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 foraminar 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 foraminal 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.

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.
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 midspinous process on axial images.

The neural foramina into which contrast entered was recorded.
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. Cranio-caudal and mediolateral 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.
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 (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).

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.

**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.
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.

REFERENCES


