Randomized Trial

Comparison of Craniocaudal Spread of Lumbar Erector Spinae Plane Block With Two Volumes of Local Anesthetics

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Background: The erector spinae plane block (ESPB) is a less invasive, safer, and technically easier procedure compared to the conventional neuraxial technique. Although the ESPB is a favored and easy technique compared to neuraxial block, there is no study with a large number of patients describing the exact spread level of injected local anesthetics.

Objectives: The purpose of this study was to identify ESPB spread in the craniocaudal direction and the incidence of spread into the epidural space, psoas muscle, and intravascular system.

Study Design: Prospective design.

Setting: A tertiary university hospital, pain clinic.

Methods: Right- or left-sided ESPBs (170 at L4) with fluoroscopy subsequent to ultrasound guidance due to acute or subacute low back pain were included. In this study, 10 mL (ESPB 10 mL group, contrast medium 5 mL) or 20 mL (ESPB 20 mL group, contrast medium 7 mL) of a local anesthetic mixture was injected. After confirming a successful interfascial plane spreading under ultrasound guidance, the remaining local anesthetic was injected under fluoroscopic guidance. The spread level of ESPB in the craniocaudal direction and the occurrence of injectate into the epidural space or psoas muscle was assessed using the saved fluoroscopic images. These images were compared between the ESPB 10 mL and ESPB 20 mL groups. Also, the presence or absence of intravascular injection during ESPB was assessed and compared between the ESPB 10 mL and ESPB 20 mL groups.

Results: The ESPB 20 mL group had a more extensive caudal distribution of contrast medium than the ESPB 10 mL group. Also, the total number of lumbar vertebral segments was significantly higher in the ESPB 20 mL group than that of the ESPB 10 mL group (1.7 ± 0.4 vs 2.1 ± 0.4, $P < 0.001$). Among all injections performed in this study, epidural, psoas muscle, and intravascular injections occurred in 2.9%, 5.9%, and 12.9%, respectively.

Limitations: Only the craniocaudal direction was evaluated without evaluating the spread pattern in the medial to lateral direction.

Conclusion: The ESPB 20 mL group showed a more extensive distribution of contrast medium than that of the ESPB 10 mL group. Inadvertent injections into the epidural space, psoas muscle, and intravascular system were observed. Among them, intravascular system injections were found to be the most common (12.9%).

Key words: Erector spinae plane block, spread level, psoas muscle, intravascular injection

Trial registry number: Clinical trial registry information service (NCT05280847).

IRB number: 2022-01-026-01

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The erector spinae plane block (ESPB) is a less invasive, safer, and technically easy alternative procedure to conventional neuraxial anesthetic techniques (1-4). Compared to common neuraxial techniques, such as paravertebral and epidural injections, ESPB targets an interfascial plane which is far from the spinal cord, root, and pleura.

First applied to thoracic neuropathic pain (5), currently ESPB is being applied for postoperative pain control and includes variable clinical situations. In the abdomen and thoracic wall, thoracic ESPB can be applied for pain control of various cardiothoracic and laparoscopic surgery (6-9). Recently, favorable postoperative pain control after lumbar spinal or lower limb surgeries has been reported with lumbar ESPB (10,11). In addition, ESPB has also been used for chronic pain conditions in the upper and lower extremities (1).

To investigate the possible mechanism of action of an ESPB, many previous studies have focused on examining the physical spread of the injected agent. Commonly, contrast medium injections in human cadavers have been utilized to assess the spread level. Physical spread level was determined using various methods including direct dissection or sectioning, computed tomography (CT), thoracoscopic inspection, or magnetic resonance imaging (MRI) with radiocontrast injection (1,12). Apart from human cadaver studies, physical spread level has been evaluated in vivo using a variable volume of local anesthetics mixed with radiocontrast (12). However, these studies are limited by the small number of included patients. Therefore, the exact spread level of injected local anesthetics remains unclear and a study on a large number of patients is still required.

