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BJAN-D-21-00247 - Case Report

Anatomic barriers to paraspinal blocks: a cadaver case series

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Abstract
The paraspinal space is intriguing in nature. There are several needle tip placements described in compact anatomical spaces. This has led to an incertitude regarding the appropriate anatomic locations for needle tip positions. Through our cadaver models we try to resolve the issues surrounding needle tip positions clarifying anatomical spaces and barriers. Further we propose an anatomical classification based on our findings in cadaveric open dissections and cross and sagittal sections.

Introduction

In patients undergoing thoracic and upper abdominal surgeries, thoracic epidural and thoracic paravertebral blocks (PVB) are used for managing acute postoperative pain.[1] Although ultrasound (US) has revolutionized needle placements and block accuracies, these are technically demanding and contraindicated in patients on anticoagulants. After thoracic erector spinae plane block (ESPB) was described, there were widespread applications in thoracotomies, and abdominal and dorsal spine surgeries. However, it also has created a furor in needle tip placements in the paraspinal space which has widened the perplexity and intricacies of the increasingly new blocks.[2,3] Classified as "paravertebral blocks by proxy", they all aim at depositing local anesthetic (LA) into the paravertebral space (PVS). Though the plausible mechanism of action of paraspinal blocks is by seepage of LA into the thoracic PVS, it is debatable if it occurs through the apertures and perforations in the bony-ligament-muscular mesh.[4] To understand the numerous needle tip placements in the paraspinal areas and the anatomic barriers encountered, we explored the anatomic structures with open dissection and cross-sections. We inspected the paraspinal area in an attempt to establish the credible anatomic structures that would offer needle tip placements and the obstacles encountered which would limit LA diffusion. Based on our dissection we propose a simple anatomic nomenclature for paraspinal blocks.

Case description

The study was approved by the Research Ethics Committee of the University of Barcelona and was performed in the dissection room of the Anatomy and Embryology Department of the Faculty of Medicine of the Universitat de Barcelona. Three adult non-embalmed (cryopreserved) cadavers without obvious pathology or previous thoracic procedures were studied. Cadaver 1(C1) underwent an open dissection, cadaver 2 (C2) was subjected to axial section, and cadaver 3 (C3) was put through a sagittal section. C2 and C3 were frozen at -20º C for 48 hours before being processed. After defrosting the specimen of C2 and C3, an exploration of the different anatomic structures with a loupe magnification was performed. The specimens of three cadavers were photographed with SLR Canon D 1000 camera.

Cadaver 1 (C1)

For open dissection, C1 was covered with a plastic sheet and kept at room temperature for 6 hours, after retrieving from the deep freeze chamber (-20° C). A skin incision along the midline over the spinous processes from C7 to L4 vertebrae was made in the prone position for C1, exposing the posterior thoracic wall and scapula. The lumbar to thoracic erector spinae muscles (ESM) were examined in C1, and the arrangement and attachments of the fibers were evaluated from medial to lateral and from caudal to cephalad. The ESM and aponeurosis were separated from bony and ligamentous attachments.

Deep to the dorsal layer of the thoracolumbar fascia and the superficial dorsal muscles (trapezius, latissimus dorsi, and rhomboids [Fig. 1A]) three vertical group of muscles were revealed: medially, was the spinalis thoracis muscle (STM) that travelled between the spinous process and thoracic transverse process (TP), the longissimus muscle (LoM) coursed cephalad in the middle, and the tendons of the iliocostalis muscle (ILcM) fanned out lateral with its attachments over the ribs (Fig. 1B). The thoracolumbar nerves emerged from LoM and could be traced laterally and superficially to the tendons of ILcM to innervate the cutaneous areas. On elevating the tendons of LoM and ILcM (Fig. 2C) from their bed, a potential space was revealed, lateral to the thoracic TP – the "lateral erector spinae plane" (L-ESP) (Fig. 1C). The bed of the L-ESPB was formed by the levator costarum brevis, longus muscles and tendons (short oblique muscle from TP to ribs) (Fig. 1C). Detaching the STM from the thoracic TP revealed the short oblique muscles of the spine, the rotatores thoracis between the spinous process, and the medial part of the thoracic TP (Fig. 1C). There was a space between the STM and rotatores thoracis which we refer to as the medial ESP (Fig. 1C). Projections of thoracic TP were visualized at regular intervals which were connected through the inter-transverse ligament (ITL). We envisaged that thoracic TP divided the ESP medially and laterally, to form the medial and the lateral ESP respectively.

