

SPINE SECTION

Original Research Articles

Epidural Contrast Flow Patterns of Transforaminal Epidural Steroid Injections Stratified by Commonly Used Final Needle-Tip Position

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Abstract

Objective. To evaluate the relationship between commonly used final needle-tip positions and subsequent contrast flow and patient-reported pain relief in transforaminal epidural steroid injections (TFESIs).

Design. Retrospective cross-sectional study.

Methods. Medical records of subjects (N = 83) having undergone a TFESI between January 2008 and January 2009 were reviewed to compare TFESIs using the superior-anterior (SA) vs. the superior-posterior (SP) quadrant.

Outcome Measures. Outcome measures included ventral and dorsal epidural contrast flow as well as near-to-complete pain relief as measured by numerical rating scale pain score pre- and post-procedure.

Results. SA TFESIs were associated with greater ventral epidural contrast flow as compared with SP TFESIs (100% vs 61.4%, $P < 0.001$). SA TFESIs with ventral epidural contrast flow were also associated with flow to a greater number of vertebral levels than SP TFESIs with ventral epidural contrast flow (41% vs 14.8%, $P < 0.001$). SP TFESIs were associated

with greater dorsal epidural contrast flow than SA TFESIs (95.5% vs 43.6%, $P < 0.05$). SA TFESIs were also associated with a larger proportion of patients who achieved near-to-complete pain relief ($P < 0.05$) and greater reduction than SP TFESIs in post-procedure pain score relative to pre-procedure (3.3 vs 1.5, $P < 0.01$).

Discussion. The evolution of TFESIs must balance both safety and efficacy. The efficacy of SA TFESIs is demonstrated to be superior to that of SP TFESIs with regards to ventral epidural flow and patient-reported pain relief. Further efforts should focus on demonstrating efficacy while optimizing safety.

Key Words. Injections, Epidural, Contrast Media

Introduction

Epidural injections have been used in the treatment of low back pain since the beginning of the 20th century, when Cathelin used a caudal cocaine injection to treat sciatica in 1901 [1]. Although local anesthetics were the first agents investigated for this purpose, they have since been largely replaced by the widespread use of corticosteroids. This change was brought about by the work of Lindahl and Rexed, who found that inflammation played a role in patients with disc herniation and radicular pain [2]. Therefore, corticosteroid preparations should prove useful given their ability to inhibit peri-neural inflammation, a possible basis for radicular pain [3,4].

The caudal route was the first used [1] to deliver medication to the epidural space. Correct placement was determined clinically and even in experienced hands could be as low as 62%. Even when the practitioner was confident about placement, fluoroscopy revealed it to be inaccurate 14.2% of the time [5]. Questionable delivery of therapeutic agent prompted the development of the interlaminar route. Ultimately, evidence-based research has shown that clinical judgment alone is not enough for consistently successful entry into the epidural space via an interlaminar approach [6–8]. In studies in which the incorrect placement rate was low, 1.3–8% [8,9], fluoroscopy was still

advocated as a consideration. More recently, it has been shown that the “loss of resistance” method led to a much higher rate of inaccurate needle-tip placement in up to 25.7% of procedures [10].

The popularity of fluoroscopically guided transforaminal epidural steroid injection (TFESI) is a result of constant innovation in developing safer, more efficacious nonsurgical techniques to treat patients with low back pain and radicular symptoms. A need to reliably deliver medication to the epidural space combined with a growing sophistication of the etiology of radicular pain has led to the prominent use of fluoroscopically guided TFESI. Robecchi and Capra pioneered the technique of TFESIs in 1952 [11]. Derby et al. refined this technique to utilize fluoroscopy and avoid pain provocation while delivering a low volume, high concentration solution to more precisely arrive at the ventral nerve root [12,13]. Needle placement has been in the superior-anterior (SA) quadrant of the neural foramina, which also has been termed the “safe triangle,” [14]. Theoretically, these injections have the advantage of delivering the injectate to the ventral epidural space, and therefore the commonest site of pathology in disc herniations.