The injection volume for ESPB ranges between 10 mL and 30 mL; this volume depends on the physician. Local anesthetic systemic toxicity has been reported previously using 30 mL of 0.5% levobupivacaine in the ESPB. A local systemic toxicity was observed even after negative aspiration and visualization of linear local anesthetic spreading under ultrasound guidance (13). Therefore, clarifying the incidence of inadvertent intravascular injection during an ESPB is an important issue.

The primary endpoint of this study was to identify ESPB spread level in the craniocaudal direction. The secondary endpoint was to identify the incidence of spread to the epidural space, psoas muscle, and intravascular system.

Methods

Patients

This prospective and randomized study was approved by our institutional review board (2022-01-026-01). The benefits and risks of this study were fully explained before patient enrollment. Patients provided informed consent. This study was registered before patient inclusion at clinical trials. gov (NCT05280847).

One hundred seventy-five patients who received a lumbar ESPB due to acute or subacute low back pain development from January 2022 through June 2022 were included. Among patients with low back pain who received a lumbar ESPB, only patients who received an ESPB by fluoroscopy subsequent to ultrasound guidance were included. Causes of low back pain included facet joint pain, myofascial pain syndrome, and lumbar muscular sprain. Patients with a history of allergic reaction to local anesthetics and contrast medium, an absence of saved fluoroscopic images, and a prior history of lumbar spine surgery were excluded.

Group Allocation

In this study, 10 mL or 20 mL of a local anesthetic mixture was injected to compare the spread level of ESPB between the 2 groups. The local anesthetic mixture of 0.1% ropivacaine in the ESPB 10 mL group included 5 mL 0.2% ropivacaine mixed with 5 mL contrast medium (Bonorex, 300 mg I/mL). For the ESPB 20 mL group, 10 mL 0.2% ropivacaine mixed with 3 mL normal saline and 7 mL contrast medium was used to make a 20 mL 0.1% ropivacaine mixture. Patients were assigned randomly to be in one of 2 groups receiving different injection volumes. According to a computer-generated randomization table, patients in the 2 groups received 10 mL 0.1% ropivacaine mixture (ESPB 10 mL group) or 20 mL 0.1% ropivacaine mixture (ESPB 20 mL group). Patients in both groups received 1-3 consecutive lumbar ESPB injections with a 2 week interval until back pain improved without assigned group crossover. If a patient complained of persistent back pain even after 3 ESPB injections, the patient received a neuraxial block. Five injections were excluded due to an absence of saved lateral fluoroscopic images. Finally, a total of 170 ESPB injections were performed in the ESPB 10 mL and 20 mL groups (Fig. 1).

Lumbar ESPB by Fluoroscopy Subsequent to Ultrasound Guidance

Three physicians with more than 5 years' experience in fluoroscopic- and ultrasound-guided injections

performed the ESPBs. Right- or left-sided ESPB was performed depending on the location of the back pain. If a patient received ESPB on both sides, only one side of the injection was used for analysis. For the performance of ESPB, patients were placed prone. A curved low-frequency probe (GE Healthcare, Logiq S8) was used in the longitudinal position, after confirming the L4 transverse process.

Once identified, a 100 mm, 23G needle was inserted in plane from the caudal to cephalad direction. We inserted the needle tip until the contact of transverse process. We identified the linear spread of the local anesthetic mixture 5 mL in an interfascial plane of the erector spinae muscle. After confirming successful linear interfascial plane spreading under ultrasound guidance, the remaining local anesthetic mixture was injected under fluoroscopic guidance for the evaluation of the spread level, and whether the spread infiltrated the epidural space, the psoas muscle, or the intravascular system.

Analysis of Contrast Medium Spread Level

The spread level of ESPB was assessed using the saved fluoroscopic images in the Picture Archiving and Communication System (PACS, M6, INFINTT Healthcare). One of the authors who was not involved in the ultrasound- and fluoroscopic-guided ESPB and blinded to the patient group analyzed the spread level. That physician had more than 10 years' clinical experience in ultrasound- and fluoroscopic-guided injections.

