

Erector Spinae Plane Block Versus Retrolaminar Block

A Magnetic Resonance Imaging and Anatomical Study

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Background and Objectives: The erector spinae plane (ESP) and retrolaminar blocks are ultrasound-guided techniques for thoracoabdominal wall analgesia involving injection into the musculofascial plane between the paraspinal back muscles and underlying thoracic vertebrae. The ESP block targets the tips of the transverse processes, whereas the retrolaminar block targets the laminae. We investigated if there were differences in injectate spread between the 2 techniques that would have implications for their clinical effect.

Methods: The blocks were performed in 3 fresh cadavers. The ESP and retrolaminar blocks were performed on opposite sides of each cadaver at the T5 vertebral level. Twenty milliliters of a radiocontrast dye mixture was injected in each block, and injectate spread was assessed by magnetic resonance imaging and anatomical dissection.

Results: Both blocks exhibited spread to the epidural and neural foramina spaces over 2 to 5 levels. The ESP block produced additional spread to intercostal spaces over 5 to 9 levels and was associated with a greater extent of craniocaudal spread along the paraspinal muscles.

Conclusions: The clinical effect of ESP and retrolaminar blocks can be explained by epidural and neural foramina spread of local anesthetic. The ESP block produces additional intercostal spread, which may contribute to more extensive analgesia. The implications of these cadaveric observations require confirmation in clinical studies.

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The erector spinae plane (ESP) block is an ultrasound-guided regional anesthetic technique for analgesia of the thoracic and abdominal wall.^{1,2} It involves injection of local anesthetic into the musculofascial plane deep to the erector spinae muscles and superficial to the tips of the transverse processes. Cadaveric and clinical evidence suggests that the local anesthetic may penetrate anteriorly through the intertransverse connective tissues into the paravertebral space where it acts on the ventral rami of spinal nerves^{1,2}; local anesthetic may also reach and block the rami communicantes and sympathetic chain to produce visceral analgesia.³

It has been suggested^{4,5} that the ESP block is identical to another paraspinal regional anesthesia technique, the retrolaminar block,^{6,7} which also involves injection into the musculofascial plane between the paraspinal muscles and underlying vertebrae.

As with the ESP block, it has been postulated that the clinical effects of the retrolaminar block may be explained by spread of local anesthetic into the paravertebral space,⁶ but this mechanism has never been systematically investigated. However, there are significant anatomical and technical differences between the 2 techniques: the retrolaminar block targets the lamina instead of the transverse process, and thus the injection point is more medial and deeper. The muscle layer over the lamina and adjacent to the spinous processes is thicker, being composed of the spinalis portion of the erector spinae muscle group as well as the transversospinalis muscle group, which comprises the multifidus, rotatores, semispinalis, interspinalis, and intertransversarii muscles (Fig. 1). These differences can conceivably result in different patterns of local anesthetic spread, which may in turn have implications for their clinical effect. To examine if this was the case, we therefore performed a comparative study of injectate spread following the ESP block and retrolaminar block in fresh cadavers, using both magnetic resonance imaging (MRI) and anatomical dissection.

METHODS

The study procedures were performed on 3 fresh human cadavers in the Multidisciplinary Lab of Penn State College of Medicine, Milton S. Hershey Medical Center, Hershey, Pennsylvania. The Institutional Review Board of Ethics of Penn State Hershey College of Medicine, Pennsylvania, approved the study for exemption from formal review.

Erector Spinae Plane and Retrolaminar Blocks

The same cadaver was used for both block techniques to minimize bias from varying body mass and tissue quality. Each cadaver was randomly allocated to receive an ESP block on either the left or right side of the body, and a retrolaminar block was performed on the opposite side. Both blocks were performed with the cadaver in a prone position and at the level of the T5 vertebra, which was identified using ultrasonography and a counting-down approach from the T1 transverse process–first rib junction. A 40-mL solution comprising 35 mL of 0.9% normal saline, 4 mL of methylene blue, and 1 mL of gadopentetate dimeglumine (Magnevist; Bayer Healthcare LLC, Whippany, New Jersey) was prepared for each cadaver, and 20 mL of this solution was injected in each block. All injections were performed by an investigator with experience in both techniques (S.D.A.).