Historically, the success rate of treatment with epidural steroids has varied considerably, with an average of 67% [15]. Despite advances in the corticosteroid preparation used, the approach to the epidural space and the use of image guidance, a significant minority of patients have not obtained relief from this procedure. Although needle-tip position has been accounted for in interlaminar epidural steroid injections (ILESIs) [16], it has never been documented in relation to flow patterns in TFESI. Specifically, placement either ventrally in the SA quadrant vs dorsally in the superior-posterior (SP) quadrant of the neural foramina may impact flow. Safety and efficacy must both be accounted for in selecting which quadrant of the neural foramina is to be utilized. Stalcup et al. [17] found a low complication rate of 5.5% overall (all complications were transient) and determined that all quadrants can be safely used. In considerations of efficacy, achieving adequate ventral flow and ultimately positive health outcomes for the patient—i.e., pain relief, have been the focus. While novel techniques for needle placement in the epidural space are being explored [18–20], further refinement of the already well-tolerated, relatively safe [21] and efficacious [22,23] procedure of TFESI should be explored.

We retrospectively evaluated commonly used final needle-tip position in TFESI as a marker for subsequent contrast spread and pain relief, specifically in the SA and SP quadrants of the neural foramina. We hypothesized that there would be a significant quantitative difference in ventral and dorsal epidural contrast spread based on SA as compared with the other commonly used SP needle-tip position, particularly with appropriate needle-tip position in the “safe triangle.” Furthermore, we postulated that the relationship between placement and response would result in a greater proportion of patients with near-to-complete relief of pain among those receiving injections into the SA

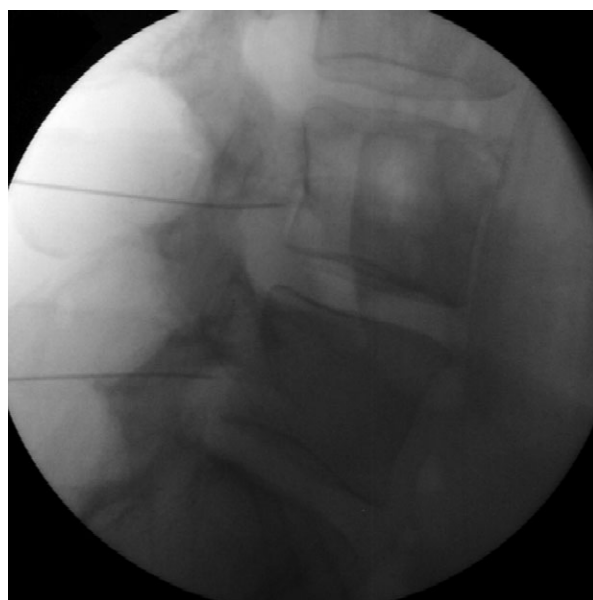


Image 1 Transforaminal approach, superior-anterior needle-tip position. Lateral view.

quadrant. Further refinement of the method to reliably and accurately deliver injectate to the site of pathology may prove useful in guiding physician practice patterns and improve efficacy.

Methods

Technique

Subjects underwent the procedure via a standardized technique in the operating room with routine monitors including blood pressure, pulse oximetry, and heart rate. The subjects were placed prone on the operating table, and the injection site was prepared in a sterile fashion. Fluoroscopic imaging (Philips BV Pulsera, Amsterdam, The Netherlands) was used to guide target-specific injections. Either a 22- or 25-gauge and a 3.5- or 5-inch spinal needle (B I Braun, Bethlehem, PA) with a curved tip (~15°) was advanced toward the appropriate foramen from a 20–30° oblique view with 0–5° cephalo-caudad tilt. Upon final needle-tip position, antero-posterior (AP) and lateral views of the fluoroscopic imaging were obtained to confirm needle positioning (Images 1–6). The use of contrast (2–3 mL of Isovue [Bracco Diagnostics, Princeton, NJ]) was used to illustrate the exact flow of contrast prior to the injection of the final mixture. AP and lateral views of the contrast spread were taken during the procedure to confirm appropriate spread.