The craniocaudal spread direction was assessed using an anteroposterior (AP) image. Since all ESPBs were performed at the L4 transverse process in both groups, one segment of cranial and caudal spreads from L4 was defined when contrast medium was detected at the upper endplate of L3 and lower endplate of L5, respectively (Figs. 2A, 2B). When contrast medium was detected only reaching halfway up the L3 or L5 body, it was defined as 0.5 segment cranial or caudal spread (Figs. 2C, 2D).

We also identified the highest and lowest L4 ESPB level. Depending on the highest cranial end of contrast medium spread in the AP image, it was defined as L4 upper body, L3-L4 disc space, L3 lower body, and L3 upper body. Depending on the lowest caudal end of contrast medium spread in the AP image, it was defined as L4-L5 disc space, L5 upper body, L5 lower body, and S1 (Fig. 3).

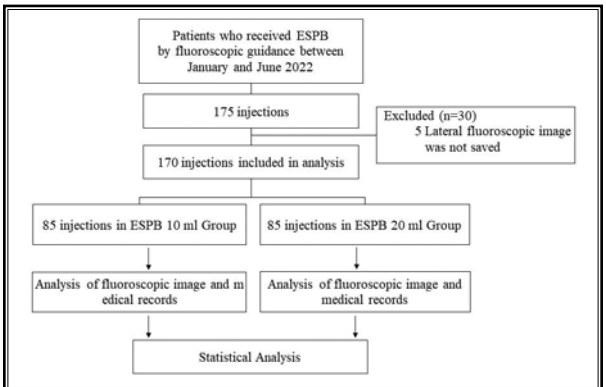

Fig. 1. *CONSORT diagram.*

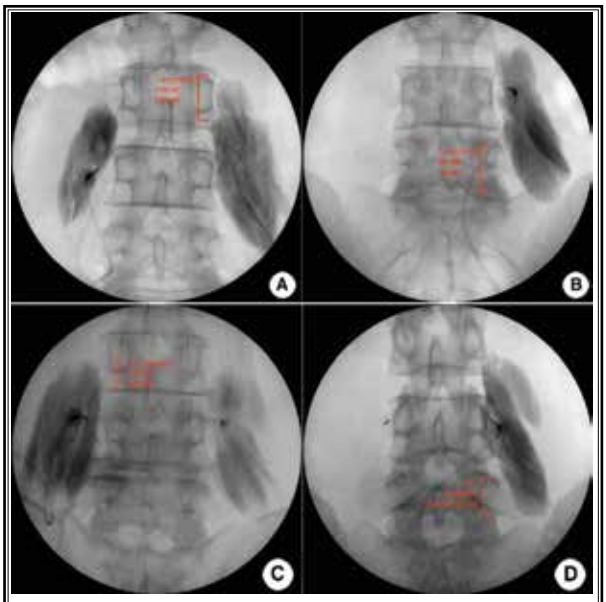

Fig. 2. *Anteroposterior images of erector spinae plane block showing one segment cranial (A), caudal (B), 0.5 segment cranial (C), and caudal (D) spreads.*

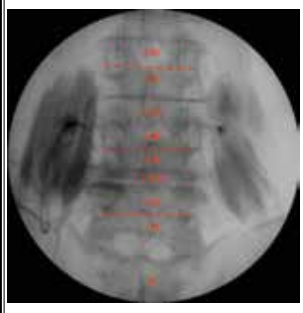

Fig. 3. *Anteroposterior image of erector spinae plane block showing the division of highest cranial and lowest caudal spread of contrast medium.*
Abbreviations: L3U, L3 upper body; L3L, L3 lower body; L3-4D, L3-4 disc space; L4U, L4 upper body; L4L, L4 lower body; L4-5D, L4-5 disc space; L5U, L5 upper body; L5L, L5 lower body.

