Ultrasound-guided selective nerve root block versus fluoroscopy-guided interlaminar epidural block for the treatment of radicular pain in the lower cervical spine: a retrospective comparative study

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Abstract

Purpose Recent studies have compared the therapeutic efficacy and safety of the procedure using ultrasound and fluoroscopy. However, there are no published studies comparing the therapeutic efficacy and safety of fluoroscopy (FL)-guided cervical interlaminar epidural steroid injection (CIESI) with that of ultrasound (US)-guided selective nerve root block (SNRB). This study aimed to compare the mid-term effects and advantages of US-guided SNRB with FL-guided CIESI for radicular pain in the lower cervical spine through assessment of pain relief and functional improvement.

Methods Patients with radicular pain in the lower cervical spine who received US-guided SNRB ($n = 51$) or FL-guided CIESI ($n = 61$) were included in this retrospective study. All procedures were performed using FL or US. The complication frequencies during the procedures, adverse events, treatment effects, and functional improvement were compared at intervals of 1, 3, and 6 months after the last injection.

Results Both the neck disability index and verbal numeric scale showed improvements at 1, 3, and 6 months after the last injection in both groups, with no significant differences between groups ($p < 0.05$). Furthermore, the treatment success rate at all time points was not significantly different between groups. Logistic regression analysis revealed that the injection method (US- or FL-guided), sex, analgesic use, pain duration, number of injections, and age were not independent predictors of treatment success. Blood was aspirated before injection in 8% ($n = 5$) and 0% of patients in the FL-guided and US-guided groups, respectively. In seven patients of the FL-guided group, intravascular contrast spread was noted during injection.

Conclusions Our results suggest that, compared with FL-guided CIESI, US-guided SNRB requires a shorter administration duration while providing similar pain relief and functional improvements.

Keywords Ultrasound · Fluoroscopy · Injection · Cervical

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Background

Cervical interlaminar epidural steroid injections (CIESIs) have been used for conservative management of cervical radicular pain for many years [1–3]. The mechanisms of therapeutic benefit include the attributed reduction of mechanical or chemical inflammation and irritation [4]. CIESIs have been performed under fluoroscopic guidance with contrast media [5], as this can improve the accuracy of needle placement and medication delivery to targeted areas and reduce procedure-related complications [5–7]. However, major complications, including direct spinal cord injury due to needle trauma, spinal cord infarction, and epidural hematoma or abscess, have been reported, even with strict guidelines [5]. Furthermore, utilization of FL during a CIESI exposes the patient and physician to the risks of radiation.

Recently, various groups, including ours, have demonstrated the reliability of ultrasound (US) guidance for cervical selective nerve root blocks (SNRBs) [8–11]. Since the main advantage of US is the direct, real-time visualization of soft-tissue structures, it is particularly beneficial for cervical spine injections, where a multitude of vulnerable vessels and other vital soft-tissue structures are confined to a small area and are often in the path of the projected needle trajectory [12]. In addition, this broadly available method does not produce ionizing radiation [11]. Narouze et al. reported that US-guided cervical nerve root injections allowed the needle to approximate the targeted location within 5 mm [9], as in the previous study. Moreover, the US-guided approach was reported to be a safe procedure, since the blood vessels near the targeted area could be avoided with continuous visualization of the real-time images of the treatment site. Yamauchi et al. have reported on the improvement of symptoms both 24 h and 1 month after utilization of the US-guided approach [10].

Currently, a few studies comparing US- and FL-guided procedures have been published. Jee et al. compared the short-term treatment effects of US-guided cervical SNRBs and FL-guided cervical transforaminal (TF) epidural blocks and observed no significant differences between the groups [11].

In this study, the US-guided cervical SNRBs were compared with FL-guided CIESIs, which is unlike the previous studies because of the following reasons.

