ORIGINAL ARTICLE

An evaluation of contrast dispersal pattern on preganglionic epidural injection through trans-lateral recess approach in patients with lumbosacral radiculopathy

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Abstract

Purpose To evaluate the accessibility of the preganglionic epidural space in patients with lumbosacral radiculopathy treated with epidural steroid injection (ESI) through trans-lateral recess (TLR) approach.

Methods From September 2016 to December 2016, we enrolled 50 consecutive preganglionic ESI through TLR approach for 38 patients with lumbosacral radiculopathy at or below L4 territory. Fifteen of patients were diagnosed with lumbar disc herniation and 23 with lumbar spinal stenosis. TLR epidural injection was performed with 20-G Tuohy needles. To achieve proper final needle placement (i.e., in the axillary portion between the exiting and transversing nerve roots), the needle direction was set laterally from the center of the infra-adjacent spinous process to the medial wall of the corresponding pedicle and superiorly from the distal tip of infra-adjacent spinous process to the corresponding vertebral foramen. Finally, 1 mL of contrast was injected to assess the epidurographic pattern.

Results All patients achieved filling of the dorsal and ventral epidural space. Rostral spreading along the exiting nerve root to the foramen of target segment was present in 48/50 (96%) patients and caudal spreading along the transversing nerve root to the foramen of lower segment in 45/50 (90%) patients. No intravascular injection or dural puncture-related neural complications were observed.

Conclusions When delivered using the TLR approach, epidural injections result in excellent drug spread within the preganglionic area (i.e., ventral epidural contrast filling and periradicular infiltration of exiting and transversing nerve roots). As noted previously that higher rates of pre-ganglionic epidural infiltration might be led to improvements in clinical pain and disability, epidural injections delivered using the TLR approach are expected to complement existing epidural modalities.

Graphical abstract
These slides can be retrieved under Electronic Supplementary Material.

Extended author information available on the last page of the article

Introduction

Although epidural steroid injections (ESI) are considered one of the most important conservative treatments for lumbosacral spondylotic radiculopathy, published clinical evidence supporting the use of ESIs is highly variable (e.g., from indeterminate to strong), likely because of differences in epidural space drug dispersal patterns [1, 2].

The preganglionic epidural space between the lateral aspect of the transversing nerve and ventral aspect of the dural sac is the presumable site of lumbar radiculopathy pathology [3]. Some researchers reported that the preganglionic ESIs are considered to have more effective than other epidural modalities in treatment of lumbosacral radiculopathy [4–6]. However, the applicability of the TF approach may be limited due to interference of the iliac crest and the orientation of the facet joint at the lumbosacral level [7].

The epidural space on the lateral aspect of the transversing nerve root accessible through the interlaminar space gets wider toward the lower lumbar spine and can be reached using the TLR approach. Here, we reviewed contrast medium dispersal patterns and the clinical features of the preganglionic ESI through TLR approach.

Materials and methods

This study was approved by the university review board (KUH1060161) and hospital ethics committee, and written informed consent was obtained from each patient. Fifty consecutive ESIs through TLR approach for lumbosacral radiculopathy at or below L4 at an outpatient spine clinic at our institution between September and December 2016 were enrolled in this study. Inclusion criteria included the following: (1) patient age > 20; (2) subacute or chronic symptoms lasting more than 6 weeks; and (3) lumbosacral radiculopathy related to neural impingement secondary to intervertebral disc herniation or lumbar spinal stenosis confirmed by magnetic resonance imaging (MRI). Patients were excluded if they met any of the following criteria: (1) previous spinal surgery or intervention, (2) spinal tumor, (3) spinal infection, (4) pregnancy, (5) history of allergic reaction to contrast medium, and (6) coagulopathies.