The ESP block was performed by placing a high-frequency (12–15 MHz) linear-array ultrasound transducer in a longitudinal parasagittal orientation over the tip of the transverse processes and inserting a 22-gauge 80-mm needle (Stimuplex Ultra 360; B. Braun, Bethlehem, Pennsylvania) in a caudal-to-cranial direction in plane with the ultrasound beam to contact the tip of the T5 transverse process. Correct needle tip position was confirmed by the injection of 0.5 to 1 mL of 0.9% normal saline and visualization of linear fluid spread that distended the fascial plane between the erector spinae muscle and the transverse process (Fig. 2). This was followed by injection of 20 mL of the radiocontrast dye solution.

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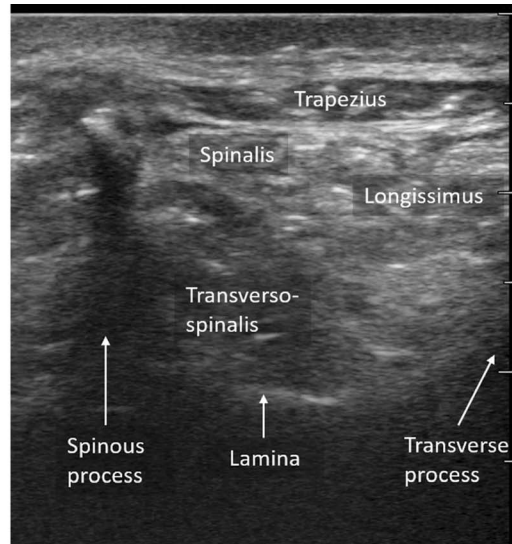
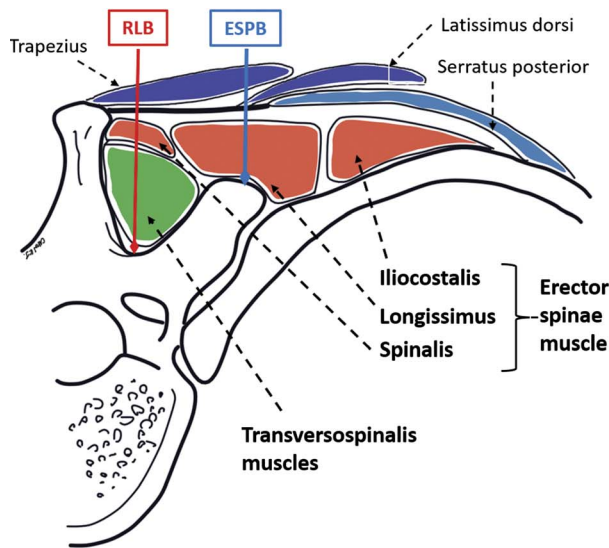


FIGURE 1. Schematic diagram of the muscles of the back in relation to a representative thoracic vertebra and rib, with accompanying ultrasound image. The superficial muscles include the trapezius, rhomboids (not shown), and latissimus dorsi. The erector spinae muscles comprise the intermediate layer, and the transversospinalis muscles (primarily multifidus, rotatores, and semispinalis) make up the deep layer. The location of injection with the retrolaminar (RLB) and ESP block (ESPB) are shown.

The retrolaminar block was also performed with the ultrasound transducer placed in a similar longitudinal parasagittal orientation but closer to the midline so as to image the laminae of the thoracic vertebrae. The same needle was inserted in a cranial-to-caudal direction in plane with the ultrasound beam to contact the T5 lamina. Correct needle tip position was verified by injection of 0.5 to 1 mL of 0.9% normal saline and visualization of linear fluid spread between erector spinae muscle and the lamina (Fig. 2). Twenty milliliters of the radiocontrast-dye solution was then injected.