First, no studies have been published comparing the therapeutic efficacy and safety of FL-guided CIESIs with that of US-guided SNRBs. Second, as mentioned above, in the previous studies, two methods showed almost similar effects when compared with US-guided SNRB and FL-guided TF in terms of therapeutic efficacy and safety. There was no statistical difference, but intravascular

injection was less in the US-guided SNRB. Therefore, if the US-guided SNRB is superior to the FL-guided CIESI in terms of therapeutic effect and safety, the US-guided procedure can be recommended as a first-line method compared with the two methods (CIESI or TF) using FL for patients with cervical radicular pain.

Therefore, this retrospective comparative study aimed to evaluate the short-term pain and functional improvements following US-guided SNRBs in comparison to that following FL-guided CIESIs in the lower cervical spine. In addition, the safety of these methods was also assessed as the secondary outcome.

Methods

Study design

This study was a retrospective comparative review of chart data. Patient privacy and data confidentiality were maintained throughout the research process. The institutional review board of the corresponding author's affiliated university approved the study. The approval included a waiver of informed consent, because the study did not include direct contact with the study population, and all patient identifiers were removed from the data set on the initial collection.

Subjects

Potential study participants were patients who received a US-guided SNRB or FL-guided CIESI at our outpatient rehabilitation department between 2014 and 2016. On the day of the procedure, prior to injection, patients were asked to fill out self-assessment questionnaires regarding their baseline information (e.g., pain level, functional status, etc.). The electronic clinical records and questionnaire responses were retrospectively reviewed to gather data and determine compliance with the inclusion criteria.

We selected patients 18 years of age and older who received the US-guided SNRBs or FL-guided CIESIs for the treatment of lower cervical radicular pain that persisted for at least 3 months. Cervical radicular pain was diagnosed using clinical profiles, medical examinations, and confirmation of a herniated disk or spinal stenosis via cervical computed tomography or magnetic resonance imaging. All patients had not responded to conservative management, including analgesic use [nonsteroidal anti-inflammatory drugs (NSAIDs) or opioids] and physical therapy, performed for at least 4 weeks. Self-reported neck pain was at least five points on a verbal numeric scale (VNS), with symptoms present on most days for at least 3 months. The exclusion criteria included the presence of psychiatric disorders, neurological deficits, cervical myelopathy, laboratory results

suggestive of inflammatory disease or rheumatoid disorders, or a history of previous cervical spine surgery.

Injection methods

US-guided SNRBs and FL-guided CIESIs are common procedures used to treat symptomatic lower cervical radicular pain at our institution. The patient is provided with detailed information regarding the procedure and the expected benefits and risks, following which consent is obtained.

The procedures evaluated in our study were performed by two physicians (Y. Park and Y.W. Lee) with more than 7 years of experience performing the US- and FL-guided procedures. All treatments were performed as outpatient procedures.

For the US-guided SNRB, an Accuvix XQ® (Samsung Medison, Seoul, South Korea) with a linear probe set at 6–12 MHz was used [8–10]. With the patient in a supine position and their head externally rotated 30–40° away from the targeted area [10], the frontal cervical spine area, from the clavicle to the mandible, was adequately disinfected with povidone-iodine (Betadine), and an aseptic dressing was applied. The C5–7 nerve roots were identified via the US by the shape of the transverse processes; the C5th and C6th transverse processes both have obvious anterior and posterior tubercles, while the C7th transverse process has a rudimentary anterior and a prominent posterior tubercle [9–12]. The targeted transverse process was identified by slowly moving the probe in all directions using the seventh

cervical spine transverse process as the reference point (Fig. 1a, b). Optimal images of the nerve root, radicular artery, and the surrounding vessels near the border of the nerve root were obtained by probe manipulation and power-mode color Doppler (Fig. 1c). Subsequently, a 50 mm, 23G needle was inserted from the posterior and directed anteriorly toward the nerve root in the short-axis view using the in-plane approach with the free-hand technique. The tip of the needle was placed on the dorsal side of the nerve by cautiously avoiding possible damage to the deep cervical artery near the insertion site and locating the area away from the radicular artery [11]. One milliliter of 1% lidocaine was injected, and then, the patient was monitored for the onset of clinical manifestations, such as mid-neck and contralateral arm pain, a metallic taste, dizziness, tachycardia, full-body paresthesia, auditory changes, slurred speech, or motor ataxia, for 1–2 min [13]. After confirming the absence of abnormal findings and performing careful aspiration, 3 cc of the treatment drug, composed of 2 ml of dexamethasone (10 mg) and 1 ml of 0.5% lidocaine, was injected under the real-time US guidance (Fig. 1d).