Cadaver 2 (C2)

In the prone position, C2 was scanned from the level of R1 to R9 (R-rib). R1 was identified in the supraclavicular fossa and the probe was shifted dorsally keeping R1 in real-time view. R3, R5, and R7 were noted in particular, and subsequently with a medial shift of the probe bilateral to costo-transverse junction (CTJ) at the 3rd, 5^{th,} and the 7th levels, were identified and marked (Fig. 1). An explicit axial section was performed in C2 with a mechanical saw through the markings at the 3rd, 5^{th,} and 7th CTJs. With C2 placed in the prone position, bilateral CTJ from the 1st to the 9th were identified and marked on the dorsum of the skin (Fig. 1A). The specimens of C2 were examined for gross anatomic structures dorsal and ventral to the thoracic TP.

The axial section demonstrated the posterior thoracic lumbar fascia that ran continuously along the dorsal aspect of the ESM. Bilaterally, lateral, and dorsal to the spinous process and laminae was the ESM engulfed in its sheath. The CTJ could be distinctly visualized. Deep to the ESM lies the deep erector spinae plane (DESP), outlined with blue. The thoracic TP arbitrarily divides the DESP into medial and lateral ESP's M-ESP and L-ESP. The paravertebral space (PVS) was situated beyond the costotransverse ligament (CTL), bordered anterolaterally by the pleura and medially by the intervertebral foramina through which communicated to the neuraxial space. The position of the thoracic ventral and dorsal nerve roots are depicted in (Fig. 1D).

Cadaver 3 (C3)

With cadaver 3 in the prone position, an ultrasound scan identified the levels of R1 to R9 (R-rib), as mentioned earlier. Eventually, bilateral CTJ at the 3rd, 5th, and 7th levels were identified and marked (Fig. 1). Exemplary sagittal sectioning at the CTJ level (from 1st to 9th) was performed using a mechanical saw.

Superficial to the posterior ESM sheath (PES), the rhomboid muscle could be observed as a thin muscular slip. Deep to the anterior erector sheath (AES), a plane filled with connective tissue was observed and was considered the erector spinae plane. Thoracic TP could be visualized at definite intervals. Between the two thoracic TP engulfed in a strong sheath was a slip of muscle layer, the "intertransverse ligament" (ITL) [Fig. 1E], which was also a constant feature connected between the two thoracic TP.

Extending from the TP to the rib was the CTL (Fig. 1E), that was consistently present in all specimens and had a definite anatomic structure (oval), and unlike the ITL possessed a relatively weak sheath enclosing connective tissue. The space between the ITL and the CTL was consistent and was termed the "inter-ligament space" (ILS). Loupe magnification dissection of the space between the ITL and the CTL demonstrated a predominant fat tissue content with the dorsal branch of the spinal nerve. The ILS was bordered by dense ligaments, on its anterior and posterior areas, the TP and the ribs on its superior and inferior aspect (Fig. 1E).

In front of CTL and behind the pleura was the PVS consistent and continuous in its superior and inferior aspects. Fat tissue and the ventral branch of the spinal nerve predominated the PVS. Loupe magnified dissection revealed the ventral nerve exiting the IVF in all 4 specimens in the thoracic PVS, but the dorsal nerve was evident in 1 specimen behind thoracic TP (Fig. 1E).

Needle tip positioning

In C2 (axial section), the needle tip could be positioned in two confirmed areas: deep to the AES and superficial to the ITL is the ESP (Fig. 2D), before the anterior sheath of the ESM in the ITS, and in front of the imaginative CTL is the PVS. In the sagittal sections, the needle tip is illustrated deep to the AES and superficial to the ITLwhichis the ESP (Fig. 2A), before the ITL and before the CTLwhich isthe ILS (Fig. 2B), and before the CTLwhich isthe PVS (Fig. 2C).

Based on our results of cadaver models of open dissection, and axial and parasagittal sections at the thoracic level, we define these barriers and spaces as depicted in the US images (Figs. 1F and 1G).