Magnetic Resonance Imaging Protocol

Within 30 to 45 minutes after completion of both injections, the cadaver was imaged in a supine position in a 3-T Siemens Magnetom Prisma Fit MRI scanner (Siemens, Washington, DC). Coronal isotropic 3-dimensional SPACE (Sampling Perfection with Application optimized Contrasts using different flip angle Evolution) images were acquired in T1 weighting (echo time, 11 milliseconds; repetition time, 600 milliseconds) with fat

saturation and T2 weighting (echo time 248 milliseconds; repetition time, 2850 milliseconds) with fat saturation (T2FS). Axial and sagittal images were reconstructed from the coronal acquisitions. The images were interpreted by comparing the T1 and T2 sequences. The T2FS images were used to differentiate the injected contrast solution from thrombosed blood within the cadaveric vessels and tissues, both of which are hyperintense in signal on T1-weighted fat-saturated images. On the T2FS images, the injected contrast solution was imaged as a low-intensity signal, whereas the thrombosed blood remained hyperintense in signal.

Images were interpreted by a musculoskeletal radiologist with 13 years of experience (S.B.). The radiologist was blinded as to which side received a retrolaminar versus ESP block. The maximum craniocaudal soft tissue distribution of injectate was recorded based on the vertebral level, and the tissue planes containing contrast were noted. The maximum medial-to-lateral distribution of injectate in the soft tissues was recorded in centimeters from the midline, measuring from the midspinous process on axial images. The neural foramina into which contrast entered was recorded,

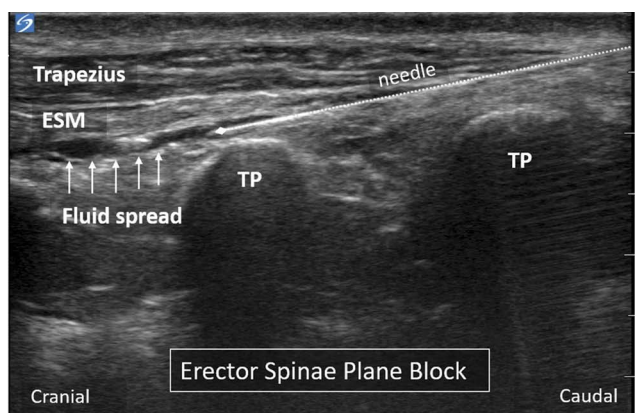
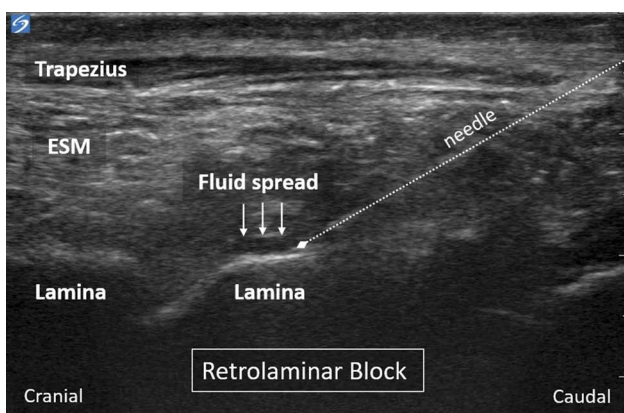
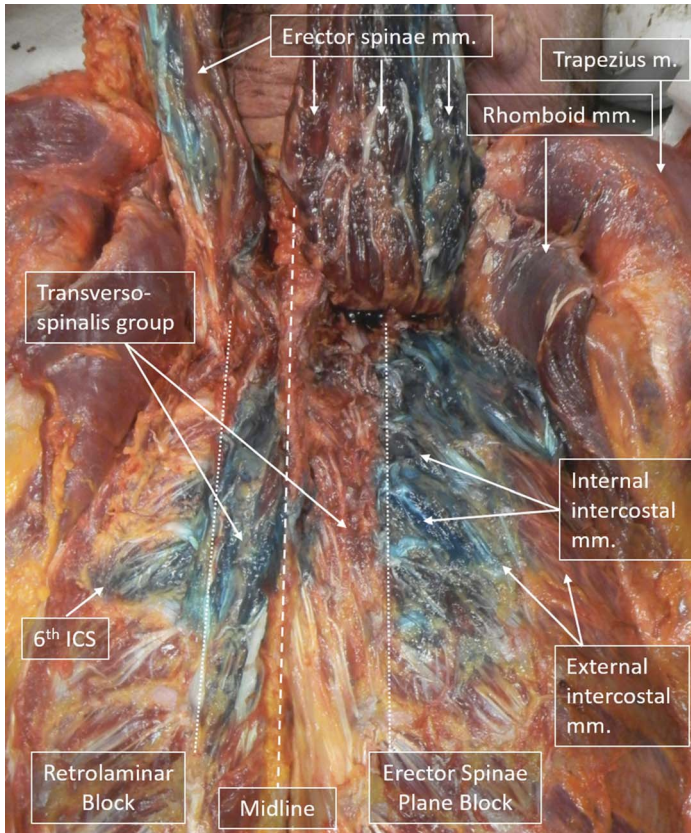