For the FL-guided CIESIs, the patient was placed in the prone position. A pillow was placed under the patient's chest to elevate the shoulders, which helps to widen the interlaminar space by flexing the spine. All injections were performed using a C-arm (KMC 950, COMED, Gwangju, South Korea). The skin of the posterior neck was prepared and draped in a sterile fashion. The epidural space was entered between C5–C7 and T1. A 22G spinal needle (Spinocan®,

Fig. 1 Ultrasonography-guided selective nerve root block (target nerve root C6). **a** This figure shows the axial transverse ultrasound image of the C7th transverse process which has only one posterior tubercle. The arrow indicates vertebral artery. **b** Axial transverse ultrasound image showing the sharp anterior tubercle of the C6th transverse process. **c** Axial transverse ultrasound image with power-mode color Doppler shows arterial blood flow. The blood flow should be identified before steroid injection. **d** Needle (arrow) is placed on the dorsal surface of the C6 nerve root. C6 TP, C6th transverse process; C7 TP, C7th transverse process; C6, C6 nerve root; C7, C7 nerve root. AT anterior tubercle, PT posterior tubercle, TP transverse process

BRAUN, Melsungen, Germany) was then advanced into the posterior epidural space using a midline approach (Fig. 2a). If the needle was just posterior to the spinolaminar line in the lateral view, it was advanced very carefully by twisting it and opening the ligamentum flavum with intermittent injections of the non-ionic contrast agent (Omnipaque 300; GE Healthcare, Carrigtohill, Co., Cork, Ireland) until the contrast agent spread smoothly through the epidural space (Fig. 2b). Once the contrast material was spreading through the epidural space, advancement of the needle was ceased and confirmation that the needle tip was in the epidural space was achieved with an additional test injection of the contrast agent. Subsequently, 3 cc of the treatment drug, composed of 2 ml of dexamethasone (10 mg) and 1 ml 0.5% of lidocaine, was injected into the epidural space.

All patients received two consecutive therapeutic injections with a 2-week interval between injections. The second injection was proceeded with conditionally. If the initial injection resulted in a significant symptom reduction (VNS $\geq 50\%$), the second injection was not administered. If the patient experienced no pain relief, worsening of pain, or the patient satisfaction score was $\leq$ 'fair', a second injection was not considered. If the patient satisfaction score was 'good' despite improvement in the VNS score to $< 50\%$, a second injection was administered.

Since none of the patients had experienced any improvement using medications, such as analgesics (NSAIDs or opioid), or physical therapy for 4 weeks, we did not set any limitations for the continuation of previous exercise programs, drug therapy, or return to work. No specific physical therapy, occupational therapy, bracing, or other specific interventions were utilized.

Review of the clinical data

A standardized chart abstraction form was used to extract data pertaining to the demographics, treatments, pain severity, analgesic use, and functional assessments. Follow-up interviews were conducted during a hospital visit 1, 3, and 6 months after the last injection by nursing personnel that were not involved in the injection procedure.

Primary outcomes included the neck disability index (NDI) and VNS scores for pain, which were recorded prior to the first injection and 1, 3, and 6 months after the last injection. The degree of physical disability was measured using the NDI, which is the most widely used questionnaire assessing cervical spine abnormalities. The NDI was first developed to evaluate the degree of limitations in the daily lives of patients with severe cervical pain, particularly those with whiplash trauma [14]. It consists of ten questions, with seven questions related to functional activity, two related to symptoms, and one related to concentration [14]. The final score is obtained by adding the scores for all questions. A higher NDI score indicates increased functional disability related to cervical abnormality. The original developer, Howard Vernon, suggested score interpretation as follows: ≤ 4 no disability; 5–14 mild disability; 15–24 moderate disability; 25–34 severe disability; ≥ 35 complete disability [14]. To obtain the VNS scores, the patients were asked to rate their pain on a scale from 0 to 10, where 0 and 10 represented no pain and the worst pain possible, respectively. Scores were assigned as whole numbers with 11 integers, including zero [15].