All procedures were performed on an outpatient basis by a single spine surgeon. The technique used in all 50 injections was standardized. Patients were placed prone on a radiology table, and their backs were prepared using an iodine-based antiseptic solution. After acquiring the corresponding level of the standard anterior–posterior (AP) view

under fluoroscopic guidance, a 20-G 3.5-inch Tuohy needle was inserted into the distal tip of the distal adjacent spinous process and advanced toward the medial wall of the corresponding pedicle. Next, after acquiring the standard lateral view, a needle was inserted into the corresponding neural foramen and adjusted as close to parallel to the lamina as possible. Then, 0.5 mL of contrast dye (Iobrix 300; Iohexol, Taejoon Pharmaceuticals Co. Ltd., Seoul, South Korea) was injected through the needle tip placed at the dorsal epidural space below the ligamentum flavum to determine the epidurographic pattern. After confirming that the needle tip was placed outside the posterolateral margin of thecal sac on the standard AP and lateral view, a needle was gently advanced until it touched the posterior aspect of the vertebral body or intervertebral disc. Contrast (1 mL) was then injected to determine the epidurographic pattern on the standard AP and lateral view (Fig. 1). After ventrolateral epidural space confirmation, 1 mL of dexamethasone (1 mL = 5 mg) plus 2 mL of 0.2% ropivacaine and 4 mL of sterile normal saline were injected. All patients were monitored for at least 30 min after the procedure.

To reduce individual bias for defining the area of contrast dispersal pattern, a blinded and independent observer assessed the presence of ventral spread and periradicular infiltration of the contrast dye. Patients were evaluated for effective pain relief (> 50% improvement of VAS score) by 0–10 visual analog scale (VAS) and functional improvement by Oswestry Disability Index (ODI < 20%) 4 weeks after the procedure.

All statistical analyses were performed using SPSS Statistical Program, version 13.0 (SPSS, Inc, Chicago, IL). Student's T tests were used to compare the clinical outcomes in relation to different anatomical diagnosis. The P values < 0.05 were considered statistically significant.