FIGURE 2. A parasagittal longitudinal view of the lamina or tip of the transverse processes (TP) is obtained for the retrolaminar and ESP blocks, respectively. In both blocks, the needle is advanced in plane to the ultrasound beam to enter the musculofascial plane between erector spinae muscle (ESM) and the bony surface. The end point is visible linear fluid spread that separates the ESM from the bony surface.



Level	Retrolaminar Block			ESP Block		
	#1	#2	#3	#1	#2	#3
C6				■		
C7				■	■	
T1		■		■	■	■
T2	■	■	■	■	■	■
T3	■	■	■	■	■	■
T4	■	■	■	■	■	■
T5	■	■	■	■	■	■
T6	■	■	■	■	■	■
T7	■	■	■	■	■	■
T8	■	■	■	■	■	■
T9		■		■	■	■
T10				■	■	
T11				■	■	
T12				■	■	
L1					■	

Extent of visible muscle staining

FIGURE 3. Anatomical dissection of cadaver 2 following retrolaminar and ESP block injections at T5. The trapezius and rhomboid muscles have been reflected laterally. The erector spinae muscles have been reflected superiorly, and dense staining is visible on the anterior surface. The ESP block has resulted in spread of injectate laterally into the intercostal spaces, whereas the distribution of the retrolaminar block is primarily confined to the transversospinalis group of muscles between the spinous processes (dashed line) and the tips of the transverse processes (dotted lines). The craniocaudal extent of visible staining of transversospinalis and erector spinae muscles on anatomical dissection is shown in the accompanying graphic.

as were the vertebral levels of cranial-caudal extension of contrast along the epidural space.

Anatomical Dissection

Anatomical dissection was performed with the cadavers in a prone position by a single anatomist (H.L.) who was blinded as to which side received a retrolaminar versus ESP injection. The skin and subcutaneous tissues over the back were removed between the midaxillary line on each side and from the external occipital protuberance to the tip of the coccyx. The trapezius, latissimus dorsi, rhomboid major, rhomboid minor, and serratus posterior superior and inferior muscles were identified, detached from their medial attachments on the spinous processes, and reflected laterally. The thoracolumbar fascia was separated and removed from the posterior surface of the erector spinae muscle. At the midthoracic level, the 3 columns of the erector spinae (spinalis, longissimus, and iliocostalis) were separated using blunt dissection so as to define and identify them. These muscle columns were cut at the caudal end and reflected superiorly to visualize the thoracic cage and the muscles of the transversospinalis group. The transversospinalis group is the deep layer of the intrinsic back muscles that lie between the spinous and transverse processes. Five sets of muscles comprise this group: the multifidus, rotatores, semispinalis, interspinalis, and intertransversarii. At each stage of the dissection, the extent of methylene blue dye staining was photographed and noted.

RESULTS

Anatomical dissection revealed that dye staining of the erector spinae and transversospinalis group of muscles was more extensive in the 3 hemithoraces that had received an ESP block versus the 3 that received a retrolaminar block. The craniocaudal extent of dye staining was greater following the ESP block (9, 14, and 14 vertebral levels in each hemithorax) compared with the retrolaminar block (6, 7, and 9 levels) (Fig. 3). The medial-to-lateral extent of dye spread following the retrolaminar block was confined to the area between the spinous processes and the edge of the bony lamina, with the exception of cadaver 2, in which staining was observed extending 6 cm lateral to the midline in the sixth intercostal space (Fig. 3). In contrast, the ESP block produced less staining of the transversospinalis group of muscles adjacent to the midline, but there was consistent lateral spread into the intercostal spaces at multiple levels following the ESP block (Fig. 3). In all 3 hemithoraces, the extent of this lateral dye staining was greatest at the fifth intercostal space, extending 9 to 10 cm lateral to the midline.