Image 7 is an example of a lateral view detailing the four quadrants as they would be visualized during the procedure. The neural foramen was bisected with a coronal and axial plane. This divided the neural foramen into SP (A), SA (B), inferior-posterior (C), and inferior-anterior (D)

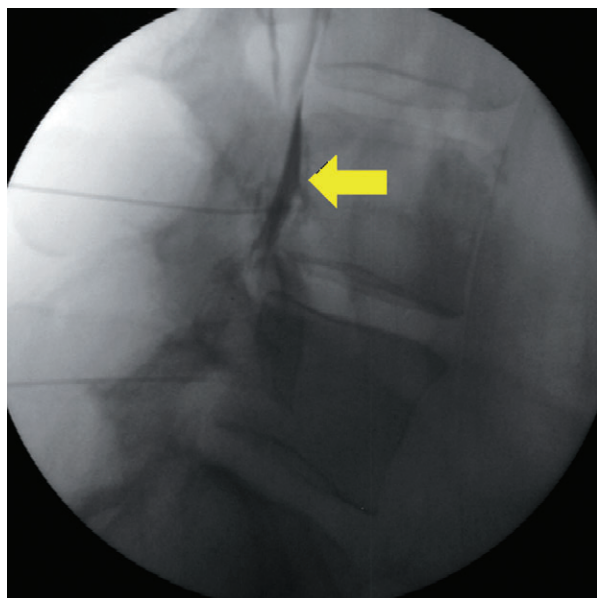


Image 2 Transforaminal approach, superior-anterior needle-tip position. Lateral view. Demonstrating ventral flow at one vertebral level.

quadrants [17]. We evaluated the most commonly utilized placements in our practice (A,B).

Design

Following Institutional Review Board approval, we retrospectively reviewed the medical records of subjects having undergone lumbar TFESIs between July 2007 and

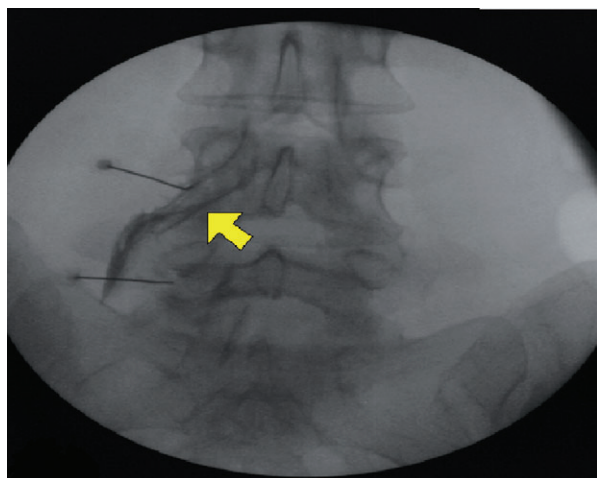


Image 3 Transforaminal approach, superior-anterior needle-tip position, left-sided. Anteroposterior view. Note contrast flow along L4 nerve root.

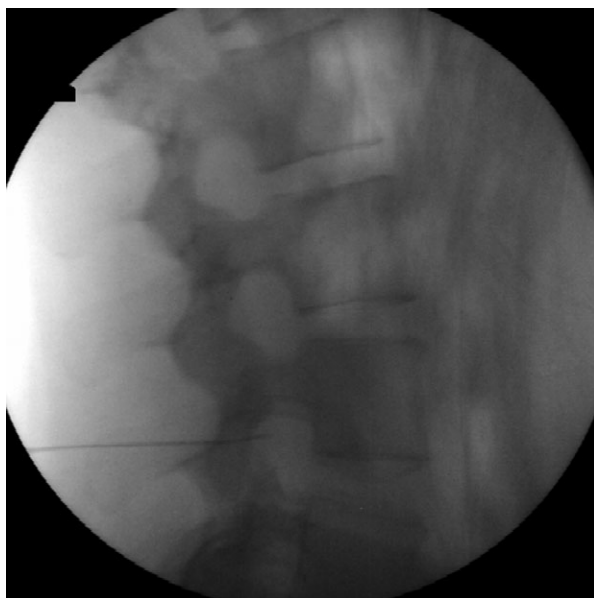


Image 4 Transforaminal approach, superior-posterior needle-tip position. Lateral view.