The patient satisfaction scores were measured using a 5-grade scale (< 0 no effect at all; 1 bad; 2 fair; 3 good; ≥ 4

Fig. 2 C5–6 interlaminar epidural injection. **a** A–P view. **b** Lateral view of the contrast media which spreads into the epidural space. The arrow indicates a needle

excellent) 2 weeks after the first injection. A score of ‘excellent’ meant that the patient was ‘satisfied with the treatment result as expected’; ‘good’ meant ‘not as effective as expected, but willing to try this treatment again when pain redevelops’; ‘fair’ meant ‘had some effect, but not enough to choose the same treatment again when pain redevelops’; finally, ‘bad’ meant ‘the same effect as previous treatment or worse’ [11].

A “responder” to the injection was defined as a patient experiencing > 50% improvement in their VNS score and > 40% improvement in their NDI score [14, 15]. A non-responder was considered to be a patient who failed to meet the criteria or for re-injection, spinal invasive procedure, and operation during the follow-up period after injection.

Patients who failed to meet these criteria or who, subsequent to undergoing SNRB or FL-guided CIESI, underwent an invasive procedure during a follow-up period, were considered to have failed the treatment.

Their VNS and NDI scores were recorded for statistical analysis and subsequently excluded. Independent variables, including the injection method, number of injections, analgesic use, pain duration, sex, and age, were documented in the medical charts. Age was classified into five groups as follows: < 39, 40–49, 50–59, 60–69, and > 70 years.

The administration duration was also recorded. For US-guided SNRB, the administration duration was defined as the time interval from when the US probe contacted the patient’s skin to the completion of the injection [16, 17]. For FL-guided CIESI, the administration duration was defined as the time interval between obtaining the first radiographic image and the end of the second injection [16, 17].

Finally, we reviewed the charts for immediate adverse events, such as vasovagal reaction, facial flushing, or brief, and severe neck pain within a few minutes following the injection. Each patient was given a questionnaire at the end of the procedure, which they had to complete within 48 h after the procedure and return at the 2-week follow-up visit.

Statistical analysis

The Pearson’s Chi-square and Wilcoxon’s rank-sum tests were used to compare the characteristics of the two groups with regard to the variables of sex, age, body mass index (BMI), number of injections, analgesic use, and pain duration. At each time point (before the first injection and 1, 3, and 6 months after the last injection), the VNS and NDI scores were compared by repeated-measures analysis of variance (ANOVA) with Bonferroni’s correction for post hoc comparisons. Pearson’s Chi-square test was used to test the differences in proportions. Wilcoxon’s rank-sum test was used to compare the two groups with regard to the administration duration and number of needle passes. Univariate and multivariate logistic regression analyses with Pearson’s

Chi-square test were performed to assess whether the age, sex, analgesic use, injection method, and number of injections were independent predictors of treatment success. All statistical analyses were performed using SAS Enterprise Guide 4.1.0.471 (SAS Institute Inc., Cary, NC, USA). A *p* value of < 0.05 was considered statistically significant.

Results

Of the 202 injections, including 83 US-guided and 119 FL-guided procedures, administered during the study period, a total of 112 (55%) met the inclusion criteria. Seventy-two (36%) patients were excluded, because they did not complete and return the follow-up surveys. Another 19 (9%) patients were excluded because of the exclusion criteria: 16 for having undergone the previous operations, and 3 for having underlying rheumatoid arthritis (RA). Ultimately, 61 and 51 patients received US-guided and FL-guided procedures, respectively (Fig. 3).

The average age of the patients in the US-guided and FL-guided groups was 53.5 ± 10.9 and 53.5 ± 10.8 years, respectively, with no significant difference observed between the groups. Moreover, there were no significant differences in sex, BMI, pain duration, analgesic use, and the number of injections between groups (Table 1).