The MRI findings were consistent with that of anatomical dissection. The ESP block was associated with greater craniocaudal and medial-to-lateral distribution than the retrolaminar block (Fig. 4). The ESP block produced injectate spread in the tissue planes around the erector spinae muscle and into the intercostal spaces (Fig. 5). The number of intercostal spaces involved ranged from 5 to 9 (Fig. 6). Injectate spread following the retrolaminar block, on the

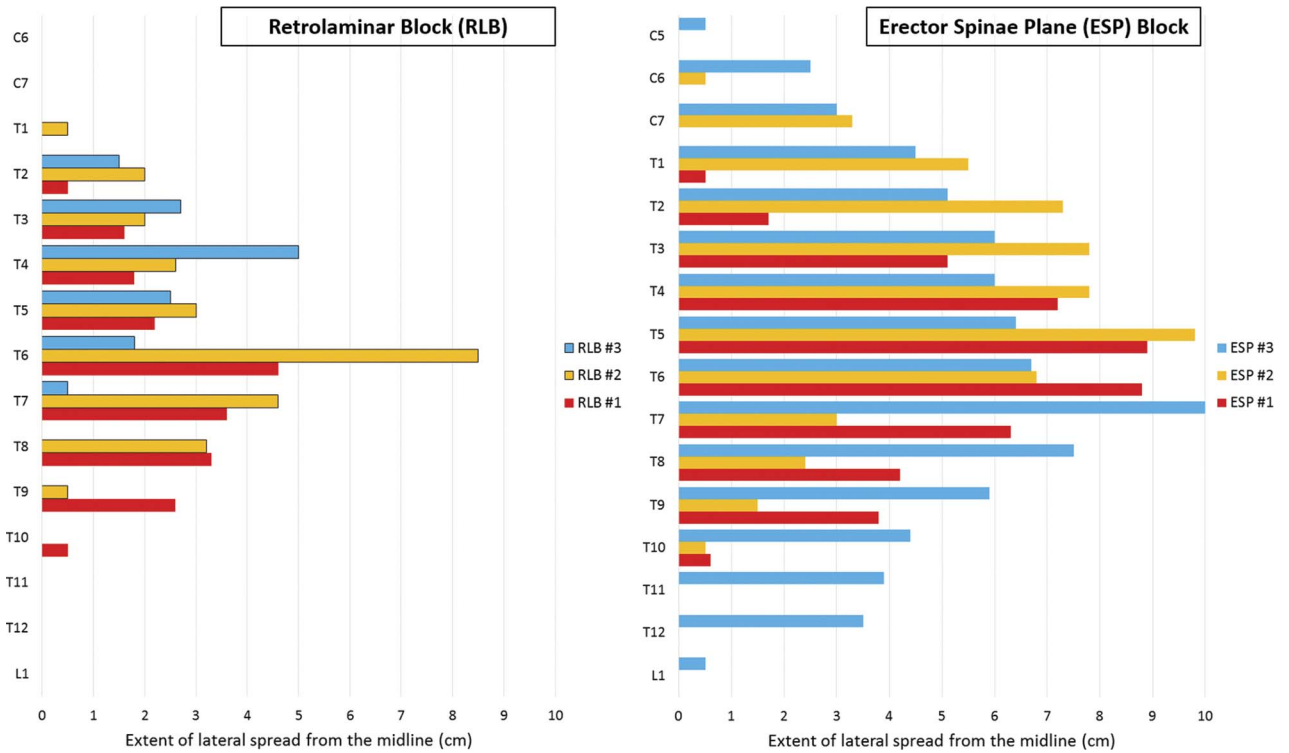


FIGURE 4. Craniocaudal and medial-lateral extent of injectate spread on MRI following single-injection retrolaminar and ESP blocks at the T5 vertebral level. Each block was performed on 1 side of 3 cadavers, and the distribution observed in each hemithorax is illustrated.