Results

Data were captured from 50 consecutive fluoroscopically guided trans-lateral recess epidural injections in 38 patients (17 male and 21 female). The mean age of the patients was 48.4 ± 12.5 years. The mean BMI was $23.1 \pm 3.6\%$. The mean duration of pain was 5.7 ± 5.5 months. These patients were diagnosed with L4 radiculopathy ($n = 2$), L5 radiculopathy ($n = 29$), and S1 radiculopathy ($n = 10$). Among them, L4 radiculopathy and L5 radiculopathy were observed together in two patients, and L5 radiculopathy and S1 radiculopathy were observed together in one patient. Fifteen had herniated intervertebral discs and 23 had lumbar spinal stenosis. Twenty-six patients with unilateral leg radicular
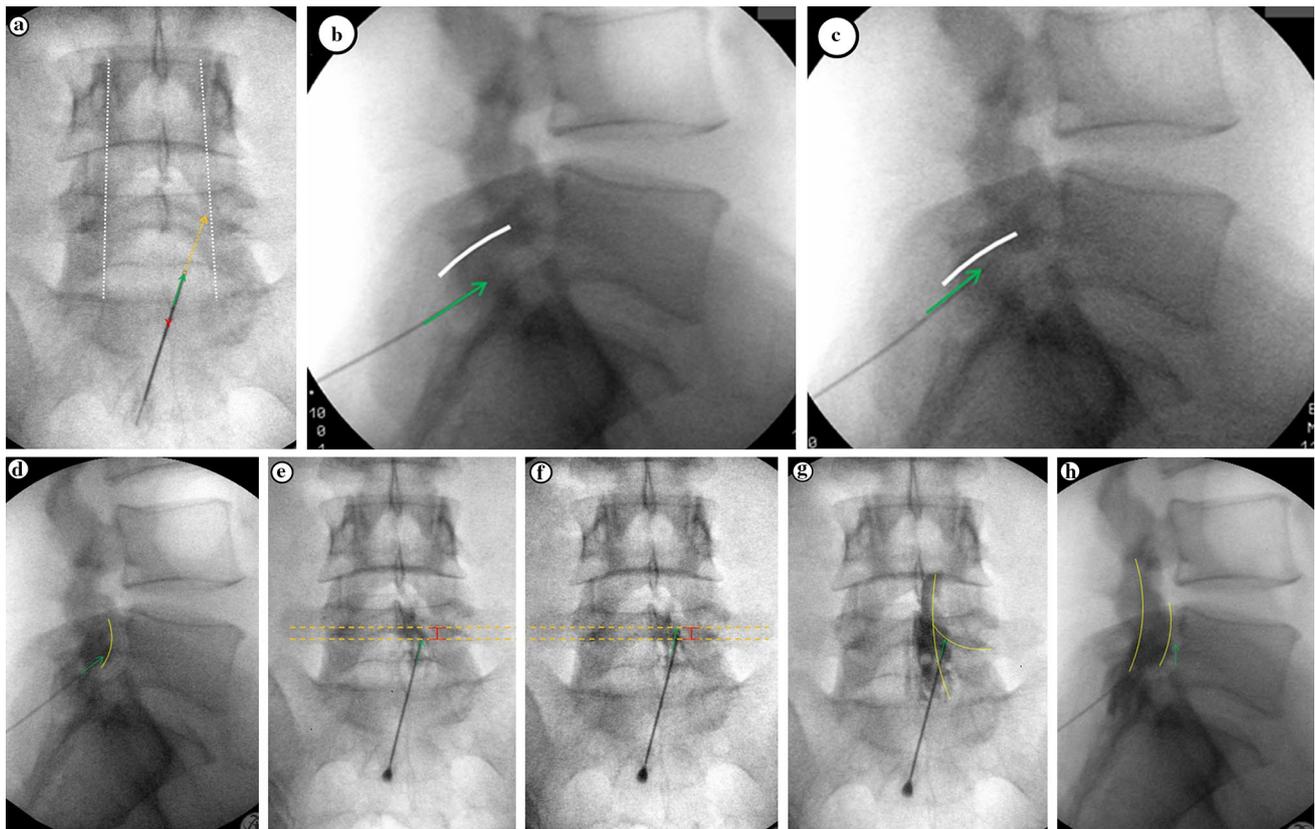
Fig. 1 Trans-lateral recess epidural injection techniques. **a** A 20-G 3.5-inch Tuohy needle which was inserted into the distal tip of distal S1 spinous tubercle and then advanced toward the medial wall of L5 pedicle. **b** After acquiring the standard lateral view, **c** a needle was inserted into the L5–S1 neural foramen and adjusted as possible to parallel to the lamina. **d** After the needle tip was placed at the dorsal epidural space below the ligamentum flavum, 0.5 mL of contrast dye was injected to determine the epidurographic pattern. **e** After confirming that the needle tip was placed outside the posterolateral margin of thecal sac on the standard AP and lateral view, **f** a needle was gently advanced until it touched posterior aspect of the vertebral body or intervertebral. A 1 mL of contrast was injected to determine the epidurographic pattern on the standard AP (**g**) and lateral (**h**) view (white dotted line: a line connecting the medial wall of L4 and L5 pedicle, white line: the lamina of L5 vertebra, yellow dotted line: contrast spread in the dorsal epidural space, yellow line: epidural contrast dispersal pattern, green arrow: a position of needle tip, orange dotted line: a running distance of the needle in the epidural space, orange dotted arrow: an incidence direction of needle in the AP plane, red Y: A distal tip of S1 spinous tubercle)

pain were injected with only the symptomatic side. One of four patients with downward extruded IVH at L4–5, one of three with downward extruded IVH at L5–S1, six of eight patients with central canal stenosis at L4–5, two of three patients with central canal stenosis at L5–S1, and two of three patients with L4 spondylolisthesis and lateral canal stenosis at L4–5 were received both-side injection at the same time (Table 1).