The NDI and VNS scores showed a significant improvement at 1, 3, and 6 months after the last injection in both groups, with no significant differences between groups at baseline and at 1, 3, and 6 months after the last injection (Table 2). One month after the injection, nine patients had received repeat injections and one had undergone surgery in the US-guided group. Thus, the 1-month treatment success rate was 80% ($n=41$) in the US-guided group. Meanwhile, 11 patients had received repeat injections and two had undergone surgery by the 1-month follow-up in the FL-guided group. Thus, the 1-month treatment success rate was 77% ($n=48$) in the FL-guided group. At 3 months, seven and nine patients had received repeat injections in the US-guided and FL-guided groups, respectively, resulting in treatment success rates of 67% ($n=34$) and 64% ($n=39$), respectively. Finally, at 6 months, four patients had received repeat injections and one had undergone surgery in the US-guided group, and three patients had received repeat injections and three had undergone surgery in the FL-guided group, resulting in response to treatment rates of 57% ($n=29$) and 53% ($n=33$), respectively (Fig. 4). There were no significant differences in the success rates at any time point between the two groups. There was no clinically significant reduction in the percentage of analgesic (NSAIDs and opioids) users in the two groups 6 months after receiving the therapeutic injections. The proportions of patients with > 50% improvement in the VNS score and > 40% improvement in the NDI

Fig. 3 Flow diagram indicates the progress of patients through the study. *US* ultrasonography, *FL* fluoroscopy, *SNRB* selective nerve root block, *CIESI* cervical interlaminar epidural steroid injection

score are illustrated in Fig. 2. The rates at 6 months were 57% and 54% in the US-guided and FL-guided groups, respectively. There were no significant differences at any time point between the two groups.

Univariate and multivariate logistic regression analyses revealed that the age, sex, pain duration, analgesic use, injection method, pain duration, and number of injections were not independent predictors of treatment success ($p > 0.05$; Tables 3 and 4). The administration duration (212 s vs. 368 s) was significantly smaller in the US-guided group than in the FL-guided group ($p < 0.001$).

Immediately after the procedure, four patients in the US-guided group and three in the FL-guided group experienced

vasovagal episodes, while four and three patients, respectively, developed transient headache ($p > 0.05$). Overall, at the 2-week follow-up session, three patients in the US-guided group and four in the FL-guided group reported transient pain exacerbation (in the head or upper limbs) 48 h after the procedure. No patients reported experiencing a headache suggestive of post-puncture syndrome. No cases of infection or hematoma were recorded during the 2-week period following the procedure. Blood was aspirated before injection in 8% ($n = 5$) and 0% of the patients in the FL-guided and US-guided groups, respectively. In seven patients of the FL-guided group, intravascular contrast spread was noted during injection.

Table 1 General characteristics of the patients

	US-guided SNRB (<i>n</i> = 51)	FL-guided CIESI (<i>n</i> = 61)	<i>p</i> value
Age (year)	53.5 ± 10.9	53.5 ± 10.8	0.979
Sex, <i>n</i> (%)			
Female	39 (76.5%)	43 (70.5%)	0.526
Male	12 (23.5%)	18 (29.5%)	
BMI (kg/m ²)	24.71 ± 3.00	25.64 ± 2.64	0.090
Number of injections	1.55 ± 0.50	1.57 ± 0.49	0.793
Etiology, <i>n</i> (%)			
HCD	15 (29.4%)	19 (31.1%)	0.842
Stenosis	36 (70.6%)	42 (68.9%)	
Target nerve root, <i>n</i> (%)			
C5	8 (15.7%)	6 (9.8%)	0.482
C6	29 (56.9%)	41 (67.2%)	
C7	14 (27.5%)	14 (23.0%)	
Analgesic use, <i>n</i> (%)			
NSAID usage	26 (51.0)	25 (49.0)	0.343
Opioid usage	25 (49.0)	28 (45.9)	0.850
Pain duration (month)	5.88 ± 2.51	6.34 ± 2.47	0.358