January 2009. We assessed contrast flow in a cohort of subjects undergoing TFESI as part of their routine course of care. Contrast spread was assessed as ventral (present/absent) and dorsal (present/absent), and the degree of ventral spread was assessed from 0–2 (0 = no ventral spread, 1 = ventral spread limited to spinal level of

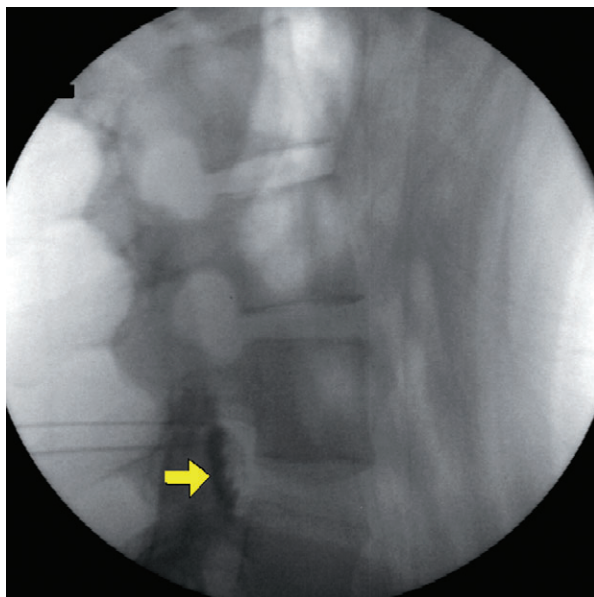


Image 5 Transforaminal approach, superior-posterior needle-tip position. Lateral view. Demonstrating dorsal flow at one vertebral level.

Epidural Contrast Flow Based on Final Needle Position

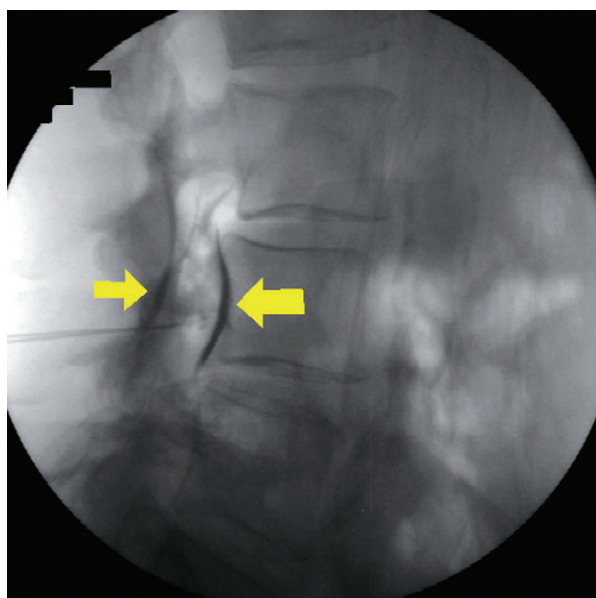


Image 6 Transforaminal approach, superior-posterior needle-tip position. Lateral view. Demonstrating ventral and dorsal flow at one vertebral level.

