroposterior diameter of the TPV space increases at lower thoracic levels because the vertebrae themselves tend to be of a larger size, whereas the differences between left and right body side seem negligible.

### **Direction of Needle Path and In-plane or Out-of-plane Technique**

The choice between either an in-plane or an out-of-plane technique is largely determined by operator experience and preference. Like in other block locations, an out-of-plane technique does not allow a continuous monitoring of the needle tip, but in turn does allow the shortest possible needle pathway with minimal angulation of the needle in the sagittal or transversal plane.

Angulation in the transversal plane, from lateral to medial, has been abandoned for landmark-based TPV block techniques due to the risk of positioning the needle within the intervertebral foramen and thereby causing central block or even spinal cord injury.<sup>2,4,5</sup> With ultrasound-guided transversal in-plane techniques, lateromedial angulation has re-entered clinical practice, which some experts consider risky.<sup>18,43</sup> When evaluating the potential risks of this approach, an important factor to consider is the distance of the needle tip toward the intervertebral foramen. With the historical landmark-based approaches, the lamina of the vertebra was initially contacted with the needle and the needle was then redirect laterally and anteriorly to approach the intercostal nerve as it exits the intervertebral foramen. In contrast, the current ultrasound-guided approaches are generally performed further lateral. The distance between the tip of the transverse process and the lateral border of the intervertebral foramen measures approximately 1.5 to 2 cm (fig. 6A).<sup>44,45</sup> Therefore, placement of the needle in the intervertebral foramen is unlikely, given careful monitoring of the needle tip and insertion depth. However, it should be noted that the distance between the tip of the transverse process and the lateral border of

**Table 1.** Literature Data on the Spread of Injectate of Ultrasound-guided Thoracic Paravertebral Block

Authors	Sample Size	Injection of	Spread of Injectate
Cowie <i>et al.</i> <sup>16</sup>	10 cadavers	20 ml colored dye	Spread over three TPV spaces (IQR, 1–7) for single injection, over four TPV spaces (IQR, 0–10) for double injection
Luyet <i>et al.</i> <sup>12</sup>	10 cadavers	10 ml CT contrast	Main portion of contrast mediastinal (2 of 20), epidural (6 of 20), and pleural (1 of 20)
Luyet <i>et al.</i> <sup>19</sup>	10 cadavers	10 ml CT contrast	Main portion of contrast near the vertebral bodies (33 of 57), prevertebral (26 of 57), epidural (6 of 57), pleural (4 of 57)
Marhofer <i>et al.</i> <sup>14</sup>	10 volunteers	10 ml mepivacaine 1% with MRI contrast	Spread over 3.5 to 4 dermatomes (range, 2–6), epidural spread in 25%
Paraskeuopoulos <i>et al.</i> <sup>15</sup>	11 cadavers	1 ml colored dye	Spread to the TPV space in 17 of 19 cases (transversal technique) and 13 of 14 cases (sagittal technique)

CT = computerized tomography; IQR = interquartile range; MRI = magnetic resonance imaging; TPV = thoracic paravertebral.

**Table 2.** Literature Data on the Sensory Distribution and Clinical Efficacy of Ultrasound-guided Thoracic Paravertebral Block

Authors	Sample size	Injection of	Sensory Distribution	Clinical efficacy
Abdallah and Brull <sup>18</sup>	33 patients	25 ml ropivacaine 0.5%	Not reported	100% block success. Compared with a control group, TPV patients had higher quality of recovery
Ben-Ari <i>et al.</i> <sup>20</sup>	12 patients	20 ml lidocaine (15 mg/ml)	Block in median of five dermatomes (IQR, 4–6)	Dermatomal block to pinprick in 23 of 24 blocks
Bouzinac <i>et al.</i> <sup>17</sup>	25 patients	20 ml ropivacaine 0.75%	Block in median of four dermatomes (range, 3–7)	100% block success
Hara <i>et al.</i> <sup>10</sup>	25 patients	15 ml of 0.5% ropivacaine	Not reported	In all patients, loss of cold sensation at least between T2 and T4.
Marhofer <i>et al.</i> <sup>40</sup>	10 volunteers	10 ml mepivacaine 1%	Block in median of 10 dermatomes (range, 3–19)	Not applicable
O Riain <i>et al.</i> <sup>11</sup>	9 patients	0.25% bupivacaine, 0.3 ml/kg	Not reported	Partial or complete sensory loss in six of nine patients at mean 20 min after block performance, in all patients in the recovery room.
Renes <i>et al.</i> <sup>13</sup>	36 patients	20 ml ropivacaine 0.75%	Block in median of six dermatomes (IQR, 5–6)	100% surgical block (= no intraoperative opioids needed)

IQR= interquartile range; TPV = thoracic paravertebral.

the intervertebral foramen measures decreases to 1 cm or less at T11 and T12.<sup>44,45</sup> Thus, additional vigilance is warranted when using lateromedial angulation at low thoracic levels.