Values are presented as mean ± standard deviation for continuous data
US ultrasonography, *FL* fluoroscopy, *SNRB* selective nerve root block, *CIESI* cervical interlaminar epidural steroid injection, *n* number, *BMI* body mass index, *HCD* herniated cervical disk, *NSAID* non-steroidal anti-inflammatory drugs

Discussion

This retrospective study assessing the treatment effects of US-guided SNRB vs. FL-guided CIESI showed clinically meaningful and significant improvements across all parameters at the end of a mid-term period of 6 months after the last injection; the treatment success rates were 57% and 54% in the US-guided and FL-guided groups, respectively. The treatment success rates showed no

significant differences between the groups at 1, 3, and 6 months after the last injection. However, the US-guided SNRB group required a shorter administration duration compared with the FL-guided CIESI. We speculate that the greater efficiency provided by US guidance stems from the inherent difficulties related to FL. Pain control and functional improvements were similar with US-guided SNRB and FL-guided CIESI. To the best of our knowledge, this study is the first to compare treatment efficacy and injection efficiency with regard to the administration duration between US-guided SNRB and FL-guided CIESI over a 6-month follow-up period in patients with radicular pain in the lower cervical spine.

Although FL-guided CIESI is a widely known standard procedure, a variety of complications have been reported. These include inadvertent dural puncture, subdural or epidural hematoma, epidural abscess, paralysis, permanent spinal cord injury, and death [18]. The causes of permanent spinal cord injury were the result of inadvertent spinal cord irritation from excess sedation, bleeding, epidural hematoma, or abscess [18, 19]. Several previous studies on US-guided SNRB reported only temporary minor complications similar to that of CIESI procedures and an absence of major complications including spinal cord or brain infarction, paralysis, infection, and death [11, 20]. However, these results are limited owing to the small number of studies, thereby requiring further studies to determine the degree to which complications occur in relation to CIESI procedures.

Intravascular injection symptoms were not identified during the US-guided SNRBs whereas five cases were identified with the FL-guided approach, though no significant difference between the groups was noted. The intravascular injection rate for CIESI is unknown [21]. Observation of backflow of blood into the needle hub or positive aspiration of blood has been reported to be less than 50% sensitive [22]. FL-guided procedures allow the injection of a contrast medium to verify the correct spread of the injectate in the cervical epidural space and to avoid intravascular or intrathecal injection [23]. However, FL-guided CIESI does

Table 2 Comparison of VNS and NDI from baseline to 1, 3, and 6 months after the last injection

	Baseline	1 month	3 months	6 months
VNS				
US-guided SNRB	6.43 ± 0.97	2.06 ± 1.03*	2.54 ± 1.61*	2.81 ± 1.62*
FL-guided CIESI	6.24 ± 0.86	2.16 ± 1.33*	2.63 ± 1.54*	2.46 ± 1.22*
NDI				
US-guided SNRB	24.76 ± 5.39	11.47 ± 6.08*	11.83 ± 5.36*	12.59 ± 3.64*
FL-guided CIESI	23.44 ± 4.38	11.33 ± 4.84*	11.98 ± 4.92*	12.90 ± 5.90*

Values are presented as mean ± standard deviation for continuous data

VNS verbal numeric pain scale, NDI neck disability index, *US* ultrasonography, *FL* fluoroscopy, *SNRB* selective nerve root block, *CIESI* cervical interlaminar epidural steroid injection

**p* < 0.05; comparison of each variable at a specific time point with that of baseline

Fig. 4 Illustration of the proportion of patients with a significant pain relief ($\geq 50\%$ reduction in verbal numeric pain scale from baseline) and functional improvement ($\geq 40\%$ reduction in neck disability index from baseline). A group, ultrasonography-guided selective nerve root block; B group, fluoroscopy-guided interlaminar epidural steroid injection

Table 3 Univariable analysis for possible outcome predictors of effectiveness in injection at follow-up