Discussion

Our findings precisely illustrated three anatomic spaces that exist in the paraspinal area, and the needle placements are in these three designated spaces (Table 1). These spaces are the ESP, the ILS, and the PVS. The numerous needle tip placements with complex names would be unnecessary since this would lead to incertitude amongst regional anesthesiologists who would like to initiate paraspinal blocks in routine clinical practice. Unpretentiously, we wish there would be no new anatomic tip locations in the thoracic ESP.

The mechanisms explained in earlier studies are conflicting and debatable.[4,5] In open dissection the tightly woven floor of deep ESP is almost anatomically impermeable, though the costotransverse foramen is implicated in translocation of solution.[4] In the sagittal sections, the potential anatomic barriers for the spread of fluid are the ITL, the ILS, and the CTL. Of the three, the ITL seems to be the strongest barrier, while the fat-filled ILS would be soaked with LA and act as a reservoir. Apart from the above factors, needle tip placement immediately medial or lateral to the thoracic TP affects the spread of solution, medially into the M-ESP and laterally into the L-ESP.

Thus, all the described paraspinal blocks can be anatomically classified into a simple nomenclature (Table 2). Of the three models, the sagittal section offered an excellent panoramic view from dorsal to the ventral aspect of the anatomical barriers, following needle tip placements in the paraspinal spaces. Cadaver numbers were a major limitation of this study. A simultaneous injection into the three spaces in different cadavers could have correlated better with the anatomic description.

In summary, based on our anatomic models we describe three important paraspinal areas where needle tips can be positioned. A subsequent cadaver injection study would further strengthen our proposed anatomic nomenclature.

Conflicts of interest

The authors declare no conflicts of interest.