Anatomical contrast dispersal patterns

A review of patient epidurography revealed contrast in the dorsal epidural space and the ventral epidural space of all patients. Lateral epidural filling patterns revealed rostral spreading along the exiting nerve root to the foramen of target segment in 48/50 (96%) patients and caudal spreading along the transversing nerve root to the foramen of lower segment in 45/50 (90%) patients. All patients showed excellent filling in the ventrolateral epidural space of target level (Table 1).

There was no difference in the contrast dispersal patterns depending on the direction of the structural abnormalities confirmed by MRI on the right and left.

Clinical outcomes: effective pain relief and functional improvement

Four weeks following the intervention, 35/38 (92%) patients obtained significant pain relief (i.e., pain relief greater than 50% against the baseline VAS score; $P < 0.001$). VAS score was significantly improved from 7.39 ± 0.75 point to 3.47 ± 1.06 point ($P < 0.001$), and ODI score was significantly improved from 58.6 ± 10.18 percentage to 19.13 ± 14.31 percentage ($P < 0.001$). There was no significant difference

Table 1 Summary of radiculopathy lesions and injection levels

Anatomical diagnosis	Clinical diagnosis			No. of ESIs	Level of ESIs	Ventral epidural filling		Periradicular infiltration	
	L4 radiculopathy	L5 radiculopathy	S1 radiculopathy			Cranial spread	Caudal spread	Exiting nerve root	Transversing nerve root
IVH, L4–5									
Protruded (N=3)		3		3	L5–S1	100% (3/3)	100% (3/3)	100% (3/3)	100% (3/3)
Upward extruded (N=2)	2	2		2	L4–5	100% (2/2)	100% (2/2)	50% (1/2)	100% (2/2)
Downward extruded (N=4)		4		5	L5–S1	100% (5/5)	100% (5/5)	100% (5/5)	100% (5/5)
IVH, L4–5–S1									
Downward extruded (N=1)		1		1	L5–S1	100% (1/1)	100% (1/1)	100% (1/1)	100% (1/1)
IVH, L5–S1									
Protruded (N=2)			2	2	L5–S1	100% (2/2)	100% (2/2)	100% (2/2)	100% (2/2)
Downward extruded (N=3)			3	4	L5–S1	100% (4/4)	100% (4/4)	100% (4/4)	100% (4/4)
LSS, L4–5									
Central canal (N=8)		8		14	L5–S1	100% (14/14)	100% (14/14)	100% (14/14)	78.5% (11/14)
Lateral canal (N=4)		4		4	L5–S1	100% (4/4)	100% (4/4)	75% (3/4)	100% (4/4)
LSS, L4–5–S1									
Central canal (N=4)		3	1	4	L5–S1	100% (4/4)	100% (4/4)	100% (4/4)	75% (3/4)
LSS, L5–S1									
Central canal (N=3)			3	5	L5–S1	100% (5/5)	100% (5/5)	100% (5/5)	100% (5/5)
L4 LSL and LSS L4–5									
Lateral canal (N=3)		3		5	L5–S1	100% (5/5)	100% (5/5)	100% (5/5)	100% (5/5)
L5 LSL and LSS, L3–4–5–S1									
Central canal (N=1)		1	1	1	L5–S1	100% (1/1)	100% (1/1)	100% (1/1)	0% (0/1)
Total (N=38)	2	29	10	50		100% (50/50)	100% (50/50)	96% (48/50)	90% (45/50)

in clinical outcomes according to anatomical diagnosis (P=0.426) (Table 2). No intravascular injection or intrathecal injection-related dural puncture complications were observed. At 4 weeks after the intervention, no neural complications (e.g., infection, rash, weakness, bladder disturbances) were reported.