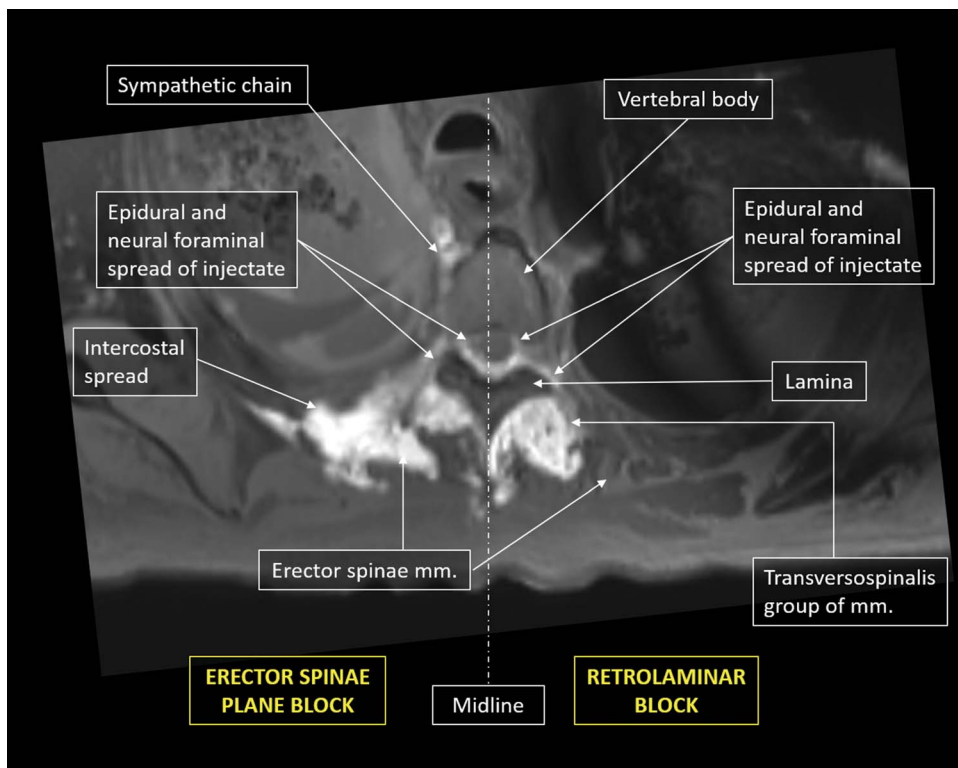


FIGURE 5. Axial MRI scan (T1-weighted with fat saturation). Injectate distribution following a retrolaminar block is confined mainly to the transversospinalis muscles, whereas the ESP block involves more of the erector spinae muscles. Both techniques result in spread to neural foramina and epidural space. The ESP block produces additional spread to the intercostal space.