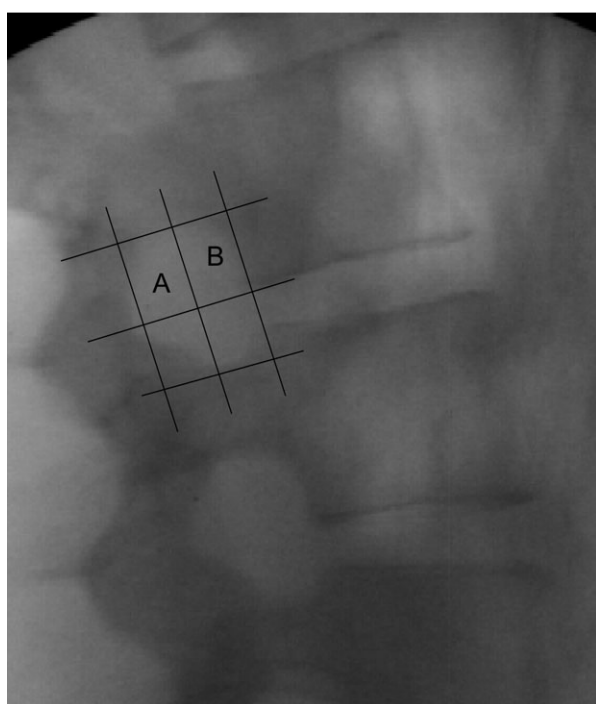


Image 7 Neural foramina—Lateral view. A = Superior-posterior; B = Superior-anterior.

entry, and 2 = ventral spread at >1 segmental level). The intervertebral level of the injection was also noted. Pre- and post-injection pain scores using the numerical rating scale (NRS) were also obtained. A post-injection score of 0–1 was defined as near-to-complete relief. This information was retrieved from the subjects' medical record devoid of any identifying information.

All injections were performed by an experienced, board-certified pain medicine physician (MJD) using bi-planar fluoroscopic imaging with non-ionic contrast. Continuous imaging was used during contrast injection in the AP and lateral planes to confirm that contrast did not spread to the intravascular, intradiscal, subarachnoid or subdural spaces. The injectate consisted of 1–2 mL of 40 mg/mL methylprednisolone acetate and 1–2 mL 1% lidocaine depending on the vertebral level(s) being injected. Injections were performed as per the routine standard of care.

Subjects were included if: their radiographic images were of suitable quality, they had at least 2 mL of contrast injected at the appropriate vertebral level, they had a history of lumbo-sacral radiculopathy, lumbar foraminal stenosis noted to be of disc-related etiology (16 subjects included), or lumbar herniated nucleus pulposus with leg > back pain, they had undergone a TFESI, and were 18 years or older.

Subjects were excluded if: data collection could not be completed via chart and radiographic review or if the subject had a primary diagnosis of lumbar spondylolisthesis, spinal stenosis, or previous lumbar surgery.

Analysis of Results

A total of 953 subjects underwent TFESIs between July 2007 and January 2009. Eight hundred seventy were excluded as summarized in Figure 1. The study ultimately considered 83 subjects having undergone lumbar TFESIs. Final needle-tip position was SA in 39/83 subjects and was SP in 44/83 subjects. The outcome measures were ventral and dorsal flow of contrast spreading in the epidural space and the proportions of subjects achieving near-to-complete pain relief, based on final needle-tip position (Tables 1 and 2, respectively). Fluoroscopic images were used to derive these measurements (AP and lateral views). Contrast flow was categorized below (Table 1). Dorsal spread was either present or absent. Ventral flow was first characterized as present or absent. If ventral flow was present, further delineation as to the number of levels and direction of spread was recorded.

Statistical testing was performed using Fischer's exact test. *P* values are recorded in the right column to demonstrate statistical significance at a level <0.05. One hundred percent of the subjects (39/39) in the SA needle-tip position demonstrated ventral flow compared with 61.4% (27/44) of the subjects with the SP position. The SA needle-tip position resulted in statistically significant greater ventral flow overall as compared with the SP needle-tip position ($P < 0.001$). Of the subjects with ventral flow, 41% (16/39)

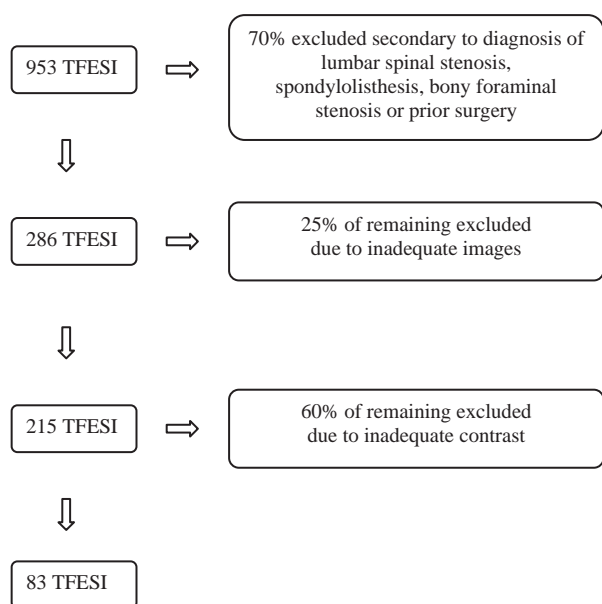


Figure 1 Exclusion flow chart. TFESI = trans-foraminal epidural steroid injection.