Analysis of Contrast Medium Spread Into the Epidural Space, Psoas Muscle, and Intravascular System

We assessed the chance of inadvertent injection into the epidural space, psoas muscle, and intravascular system. For determining epidural space and psoas muscle injections, AP and lateral images were evaluated. When contrast medium appeared at the medial side of the pedicle in the AP image and within the spinal canal in the lateral image, it was considered an epidural space injection (Figs. 4A, 4B). When a psoas muscle shadow was apparent in AP and lateral images, it was considered as a psoas muscle injection (Figs. 5A, 5B). The presence or absence of epidural space and psoas muscle injections was recorded.

The presence or absence of intravascular system injection was checked by fluoroscopy. When blood was observed, the needle was redirected until no blood was detected. If an aspiration test was negative, the remaining 0.1% ropivacaine mixture was injected. Thereafter, a fluoroscopic image was obtained to assess any inadvertent intravascular injection. If only the ES muscle appeared without any intravascular injection, it was considered a successful injection. We considered an intravascular injection to be when we observed the characteristic fleeting pattern without any ES muscle shadow. When images of such intravascular injections were obtained, the needle was redirected until successful observation of the ES muscle. After injecting 10 mL or 20 mL 0.1% ropivacaine mixture injection, AP and lateral images of the ESPB were obtained to evaluate the spread pattern. Those images were saved and transmitted to PACS.

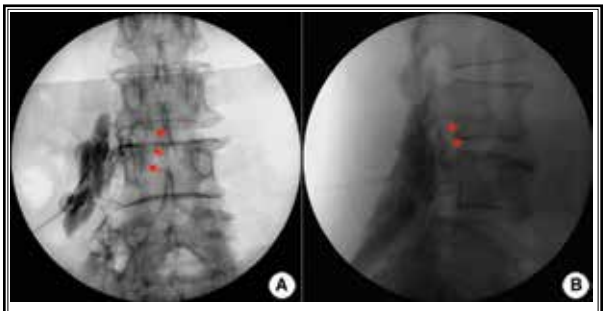

Fig. 4. *Anteroposterior (A) and lateral (B) images of erector spinae plane block showing epidural injection. Red arrow indicates the epidural spread.*

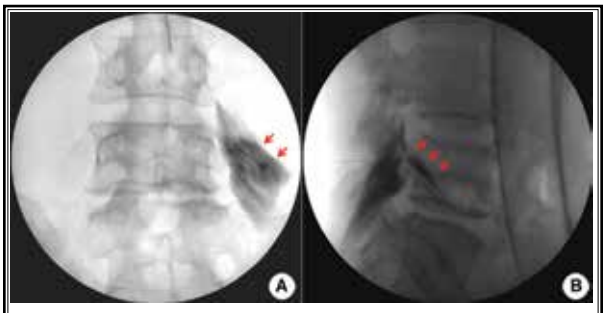

Fig. 5. *Anteroposterior (A) and lateral (B) images of erector spinae plane block showing psoas muscle injection. Red arrow indicates the psoas muscle spread.*

Medical records including age, gender, body mass index, side of injection, and diagnosis were obtained using an electronic medical record system (BESTCare).

Sample Size and Statistical Analysis

Since there have been no studies showing mean differences in vertebral segments using different injection volumes during ESPB in vivo, we performed a preliminary study for sample size calculation. Assuming the mean differences of vertebral segments between ESPB 10 mL and 20 mL groups as 0.3 ± 0.6 and an α error level of 0.05, a β error level of 0.2, and a dropout rate of 15%, 78 injections were required in each group to achieve 80% power and a significance level of 5%.

Demographic data including patient characteristics and diagnosis was presented as mean ± SD or number of injections (%). A χ^2 test, or an unpaired t test was used to compare values of demographic data between the ESPB 10 mL and ESPB 20 mL groups.

Differences in mean vertebral segment covered with contrast medium between ESPB 10 mL and ESPB 20 mL groups were compared using an unpaired t test. The incidence of an inadvertent epidural space, psoas muscle, and intravascular system injection was compared using a χ^2 test using IBM SPSS Statistics 20.0 (IBM Corporation). A P value < 0.05 was considered statistically significant.

Results

Eighty-five ESPB injections were performed in ESPB 10 mL and 20 mL groups, respectively (Fig. 1). Neither group showed any significant differences in age, gender, body mass index, side of injection, and back pain diagnosis (Table 1).