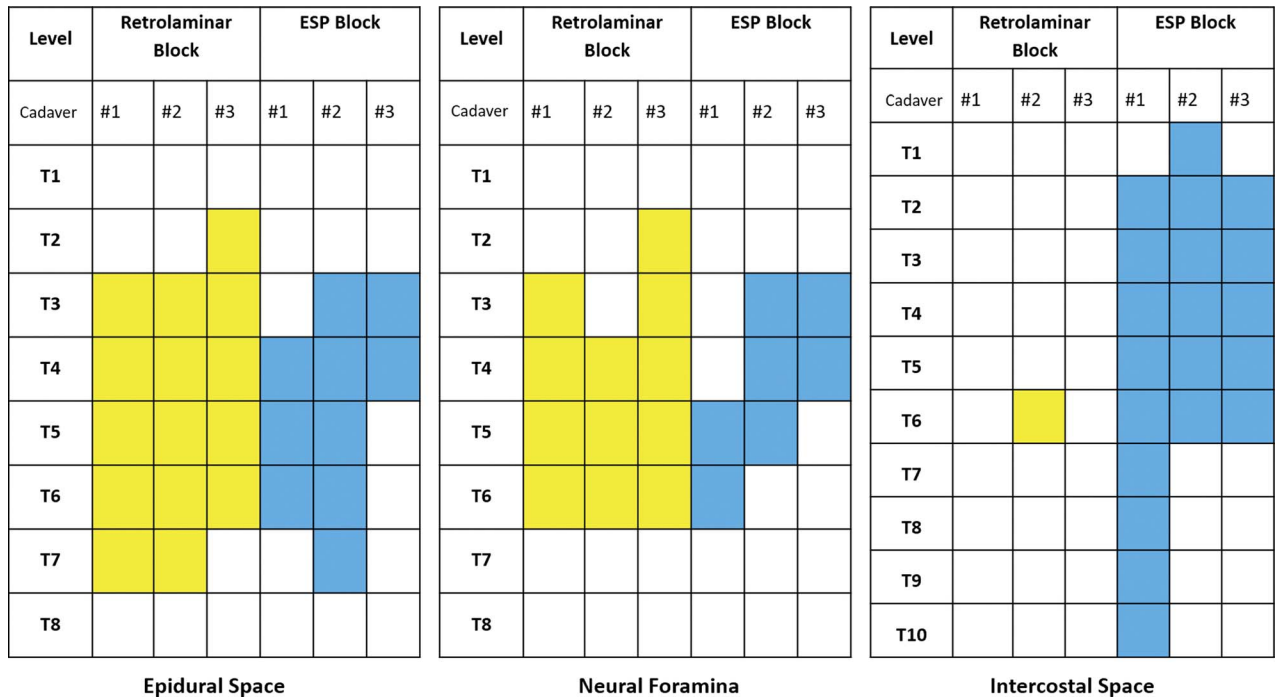


FIGURE 6. Distribution of visible spread on MRI to the epidural space, neural foramina, and intercostal space following single-injection retrolaminar and ESP blocks at the T5 vertebral level in each of the 3 cadavers.

other hand, was confined to the transversospinalis muscle group, except (as previously noted) in cadaver 2, where there was lateral spread in the sixth intercostal space.

There was visible injectate distribution to the neural foramina and epidural space with both techniques (Figs. 5 and 7). Epidural spread spanned 2 to 5 levels with the ESP block, and 5 levels consistently with the retrolaminar block (Fig. 6). Injectate distribution to neural foramina was somewhat less extensive than that in the epidural space, spanning 2 to 3 levels with the ESP block and 3 to 5 levels with the retrolaminar block (Fig. 6).

DISCUSSION

The results of our study reveal both significant similarities and differences between the distribution of injectate produced by the ESP block and retrolaminar block, which may have implications for clinical efficacy. There was spread to the neural foramina and epidural space with both techniques. This was seen across 2 to 5 vertebral levels centered around the level of injection and provides a basis for the somatic and visceral analgesia that has been reported.^{1-3,6-13} It also confirms the existence of anatomical pathways for anterior spread of local anesthetic. While the exact pathways have yet to be defined, they probably include the perforations in the intertransverse connective tissues through which the dorsal rami of spinal nerves and accompanying vessels emerge. The fact that epidural spread does occur raises the possibility of symptomatic hypotension following either technique. The incidence is unlikely to exceed that observed with thoracic paravertebral blockade, which has recently been estimated as ranging from 0.07% to 1.5% in adults¹⁴ and 0.006% to 0.3% in pediatric patients,¹⁵ but practitioners should remain vigilant. The observed pattern of spread with both retrolaminar and ESP blocks is in fact very similar to that described in imaging studies of thoracic paravertebral blockade using landmark-guided^{16,17} and ultrasound-guided¹⁸ approaches. These have invariably demonstrated that injectate spreads beyond

the paravertebral space into the epidural and intercostal spaces in a significant proportion of cases. Our findings lend further support to the presumption that retrolaminar and ESP blocks are viable alternatives to thoracic paravertebral blockade^{8,9,13}; however, comparative clinical studies are clearly required for confirmation.