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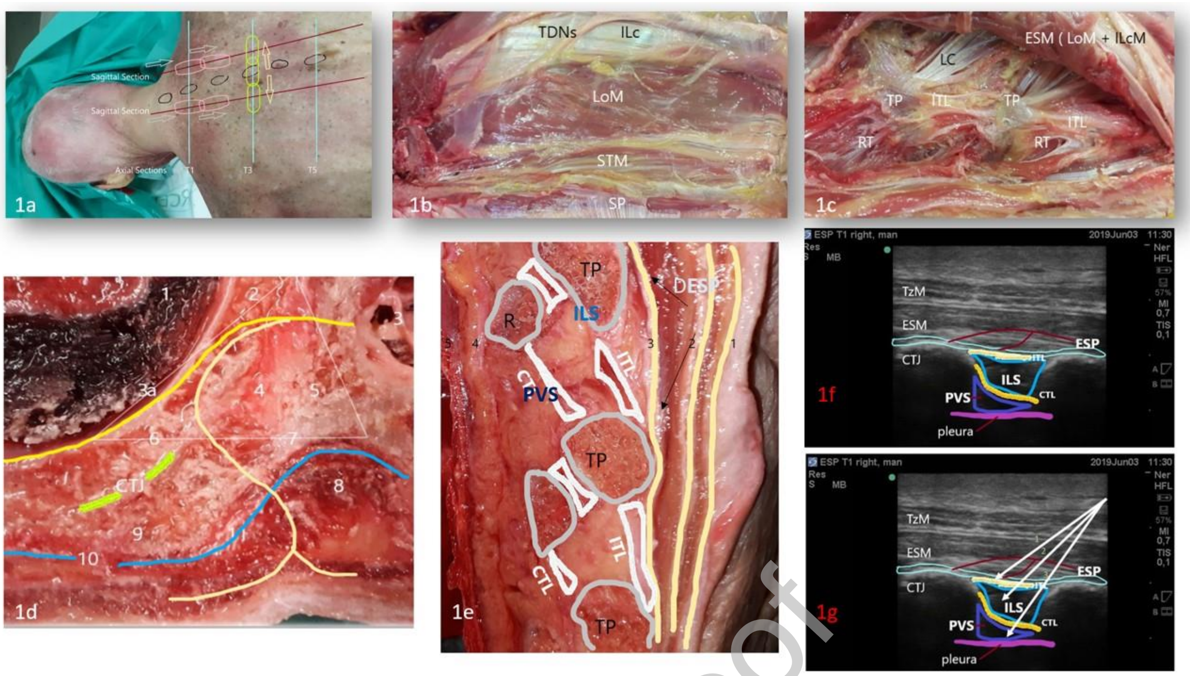
Figure 1 Anatomic barriers and spaces. A, Cadaver in prone position; probe position in parasagittal scan from R1 and shifting (Grey arrows) caudal-Rose; bilateral parasagittal lines-Dark red; blue lines for sections at the level of thoracic spinous process' 1st, 3rd and 5th levels; Axial probe placements (light blue from the midline (black oval-spinous process) to the CTJ. B, Prone dissection of the back revealing the three erector spinae muscles spinalo thoracis (STM); Longissimus muscle (LoM); Iliocostalis (ILc); emergence of thoracodorsal nerves (TDNs) between Lo and ILco traversing lateral are visualized. C. ESM (LoM and Ilc) detached from its attachments demonstrating the lateral and medial erector spinae plane in relation to thoracic TP. Short oblique muscles are visualized lateral (LC-leavator costarum) and medial (RT-rotator thoraces) to thoracic TP forming the floor of the erector spinae plane. D, Outlay of axial section through the costotransverse junction; 1-lung; 2 hof rib; 3- spinal cord; 3a- parietal pleura; 4-paravertebral space;5-intervertebral foramina;6-rib; 7-lamina;8-erector spinae muscle; 9-transverse process; 10-lateral erector spinae plane; 11-medial erector spinae plane (10 and 11 continuous blue line); dark yellow – ventral nerve root; light yellow – dorsal nerve root; thick light green – site of costotransverse ligament. E, Outlay of sagittal section through the costotransverse junction: 1 is the posterior thoracolumbar fascia; 2 is the posterior erector spinae sheath, 3 is the anterior erector spinae sheath, 4-ITL-inter-transverse ligament; 5-CTL – costotransverse ligament; 6-R-Rib; 7-TP – transverse process. The space deep to the AES is the DESP (light blue), deep to ITL and superficial to the CTL is the ILS (blue) and deep to the CTL is the PVS (dark blue). F, Cadaveric parasagittal dorsal ultrasound at the T 4–5 CTJ level depicts the three spaces (ESP, ILS, and PVS) and barriers (ITL, ILS and CTL). G, Cadaveric parasagittal dorsal ultrasound at the T 4–5 CTJ level depicts the three needle positions; 1-ESPB; 2-ILSB; and 3-PVB. TzM, trapezius muscle; ESM, erector spinae muscle; CTJ, costotransverse junction; ESP, erector spinae plane; ITL, intertransverse ligament; ILS, inter-ligament space; PVS, paravertebral space; CTL, costotransverse ligament.


Sagittal Section
Sagittal Section
Axial Sections
T3
T5
1a
TDNs
ILc
LoM
STM
SP
1b
ESM (LoM + ILcM
LC
TP
ITL
TP
ITL
RT
RT
1c
1
2
3
3a
4
5
6
7
CTJ
8
9
10
1d
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DESP
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2019Jun03 11:30
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Figure 2 Possible needle tip positions in DESP, ILS and PVS – In Sagittal section (top row) and Transverse section (bottom row). A, Sagittal section – needle in DESP; B, Sagittal section – needle in ILS; C, Sagittal section – needle in PVS; D, Sagittal section – needle in DESP; E, Sagittal section – needle in ILS; F, Sagittal section – needle in PVS. ITL, inter-transverse ligament; CTL, costotransverse ligament; R-Rib; TP, transverse process R-rib; TP, thoracic transverse process; Vnr-ventral nerve root; Dnr-dorsal nerve root.