subjects demonstrated ventral flow to more than one level, whereas only 14.8% (4/27) of subjects in the SP demonstrated flow to more than one level. The SA needle-tip position resulted in flow to a higher number of vertebral levels than the SP needle-tip position, and this difference was found to be statistically significant ($P < 0.05$). In the SP group, 95.5% (42/44) of subjects demonstrated dorsal flow, while 43.6% (17/39) of the subjects in the SA group demonstrated dorsal flow. The SP needle-tip position resulted in greater dorsal flow, and this was found to be statistically significant ($P < 0.001$). There was no statistically significant difference in the direction of flow when anterior flow had spread to more than one vertebral level in any direction. Of the subjects in the SA needle-tip group, 12/31 subjects demonstrated near-to-complete relief. Meanwhile, 4/30 subjects in the posterior-anterior needle-tip group demonstrated near-to-complete relief ($P < 0.05$) with an odds ratio of 4.1 (95% CI = 1.01–

19.78). Of note, 8/31 subjects in the SA group demonstrated a NRS = 0. Four subjects reported a NRS ≤ 1 . Conversely, 3/30 in the SP group demonstrated NRS = 0. One subject reported a NRS ≤ 1 .

Secondarily, reduction in pain score post-injection relative to the pre-injection baseline was recorded using the NRS. Data was available for 61/83 subjects for whom contrast flow data was available, and therefore only they were included in the pain analysis. These subjects had follow-up appointments between 2–4 weeks post-injection. Of the subjects having undergone TFESI with the SA needle-tip position, the respective mean pre- and post-injection pain scores were 6.8 and 3.5, with a mean decrease of 3.3 (standard deviation [SD] = 2.66) points on the NRS. Of the subjects having undergone TFESI with the SP needle-tip position, the average pre- and post-injection scores were 5.9 and 4.4, respectively, with a mean pain score reduction of only 1.5 (SD = 2.59) points on the NRS. The SA position demonstrated a statistically significant greater reduction in pain score than the SP position ($P < 0.01$) (Table 3).

Discussion

The evolution of TFESIs has been precipitated by the need to optimize safety while demonstrating efficacy. Increasingly there are reports of catastrophic complications, including paraplegia, following TFESI [24]. This has placed an even greater burden on the clinician to prioritize safety, possibly at the expense of efficacy. This study offers some guidance regarding the efficacy of a generally well-tolerated and safe procedure. Inherently, there is an assumption that epidural flow should be reliable despite needle placement in a specific quadrant of the neural foramina. Several potential reasons exist for SP placement: accepting SP placement due to spinal nerve location high in the intervertebral foramen, particularly in the setting of foraminal stenosis or far lateral disc herniations, or avoidance of the SA position due to potential presence of radicular arteries. In some cases, there is a tendency for SP placement of the needle due to relative ease and the desire to avoid paresthesias. Consideration of which quadrant is to be utilized should occur for each patient,

Table 1 Comparison of contrast flow of SA vs SP position by vertebral level

Needle-Tip Position	Superior-Anterior	Superior-Posterior	P Value
Number	39/83 (47.0%)	44/83 (53.0%)	—
Dorsal spread	17/39 (43.6%)	42/44 (95.5%)	<0.001
Ventral spread (to any level)	39/39 (100.0%)	27/44 (61.4%)	<0.001
Ventral spread (to 1 level)	23/39 (59.0%)	23/27 (85.2%)	0.065
Ventral spread (to >1 level)	16/39 (41.0%)	4/27 (14.8%)	0.03
Ventral spread (>1 level cephalad)	14/16 (87.5%)	4/4 (100%)	1.000
Ventral spread (>1 level caudad)	1/16 (6.3%)	0	
Ventral spread (>1 level both directions)	1/16 (6.3%)	0	

SA = superior-anterior; SP = superior-posterior.