Discussion

Some researchers reported that the preganglionic ESIs through retrodiscal transforaminal approach are considered to have more effective than other epidural modalities in

Table 2 Clinical outcomes of effective pain relief (VAS score) and functional disability (ODI score)

	Visual analog scale				Oswestry Disability Index		
	Preoperative	Postoperative 2 weeks	Postoperative 4 weeks	P value	Preoperative	Postoperative 4 weeks	P value
IVH group	7.2 ± 0.65 (6–8)	2.73 ± 0.77 (1–4)	3.33 ± 0.79 (3–6)	< 0.001	58.67 ± 9.35 (42.2–77.8)	17.05 ± 10.46 (11.1–55.6)	< 0.001
LSS group	7.52 ± 0.77 (6–9)	2.78 ± 0.72 (1–4)	3.56 ± 1.17 (3–8)	< 0.001	58.5 ± 10.48 (37.8–77.8)	20.49 ± 15.91 (13.3–77.8)	< 0.001
Total	7.39 ± 0.75 (6–9)	2.76 ± 0.75 (1–4)	3.47 ± 1.06 (3–8)	< 0.001	58.6 ± 10.18 (37.8–77.8)	19.13 ± 14.31 (11.1–77.8)	< 0.001

treatment of lumbosacral radiculopathy [4–6]. Additionally, the trans-lateral recess approach proposed here provides access to the preganglionic epidural space through the interlaminar space because of the unique needle incidence angle compared with the conventional paramedian interlaminar approach that is only directed inward 10° to 15° to the sagittal plane. In this study, all patients underwent the preganglionic ESI through TLR approach and experienced excellent contrast filling of the ventral epidural space. Also, rostral spreading along the exiting nerve root to the foramen of target segment was observed in 48/50 (96%) patients and caudal spreading along the transversing nerve root to the foramen of lower segment in 45/50 (90%) patients. Good short-term clinical outcomes (i.e., 4 weeks after intervention) were reported, and no specific complications were reported.

Although ESI is a widely used minimally invasive treatment for lumbar degenerative disc disease, there remains a great deal of debate about its utility, including the potential benefits of including steroids in the drug composition, the ideal approach (e.g., caudal, interlaminar, transforaminal), whether hydrostatic or proteolytic adhesiolysis are possible, or whether there is a meaningful therapeutic benefit [1, 8].

Kirkaldy-Willis et al. [9] presented the concept of a cascade of spinal motion segment degeneration invoking progressive wear of the intervertebral disc and facet joints. Lumbar degenerative disc disease, including intervertebral disc herniation, spinal stenosis, listhesis, segmental instability, and adult spinal deformity, is a pathological cascade associated with aging of the spinal functional unit. In this process, afferent nociceptive fibers of intervertebral discs originating from the sinuvertebral nerve and dorsal root ganglia become densely innervated in annulus fibrosus that lack innervations under normal conditions [10]. Also, a significant number of nociceptive fibers have been reported to be significantly higher in the ligamentum flavum and facet joint capsule than intervertebral disc [11]. Increased expression of nociceptors is also observed in the ventral aspect of the dural sac, posterior longitudinal ligaments, facet joint capsule, and ligament flavum [11], and the increased abundance of nociceptors within the epidural space is associated with spinal origin pain (e.g., radicular, discogenic, facetogenic) [10]. Therefore, understanding the pathways associated with spinal pain at each stage of degenerative disc disease and how they may be blocked may result in favorable clinical outcomes.

The distribution of contrast medium following epidurography can help determine whether a drug is delivered to spinal pathologies. Hashemi et al. [2] suggest that higher infiltration of the ventral and lateral compartment of epidural space could lead to improvements in disability and pain.

In the standard paramedian interlaminar approach, after finding the most widely visible anteroposterior image of the interlaminar space of target level under fluoroscopy, the needle is inserted into the center of the afflicted hemisphere of interlaminar space to the anteroposterior plane and directed inward 10° to 15° to the sagittal plane. Thereafter, the needle enters the interlaminar space, engages the ligamentum flavum, and enters the epidural space with the technique of loss of resistance. However, accessing the ventral epidural space can be difficult using this approach, and there is a risk of complications such as dural puncture [12]. In the traditional superoanterior approach for transforaminal ESIs, the needle is inserted into the "safe triangle," inferior to the pedicle, and superolateral to the exiting spinal nerve under intermittent fluoroscopy [13].