To assess the contrast medium spread in the cranial or caudal direction, one and 0.5 segments of cranial or caudal spread were defined (Figs. 2A–2D). The number of lumbar vertebral segments in the cranial direction

was similar between groups (0.3 ± 0.3 vs 0.2 ± 0.3, P = 0.516, Table 2). However, the number of lumbar vertebral segments in the caudal direction was significantly higher in the ESPB 20 mL group than in the ESPB 10 mL group (0.5 ± 0.4 vs 0.9 ± 0.4, P < 0.001, Table 2). The ESPB 20 mL group showed a more extensive distribution of contrast medium in the caudal direction than the ESPB 10 mL group (Table 2). Also, the total number of lumbar vertebral segments was significantly higher in the ESPB 20 mL group than in the ESPB 10 mL group (1.7 ± 0.4 vs 2.1 ± 0.4, P < 0.001, Table 2).

In the cranial direction, contrast medium spread to the L3-L4 disc level was found commonly in both groups of ESPB. However, the most common contrast medium spread level in the caudal direction was the L5 upper body and L5 lower body in the ESPB 10 mL and 20 mL groups, respectively (Figs. 3, 6A, 6B).

Epidural space and psoas muscle injections occurred in both ESPB groups, but their incidence was rare. Particularly, the total incidence of epidural space injection during ESPB was less than 5%, smaller than that of psoas muscle injection (Table 3). Both groups of ESPB demonstrated a similar incidence of intravascular system injection (12 [14.1%] vs 10 [11.8%], P = 0.648, Table 3).

Discussion

In this study, the total number of lumbar vertebral segments in the craniocaudal direction was 1.7 and 2.1 segments in the ESPB 10 mL and 20 mL groups, respectively. An increased spread level presents a clinically relevant meaning since the analgesic or sensory block effect of ESPB depends on the craniocaudal direction spread of local anesthetics extending several vertebral levels in the fascial plane (14). When local anesthetics are injected into this space, they diffuse anteriorly into the adjacent neural foramen and ventral and dorsal rami, where they act on the spinal nerves (5,14).

Table 1. *Patient demographics.*

	ESPB 10 mL Group (n = 85)	ESPB 20 mL Group (n = 85)	*P* value
Age (years)	57.9 ± 12	60.8 ± 16.5	0.786
Gender (M/)	33 (38.8)/52 (61.2)	34 (40.5)/50 (59.5)	0.826
Body mass index (kg/m^2)	23.9 ± 3.4	23.9 ± 3.0	0.920
Side of injection (Right/ Left)	38 (44.7)/47 (55.3)	50 (59.5)/35 (40.5)	0.054
Diagnosis			0.986
Facet joint pain	44 (51.8)	45 (52.9)	
Myofascial pain syndrome	30 (35.3)	29 (34.1)	
Lumbar sprain	11 (12.9)	11 (12.9)	

Values are mean ± SD or number of injections (%).
ESPB: erector spinae plane block.

Table 2. *The mean vertebral segment covered with contrast medium of L4 erector spinae plane block.*

	ESPB 10 mL Group (n = 85)	ESPB 20 mL Group (n = 85)	*P* value
Number of segment with cranial spread	0.3 ± 0.3	0.2 ± 0.3	0.516
Number of segment with caudal spread	0.5 ± 0.4	0.9 ± 0.4	< 0.001
Total number of segment	1.7 ± 0.4	2.1 ± 0.4	< 0.001

Values are mean ± SD. ESPB: erector spinae plane block.