Epidural Contrast Flow Based on Final Needle Position

Table 2 Proportion of patients who achieved near-to-complete pain relief in the SA vs SP position

Needle-Tip Position	Proportion	P Value	Odds Ratio
Superior-anterior	12/31	<0.05	4.1
Superior-posterior	4/30		

SA = superior-anterior; SP = superior-posterior.

weighing that patient's specific anatomy and pathology and the current evidence to ultimately decide which quadrant will lead to optimal flow of injectate to the site of pathology.

TFESIs are typically performed for ventral epidural pathology, hence utilizing ventral contrast flow as a predictor of future injectate delivery should prove advantageous. Concerns regarding safety have prompted comparisons of far lateral ILESIs to TFESI with regards to ventral contrast flow and efficacy [20]. Candido et al. concluded superiority of lateral parasagittal ILESIs vs TFESI with regards to these parameters. This is inherently a flawed conclusion as this study in fact compared lateral parasagittal ILESIs with SP placement of TFESI. Furthermore, an assessment of images provided in that publication did not demonstrate ventral flow via lateral parasagittal ILESIs.

This analysis demonstrates the superiority of SA needle-tip position vs SP position with regards to ventral contrast flow. Furthermore, SA placement resulted in a greater number of levels with demonstrable flow suggesting an increased volume delivered ventrally. One hundred percent of SA placements resulted in ventral flow with 41% of those demonstrating flow to more than one level. On the other hand, despite 61.4% of SP placements resulting in ventral flow, only 14.8% were noted to deliver contrast to the greater than one level. Theoretically, achieving flow at a greater number of vertebral levels suggests superior coverage of the site of pathology in the ventral epidural space. The SP needle-tip position demonstrated greater posterior flow than the SA needle-tip position. Conceivably, for clinical scenarios with dorsal epidural disease or more generalized pathology, such as multifactorial spinal stenosis, this may be a more ideal placement.

We defined "success" as near-to-complete resolution of pain as defined by NRS ≤ 1 . This was determined by the

Table 3 Average pain score difference pre- and post-injection

Needle-Tip Position	Superior-Anterior	Superior-Posterior	P Value
Average difference in pain score	3.3	1.5	<0.01

subjective nature of reporting NRS and an anecdotal threshold to limit further injections in the immediate future. Subjects in the SA group were four times as likely as those in the SP group to demonstrate near-to-complete pain relief.

Given the pathology in the ventral epidural space, this may be an expected result.

Limitations of this study included its retrospective design. The study was also limited by the fact that it presents a snapshot of contrast flow. Dynamic testing following standing or other motions that incorporated gravity may result in shifting of contrast and ultimately injectate. However, dynamic testing would result in further exposure to radiation. This study simply suggests where the majority of contrast, and therefore injectate is delivered. Other limitations included uncontrolled concomitant therapies; however, we suspect that this would not result in undue variance due to a relatively standardized approach to patients with these diagnoses in our practice. No adverse events were identified during chart review as reported by patients undergoing TFESI that were included in our analysis.

Ultimately, the SA needle-tip position demonstrated superiority with regards to ventral contrast flow as well as pain relief. These findings contribute to the body of knowledge informing physician decision-making in performing TFESIs. There is a high degree of variability in the technique regarding epidural injections, and the standard of care is constantly changing as new methods are discovered and established methods are further delineated.

Conclusions

SA quadrant placement of TFESI results in significantly increased ventral contrast flow in comparison to SP placement. Furthermore, SA placement results in greater likelihood of near-to-complete pain relief. In the setting of suspected ventral pathology, the SA approach should be the technique of choice following considerations of other issues. Certainly, a prospective study assessing contrast flow with needle placement including all four quadrants should be considered in the effort to mitigate risk and evaluate efficacy.

Disclosures

The authors do not have any relevant disclosures.

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