The risk of pleural puncture may be smaller when a lateromedial needle pathway is used because the needle is inserted tangentially rather than perpendicular to the pleura.<sup>22</sup> This is particularly true if a shallow insertion angle is used because the improved needle visibility helps in monitoring the advancement of the needle. However, a longer needle pathway may be associated with more procedural pain for the patient.<sup>46</sup>

With sagittal in-plane techniques, the needle is angulated in the sagittal plane, usually from caudal to cranial. The required insertion angle is often quite steep, resulting in reduced visibility of the needle,<sup>11,18</sup> which, however, may be overcome by the usage of echogenic needles. Insertion of the needle into the TPV space using sagittal angulation can furthermore be technically challenging because the range of motion of the needle is limited due to the presence of the ultrasound transducer and narrowness of the interspace between transverse processes (small acoustic window). One suggestion to overcome this “double-fulcrum” effect has been to place the target TPV space at the caudal border of the ultrasound image rather than at the center.<sup>18</sup>

### Single-shot or Catheter-based Technique

It also may matter whether a single-shot or a catheter-based technique is used for TPV blockade. Despite correct positioning of the needle tip in the TPV space, the tip of catheter has been found dislocated to adjacent areas, for example, prevertebral, epidural, or intercostal.<sup>12,19</sup> A greater insertion depth of the catheter beyond of the tip of the needle may increase the likelihood of catheter migration.<sup>47</sup> The direction of the needle could also be of influence. Interestingly, catheter

migration toward anterior and medial has been observed with not only an approach using caudolateral to craniomedial angulation but also with an approach using mediolateral angulation.<sup>12,19</sup> Usage of coiled catheters has been suggested as a solution to catheter migration.<sup>47</sup> At this moment, it is not known whether any of the approaches to ultrasound-guided TPV blockade is associated with a greater risk of catheter misplacement, and further evaluation is expedient.

### Recommendations for Clinical Practice

The current literature on ultrasound-guided TPV blocks is limited to the description of techniques in small numbers of patients or cadavers. In this review, this information has been brought together and arranged clearly to facilitate decision making among practitioners wanting to use ultrasound guidance for TPV blockade. In tables 1 and 2, the available information on spread of injectate and sensory distribution as well as clinical efficacy is summarized. It is currently not possible to provide an evidence-based recommendation on the choice between techniques. The weighing of individual factors may result in different preferences per individual physician, depending, for example, on his or her experience with other ultrasound-guided regional anesthesia techniques and with landmark-guided TPV blockade.

However, in the absence of other evidence, we would like to state the following expert opinion:

For a novice, the simplest approach to image the paravertebral space is to use a sagittal transducer position at approximately 2 cm lateral to the midline (fig. 13). Placing the needle deep to the SCTL using an in-plane technique can be difficult because of the small distance between adjacent transverse processes and the steep insertion angle that is required (fig. 16B, arrow 8). An out-of-plane approach is recommended

to those that have prior experience with out-of-plane techniques for other blocks (fig. 16B, arrow 9). It also may suit practitioners who have previously used the landmark-guided technique because the needle trajectory is the same. With either sagittal technique, the needle does not point toward the epidural space, which makes spread of the local anesthetic and inadvertent placement of a catheter into the epidural space less likely.

For skilled practitioners, an in-plane transversal technique (fig. 6) is another option. It requires more practice to obtain a good view of the transverse process, the SCTL, and the pleura. The needle is advanced from lateral to medial and can usually be seen quite clearly on the ultrasound image (fig. 9B, arrow 2). Moreover, this approach allows close supervision during training because the needle shaft, tip, and injection of local anesthetic may be observed during insertion and injection. The medial angulation of the needle poses, theoretically, a higher risk of epidural spread of local anesthetic *via* the lateral recess. To prevent that a catheter is threaded into the epidural space, it is advised not to thread the catheter more than 2 cm beyond the needle tip.

It is imperative that the currently used approaches are subjected to a critical evaluation based on reported outcomes of effectiveness and safety in clinical practice, whereas results from the present survey may help in a better comprehension of differences between those approaches.

## Conclusion

With ultrasound guidance, the distance to the TPV space and pleura can be determined before performing a TPV block, whereas the position of the needle and the injection itself can be monitored in real time during the block. This should contribute to an increased success rate and safety profile of the technique. For that reason, an increasing number of anesthesiologists have incorporated ultrasound-guided TPV blockade into their clinical practice or aim to do so. This review brings together the necessary anatomical background to successfully interpret ultrasound images of this complex area. Although previous reports mainly use schematic drawings or photographs of dissected cadavers, this article presents a unique spatial view of the TPV space and the various techniques using constructed cross-sections within the same human specimen. The relative advantages and/or disadvantages of the various techniques are better understood by the reconstructions of their needle pathways, and this also may help in the choice of an approach to ultrasound-guided TPV block.

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## Competing Interests

Dr. van Geffen has had financial relationships with Philips, Eindhoven, The Netherlands, and is the treasurer of the European Society of Regional Anaesthesia and Pain Therapy, Geneva, Switzerland. The other authors declare no competing interests.

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