It has been shown that fluoroscopy-guided lumbar interlaminar (IL) injections—accessible via the ventral epidural space in only approximately 36% of cases—are less effective compared with conventional TF epidurals [12, 14]. Fluoroscopy-guided lumbar TF injections through the safe zone are: (1) known to have a specific target requiring the smallest volume to reach the primary site of pathology and (2) considered more efficacious than caudal and interlaminar epidurals [15]. Despite the purported superiority of the TF route compared with other epidural modalities, when we consider that the hypotenuse of the triangular space called the so-called safety zone is a nerve root, the final position of the needle in the TF approach cannot be placed further inward from the neural foramen. As such, this is not a safety

zone for blood vessels, as a microsurgical anatomical study of branch of lumbar segmental artery demonstrated that the dorsal root ganglion–ventral root complex invariably lies in the "subpedicular notch" (which is the superior part of the foramen) together with the branches of lumbar artery, such as the artery of Adamkiewicz and radicular arteries, implying superior location [16–19]. In this respect, TFE-SIs are extremely rare but they are associated with potential hazards: (1) intravascular injection, (2) vascular trauma, (3) particulate emboli, (4) cerebral thrombosis, and (5) epidural hematoma. Neurological or spinal cord injury raises serious concerns about the true safety of these safe zones [20].

To overcome these previously described complications, Jesper et al. [21] suggested the retrodiscal TF approach. The retrodiscal TF approach is performed using a 17-G, 7-inch Pajunk Tuohy needle with approximately 45° angle of incidence in the prone position as if the patient were a percutaneous endoscopic lumbar discectomy through the Kambin's triangle. A needle is advanced gently past the lateral surface of superior articular process in the lateral view and the interpedicular line in the anteroposterior view. Finally, it gets to the lateral recess zone of spinal canal, which is the preganglionic area. However, the preganglionic epidural injection through the retrodiscal TF approach is often

technically limited because of neural foraminal stenosis due to the hypertrophy of the superior articular process and loss of disc height. Also, there are intradiscal injection-related complications that occur at a relatively high frequency [22, 23].

Although it is known that accessing the ventral epidural space using the conventional IL approach is difficult, Candido et al. and Kim et al. have suggested alternative methods to access the preganglionic area by modification of the IL approach [22, 24]. In the parasagittal interlaminar approach, a Tuohy needle is inserted at the most lateral point of the interlaminar space and advanced directly perpendicular to the skin in a posterior to anterior direction [14, 24–26]. However, the parasagittal IL approach requires that the final needle tip position be directly above the inflamed intervertebral disc and that periradicular infiltration along the transversing nerve root of the corresponding level is required. In the modified interlaminar approach, a Tuohy needle is introduced into the midline of the interlaminar foramen at the level of pathology and is advanced toward the superomedial margin of the interlaminar foramen. The final needle tip position of this approach was placed laterally to the superomedial bone margin of the interlaminar foramen in fluoroscopic AP view and placed midpoint between the superior

Table 3 Epidural contrast dispersal pattern according to published epidural approaches