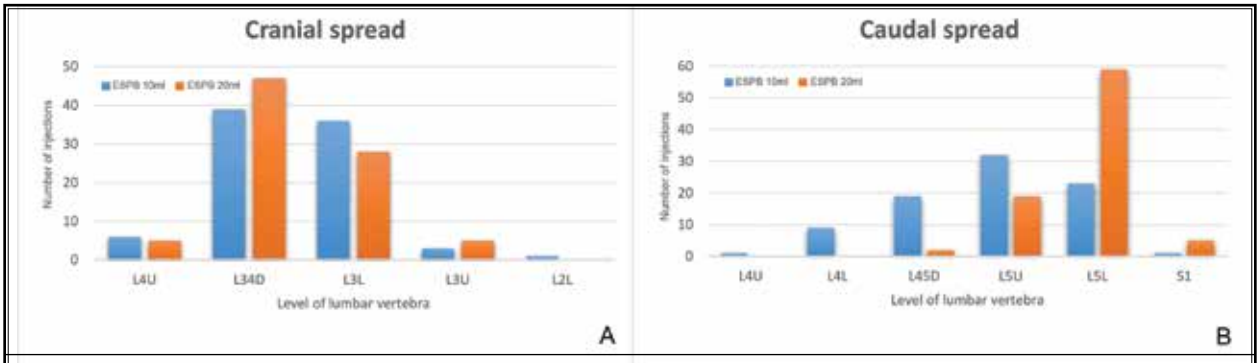

Fig. 6. *Number of injections showing contrast medium spread to highest cranial and lowest caudal directions.*
Abbreviations: L3U, L3 upper body; L3L, L3 lower body; L3-4D, L3-4 disc space; L4U, L4 upper body; L4L, L4 lower body; L4-5D, L4-5 disc space; L5U, L5 upper body; L5L, L5 lower body.

Table 3. *The incidence of an inadvertent epidural, psoas muscle, or intravascular injection in L4 erector spinae plane block.*

	ESPB 10 mL Group (n = 85)	ESPB 20 mL Group (n = 85)	Total n (%)	*P* value
Epidural injection	5 (5.9)	0 (0)	5 (2.9)	0.059
Psoas muscle injection	8 (9.4)	2 (2.4)	10 (5.9)	0.050
Intravascular injection	12 (14.1)	10 (11.8)	22 (12.9)	0.648

Values are number of injection (%). ESPB: erector spinae plane block.

When an L4 ESPB was performed using 20 mL of methylene blue in a human cadaver, craniocaudal spread was found between L2-L5 (15) or L3-L5 (16). Moreover, spread into the dorsal ramus occurred in all cases, whereas spread to the ventral ramus occurred only in 17% (15). The injection volume used in the cadaver was the same as in the present study, but the injected solution (methylene blue) was different (15,16). In comparison to methylene blue, the contrast medium mixed with local anesthetics in this study has distinct characteristics due to its unique osmolality and viscosity (17). Therefore, such differences in injected material characteristics might lead to a different level of craniocaudal spread. In addition, the spread of dye in a cadaveric model might have some differences due to reduced tissue tension and elasticity in the cadaver.

Two clinical case reports and one study evaluated the contrast medium spread pattern in L4 ESPB. The case reports used a mixture of local anesthetics mixed with contrast medium 40 mL for ESPB; CT or MRI was performed 60-90 minutes after the block. Craniocaudal spread was found from T12 to L5 or S1; this distribution was more extensive than in our study (18-20). However, the injection volume was double as much as what we used and CT or MRI was performed much later than in our study, but a fluoroscopy evaluation occurred within 5 minutes of the ESPB completion.

Our study shows a similar spread level in the cranial direction for double the ESPB injection volume. However, the ESPB 20 mL group showed a significantly more extensive spread in the caudal direction than the ESPB 10 mL group. Moreover, the total number of segments covered with contrast medium was significantly higher in the ESPB 20 mL group than in the ESPB 10 mL group.

When the injection volume was increased, the reason the physical spread moves caudally rather than cranially might be related to the anatomical feature of lumbar vertebrae and ES muscle. The injected local anesthetic mixture is supposed to spread within the fascial plane. However, given the different size of upper and lower lumbar vertebrae and ES muscle, the space of the fascial plane where the local anesthetics will spread might be larger in the lower vertebrae. The larger space of the interfascial plane in the lower lumbar vertebrae might be related to the significantly more extensive caudal spread in the ESPB 20 mL group.