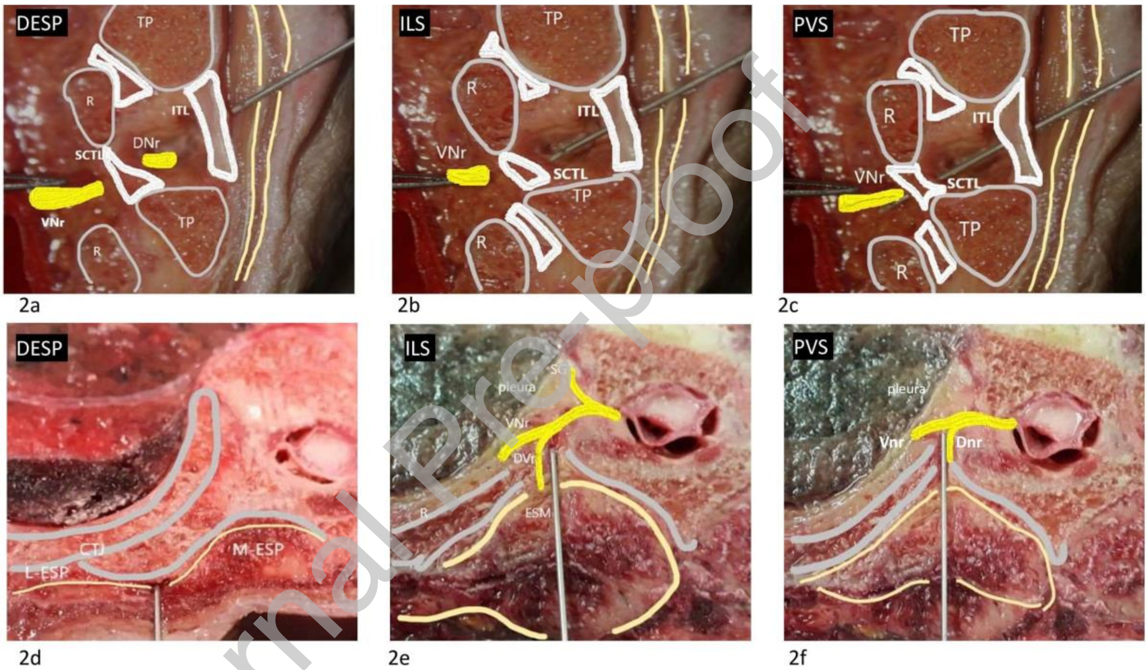

Table 1 Macroscopic and loupe magnification details.

	OD/C1 left	**OD/C1 right**	**AX/C2 left**	**AX/C2 right**	**SAG/C3 left**	**SAG/C3 right**
PESS	Y	Y	Y	Y	Y	Y
AESS	Y	Y	Y	Y	Y	Y
DESS	Y	Y	Y	Y	Y	Y
ITL	Y	Y	-	-	Y	Y
ILS	-	-	-	-	Y	Y
DNr	Y	Y	-	Y	Y	-
CTL	-	-	Y	Y	Y	Y
PVS	-	-	Y	Y	Y	Y
VNr	-	-	Y	Y	Y	Y

OD/C1 left, Open Dissection Cadaver 1 left side specimen; OD/C1 right, Open Dissection Cadaver 2 right side specimen; SAG/C2 left, Sagittal Cadaver 2 left side specimen; SAG/C2 right, Sagittal Cadaver 2 right side specimen; AX/C3 left, Axial Cadaver 3 left side specimen; AX/C3 right, Axial Cadaver 3 right side specimen.

PESS, posterior erector sheath; AESS, anterior erector sheath, DESS, deep erector spinae plane; ITL, intertransverse ligament; ILS, inter-ligament? space; Dnr, dorsal nerve root; CTL, costotransverse ligament; PVS, paravertebral space; VnR, ventral nerve root.

Table 2 Anatomic classification of paraspinal blocks.

Block type	**Block space**		
	Erector Spinae Plane	Inter Ligament? Space	Paravertebral Space
ESPB towards TP Barriers = ITL, CTS, CTL	YES	NO	NO
ESPB between TP Barriers = ITL, CTS, CTL	YES	NO	NO
Mid – Transverse process block Barriers = CTL	NO	YES	NO
Costotransverse Block Barriers = CTL	NO	YES	NO
ESPB at corners of TP Barriers = ITL, CTS, CTL	NO	NO	NO
Multi Injection CTB Barriers = CTL	NO	YES	NO
Retrolaminar Plane Block Barriers	YES	NO	NO
Costotransverse foramen plane block Barriers = CTL	NO	NO	NO
Subtransverse interligament? plane blocks Barriers = CTL	NO	YES	NO
Paravertebral block Barriers = NONE	NO	NO	YES