Characteristic	Responders (<i>n</i> = 62)	Non-responders (<i>n</i> = 50)	<i>p</i> value
Injection method, <i>n</i> (%)			
Ultrasonography	29 (46.8)	22 (44.0)	0.849
Fluoroscopy	33 (53.2)	28 (56.0)	
Etiology, <i>n</i> (%)			
HCD	18 (29)	16 (32)	0.734
Stenosis	44 (71)	34 (68)	
Pain duration (month)			
< 6	29 (46.8%)	20 (40.0%)	0.586
> 6	33 (53.2%)	30 (60.0%)	
Sex, <i>n</i> (%)			
Female	44 (71.0)	38 (76.0)	0.669
Male	18 (29.0)	12 (24.0)	
Age, <i>n</i> (%)			
≤ 39	6 (9.7)	5 (10.0)	0.986
40–49	18 (29.0)	14 (28.0)	
50–59	21 (33.9)	15 (30.0)	
60–69	12 (19.4)	11 (22.0)	
> 70	5 (8.1)	5 (10.0)	
Number of injections, <i>n</i> (%)			
1	29 (46.8)	20 (40.0)	0.721
2	33 (53.2)	30 (60.0)	
Analgesic use, <i>n</i> (%)			
NSAID usage	30 (48.4)	21 (42.0)	0.569
Opioid usage	32 (51.6)	21 (42.0)	0.345

n number, HCD herniated cervical disk, NSAID nonsteroidal anti-inflammatory drugs

Table 4 Multiple logistic regression analysis for possible outcome predictors of effectiveness in injection at follow-up

Factor	OR	95% CI	p value
US vs. FL-guided method	0.912	0.424–1.961	0.813
Cause (HCD, stenosis)	1.187	0.381–1.523	0.682
Sex	1.523	0.622–3.725	0.357
Age	1.012	0.976–1.050	0.511
Opioid	0.634	0.293–1.372	0.247
NSAID	0.787	0.364–1.699	0.541
Pain duration	1.382	0.630–3.033	0.420

OR odds ratio, CI confidence interval, US ultrasonography, FL fluoroscopy, HCD herniated cervical disk, NSAID nonsteroidal anti-inflammatory drugs

not diminish the false-positive injection rate on the first attempt [24]. Although intermittent fluoroscopic imaging can be used to demonstrate epidural flow of the injectate, both epidural flow and vascular uptake can occur simultaneously [25]. In such cases, an image obtained after vascular runoff of the contrast medium would potentially not detect vascular placement [25]. No previous prospective or retrospective studies have compared the false-positive injection rate in the cervical region when contrast is used [24].

The main advantage of the US approach is the real-time visualization of vulnerable vessels and other vital soft tissue in the path of the projected needle trajectory [11]. Narouze et al. published a report regarding two major vessels on the frontal and posterior side of the foramen in six patients imaged with a color Doppler during a procedure [9]. A different study reported that more than 20% (21 of 95) of the subjects under investigation had either an ascending or deep cervical artery, or a large branch within 2 mm of the needle's pathway for the cervical transforaminal procedure [26]. One-third of these vessels were spinal branches that entered the foramen posteriorly, potentially forming a radicular or segmental feeder vessel to the spinal cord [26]. According to the study conducted by Jee et al. on US-guided SNRB, a deep cervical artery was observed in the posterior foramen in 4 out of 55 patients [11]. In all cases, the vessels were located in areas vulnerable to needle-related damage using FL guidance [9, 11].

Although US may assist in avoiding intravascular injection, it is not clear if it can help to detect such injections [11]. The aforementioned study's results are inadequate to validate the safety of the US-guided approach compared with that of the FL-guided approach, because it was a single-center study with a small sample size, having only one highly experienced sonographer. Therefore, not detecting critical vessels with US does not necessarily ensure the absence of these vessels [27].