Although the ESPB 20 mL group demonstrated a significantly extensive distribution of contrast medium compared to the 10 mL group, the craniocaudal distribution was not as extensive as thoracic ESPB. When thoracic ESPB was performed at T8, most methylene blue was found to be from C4 to L4, encompassing more than 10 segments of vertebra (21).

The lumbar region has a different musculofascial anatomy compared to the thoracic region. Due to such anatomical differences, a more limited spread of lumbar ESPB than thoracic ESPB might be observed. The thoracolumbar fascia in the lumbar region is thicker, multilayered, and more complex than in the thoracic region (15,16). Moreover, the arrangement and thickness of the deep back muscles are different from the thoracic region. Longissimus and multifidus muscles are the most prominent muscles in the lumbar region whereas the spinalis, longissimus, and iliocostalis muscles in the thoracic region are considerably thinner. Most muscle fibers in the thoracic region are semispinalis and longissimus, and the iliocostalis muscle takes the shape of a narrow fusiform muscle (15,16). These thinner muscles in the thoracic region might contribute to more extensive craniocaudal and medial-lateral spread of injectate.

Although injection into the epidural space or psoas muscle was found during lumbar ESPB, its incidence was less than 6%. Psoas muscle injection was observed more frequently than epidural space injection. If psoas muscle or epidural space spread was found, it means that the injected material moved anterior to the transverse process. According to the study by Harbell (16), there was extensive methylene blue staining around the ES muscles and dorsal rami in all specimens. However, there was no methylene blue staining anteriorly into the dorsal root ganglion, ventral rami, or paravertebral space. The lack of contrast medium spreading anterior to the transverse process could be due to contrast medium entrapment within the ES muscle by the middle layer of the thoracolumbar fascia, which attaches to the transverse process and divides the abdominal wall muscles from the back muscles (16,22).

Since the injection volume of local anesthetics during ESPB ranges between 10 mL–40 mL depending on physician, determining the actual incidence of intravascular injection is important. No previous clinical studies evaluated the overall incidences of intravascular injection in thoracic or lumbar ESPB. The overall incidence of intravascular injection was 12.9%. There were no significant differences when the injection volume was doubled in the ESPB 20 mL group compared to the 10 mL group. The best way of confirming intravascular injection is using fluoroscopy instead of ultrasound. Local anesthetic toxicity was reported even after visualization of the linear spread of injected material using ultrasound (13). This finding was also confirmed in this study since 22 fluoroscopic confirmed intravascular ESPBs were visualized initially with a linear spread of the interfascial plane by ultrasound guidance. Fluoroscopy is a safer method to avoid such complication, but it has a limitation in confirming the spread of injected material into the interfascial plane.

Limitations

Our study has several limitations. First, we did not evaluate the spread pattern in the medial to lateral or anteroposterior dimension; only the craniocaudal direction was evaluated. Since this study was performed using fluoroscopic images, there was no clear radiologic landmark to assess the medial to lateral direction. However, the clinical relevance of spread into the medial to lateral dimension is less compared to the craniocaudal direction. The level of sensory block depends on the craniocaudal spread of local anesthetics, not the medial to lateral spread (5,14).

Second, the proportion of contrast medium mixed in the local anesthetics in the ESPB 10 mL group was different from that of the contrast medium in the ESPB 20 mL group. We considered that using 10 mL of contrast medium in the ESPB 20 mL group to reach the same proportion as in the ESPB 10 mL group was not beneficial considering the toxicity of contrast medium (17). Despite the lower proportion of contrast medium in the ESPB 20 mL group, there were not any difficulties in identifying the spread level or inadvertent injection into the epidural space, psoas muscle, or intravascular system. We believe that the effect of different fluid properties is minimal since the influence of viscosity of injected material was not statistically significant during epidural distribution (23).

Conclusion

In conclusion, the ESPB 20 mL group showed more extensive distribution of contrast medium than that of the ESPB 10 mL group. Inadvertent injections into the epidural space, psoas muscle, and intravascular system were observed. Among them, intravascular system injections were the most common (12.9%).

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