Compared with the retrolaminar block, the ESP block appears to have an additional mechanism of action for analgesia of the anterolateral thoracic and abdominal wall, namely, injectate spread into the intercostal spaces where local anesthetic can act on the ventral rami. This lateral distribution was not seen to any significant extent with the retrolaminar block. This is probably due to the more medial site of injection and the fact that the target plane is deep to a thicker layer of muscle that may be more adherent to the underlying laminae. This would also explain the more restricted craniocaudal spread that was seen with the retrolaminar block. The ESP block stained the erector spinae muscle across a range of 9 to 14 vertebral levels compared with a range of 6 to 9 levels with the retrolaminar block. More importantly, the ESP block produced spread into up to 9 intercostal spaces from a single point of injection. This enhanced coverage allows for effective somatic analgesia in surgeries where incisions are widely spaced (such as thoracotomy with chest tube insertion⁹), multiple rib fractures,¹³ or where the surgical field or wound dressings prevent injection at a level congruent with the surgical site.¹¹

Limitations of this study include the small sample size and the fact that it was performed in cadavers, albeit fresh ones. Post-mortem changes in the integrity and permeability of tissues may influence fluid dispersion, and a similar study should ideally be performed in live subjects to confirm the findings as well as to document the extent of associated sensory block and analgesia. Studies of thoracic paravertebral block have shown that the radiographic spread and sensory block distribution often correlate poorly, with the latter tending to be more extensive.^{17,18} Another caveat is that the observed epidural spread could have occurred because of spillover from the contralateral block technique; however, the fact

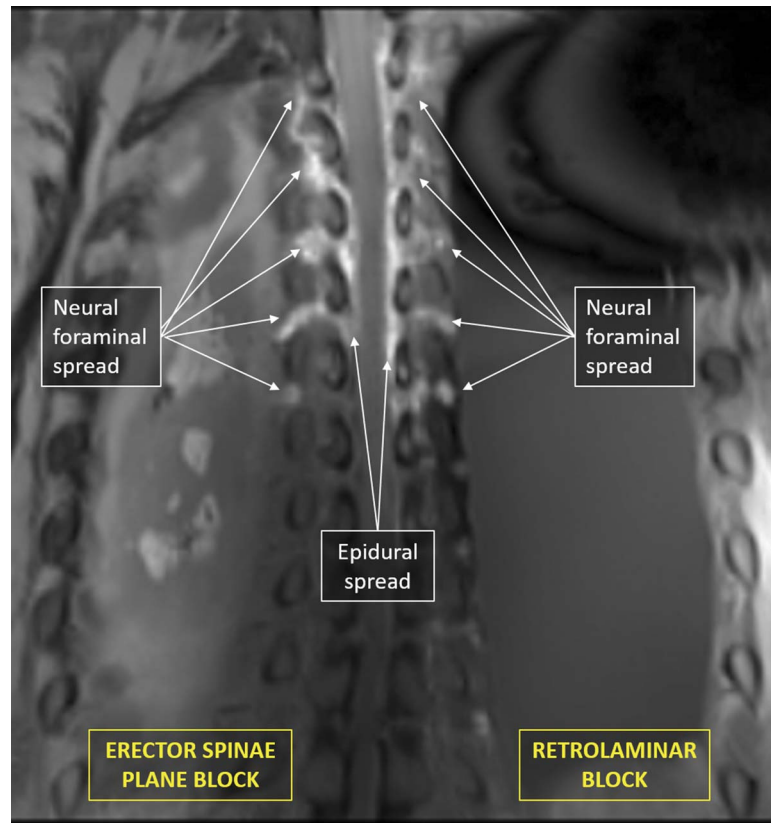


FIGURE 7. Coronal MRI scan (T1-weighted with fat saturation). Injectate distribution is visible in the region of the neural foramina and epidural space across multiple vertebral levels following both ESP and retrolaminar blocks.

that this spread was contiguous with ipsilateral neural foraminal and perimuscular spread makes this less likely.

CONCLUSIONS

We have established an anatomical basis for the clinical action of retrolaminar and ESP blocks and identified important differences between them. Single-injection retrolaminar and ESP blocks in fresh cadavers both produce epidural and neural foraminal spread across several levels that are centered around the level of injection and thus can be expected to have clinical effects similar to thoracic paravertebral blockade. The ESP block exhibits additional intercostal spread that may contribute to wider analgesic coverage than the retrolaminar block. This may be advantageous in certain clinical scenarios. Randomized controlled trials in patients are required to explore the clinical implications of our observations.

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