Approach	Study	Ventral epidural filling	Periradicular infiltration
Paramedian interlaminar approach 9	Botween KP, Natalicchio J, Hanna A. Pain Physician. 2004; 7:77–80	36% (36 of 100 injections)	Not investigated
	Ghai B, Vafaje KS, Wig J, et al. Pain Medicine. 2013; 117:219–227	31.7% (13 of 41 injections)	14.63% (6 of 41 injections)
Conventional transforaminal approach	Manchikanti L, Cash KA, Pampati V, et al. Pain Physician. 2004;7:217–223	88% (211 of 239 injections)	97% (232 of 239 injections)
	Ghai B, Bansal D, Kay JP, et al. Pain Physician 2014; 17:277–290	89.6% (52 of 58 injections)	62% (36 of 58 injections)
	Hong JH, Park EK, Park KB, et al. Korean J Pain 2017; 30:220–228	80.6% (25 of 31 injections)	Not investigated
Retrodiscal transforaminal approach	Kim C, Choi HE, Kang SH. Ann Rehabil Med 2012; 36: 474–479	98.4% (62 of 63 cases)	95.2% (60 of 63 injections) Exiting nerve root: 63.5% (40 of 63 injections) Transversing nerve root: 30.2% (19 of 63 injections)
Parasagittal interlaminar approach 2	Hasemi M, Mofrad ML, Mohajerani SA et al. Pain Physician 2015; 18:317–324	75% (42 of 56 injections)	Not investigated
	Ghai B, Bansal D, Kay JP, et al. Pain Physician 2014; 17:277–290	91.6% (55 of 60 injections)	95% (57 of 60 injections)
	Hong JH, Park EK, Park KB, et al. Korean J Pain 2017; 30:220–228	82.9% (34 of 41 injections)	Not investigated
Modified interlaminar approach 14	Kim ED, Roh MS, Park JJ, et al. Pain medicine 2016;17:1620–1627	83.33% (35 of 42 injections)	100% (42 of 42 injections) Exiting nerve root: 76.2% (32 of 42 injections) Transversing nerve root: 95.2% (40 of 42 injections)

articular process and posterior aspect of the vertebral body in fluoroscopic lateral view [22]. The modified interlaminar approach is similar to trans-lateral recess approach in that a needle is advanced outward from the center of the spinal canal and is placed outside the dural sac. However, when considering the morphology of lumbar lamina, such as laminar slope and overhanging, it is difficult to place the final needle position to the neural foraminal level [27–29].

When considering the epidurographic contrast dispersal pattern (e.g., ventral epidural spread, periradicular infiltration of the exiting and transversing nerve roots) of the published epidural modalities, the paramedian interlaminar approach has shown very limited results [12, 14]. The retrodiscal TF approach has been reported to have higher ventral epidural contrast spread pattern than other modalities. However, depending on the level of injection site periradicular infiltrations of different patterns were observed in each of the epidural approaches. In this concept, the target level should be set differently for each epidural modality depending on the level of primary pathology [2, 13, 22, 25, 26, 30] (Table 3).

There are several limitations to this study. First, the overall sample size is small and comparing the few numbers of simple herniated intervertebral disc to complicated lumbosacral spinal stenosis patients should be done with a larger sample size to better draw conclusions as to the patterns of contrast spreading within each of these diagnoses. Longer-term studies would also help elucidate longer-term clinical outcomes. Also, a comparative clinical trial with other approaches for epidural injection should be performed. However, the strengths of our approach were that it has a unique incidence angle of needle that makes it possible to reach the target disc level by running parallel to the lamina and to reach the given foramen by divergently running from the distal tip of the infra-adjacent spinous process. In this fashion, when the needle enters the epidural space through the ligamentum flavum, the needle is placed in a space mainly devoid of neural structures and adipose tissue. Therefore, the needle can be advanced until it touches the posterior aspect of the vertebral body or annulus fibrosus and safely reach the ventral and lateral compartment of epidural space (i.e., the preganglionic space). Also, drug delivery to primary pathologies present at the upper level is allowed because the needles trajectory is directed from the caudla to the cephalad. This was confirmed through an evaluation of contrast dispersal patterns visualized with fluoroscopy.

Conclusions

The trans-lateral recess approach results in excellent preganglionic drug spread when using ventral epidural contrast filling and periradicular infiltration of exiting and transversing nerve roots compared to other published epidural modality. As noted previously that higher rates of preganglionic epidural infiltration might be led to improvements in clinical pain and disability, epidural injections delivered using the TLR approach are expected to complement the want for the existing epidural modalities.

Compliance with ethical standards

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