To prevent complications associated with intravascular injections, two approaches can be used. First, an injection

of a non-particulate steroid agent must be used as a preventive method, since the microvessels which may induce neurological damage cannot be identified with ultrasound alone. Tiso et al. recommended small-particle dexamethasone or betamethasone, since methylprednisolone and triamcinolone particles tend to coalesce into larger aggregates far in excess of 100 μm , thus increasing their embolic potential [28]. Derby et al. also reported that arterial or capillary obstruction should be avoided during inadvertent injection into the artery due to the size of the dexamethasone sodium phosphate particles, which is one-tenth of the size of red blood cells [29]. Second, an anesthetic test dose can be used prior to injection of any particulate steroids. Smuck et al. recommended using 1 cc of 1% lidocaine as the anesthetic test dose to prevent intravascular injection during transforaminal injection procedures [13]. The rate of positive findings indicating intravascular injection was 0.56% during test dose injections [30]. One cc of 1% lidocaine was used as the test dose prior to the drug injections in the present study. The patients were monitored for any unusual reactions for 1–2 min after the test dose injections before proceeding with the actual treatment injections [11, 20]. The test dose method was applied during both the procedures to prevent possible intravascular injection [11, 20], and the positive findings of intravascular injection were not observed.

The target point of the US-guided SNRB is the distal neural foramen [11, 20]. Jee et al. reported that only about 30% of the injections produced the typical epidural spread [11]. Therefore, if an insufficient volume reaches the target lesion, the effect of injection will not be sufficient. However, despite the differences of the injection targets and the spread pattern of the contrast media, some previous studies that compared the efficacy of the FL-guided procedure with that of the US-guided SNRB reported that no significant differences in the patient satisfaction score, pain reduction, and functional improvement during the 12-month follow-up period were observed [20]. Such results could be explained by several hypotheses. First, Yamauchi et al. explained that such results occur due to hydrostatic pressure and osmotic effects [10]; in that, such mechanisms may enable the solution to be absorbed further into the nerve fiber. In other words, the intracellular fluid flow may have pushed the local anesthetics and steroids toward the central lesion, the site of possible nerve root compression, or inflammation. Second, the differences in viscosity of the drug and contrast medium could also support the findings [11]. Jee et al. reported that spread of the contrast media into the intraforaminal epidural space was observed by comparing the anteroposterior images taken after the contrast media injections with the washout images taken after the drug injections in 25 patients [11]. The observation of the contrast media (Omnipaque) in the intraspinal epidural area post-washout, despite its comparative highly viscous nature [31], could be explained by the injected drug

(1 ml of 0.5% lidocaine + 1 mg of dexamethasone) [11]. The injected drug, with its low viscosity, may have diluted the contrast media, including further spread into the targeted area [11]. Such a phenomenon may explain the proximal delivery of the drug to the lesion, resulting in higher efficacy [11, 20].

According to the existing data, the long-term efficacy of TFESI is greater than that of ILESI [32]. Nonetheless, there are conflicting data regarding the benefits common to both these methods [32, 33]. A recent systematic review revealed that the efficacy of these two techniques, in terms of improvement in functionality and pain relief, is not significantly different, despite the respective risks of each [35]. Both methods have the potential for catastrophic complications. Whether one technique is safer than another is unknown [34]. US-guided SNRB does not expose the patients or clinician to radiation, and the imaging can be performed continuously during the injection. In addition, it can be injected without causing injury to aberrant vessels [11, 20]. In terms of treatment effect, comparison between the US-guided SNRB and FL-guided TFESI showed no difference in efficacy [11, 20]. In this study, no difference in outcomes was found 6 months after the injections when US-guided SNRB and FL-ILESI were compared as treatment options. US-guided SNRB, when compared with FL-guided CIESI, is considered to be a better treatment option for lower cervical radicular pain given its lower risk of complication and that there is no radiation exposure; this is backed by the literature, including this study.

In conclusion, the US-guided SNRB may be superior to the two FL-guided methods in terms of therapeutic effect, safety, and shorter procedure time. Therefore, it is considered to be the most preferred treatment for lower cervical radicular pain. However, large-scale multicenter prospective studies are required to compare the efficacy of the three approaches.

Limitations of the study

The present study had several limitations. First, this study was retrospective in design. Although we selected the patients using the extensive inclusion and exclusion criteria described in the “Methods”, there could still have been heterogeneity among the patients included in this study. However, these shortcomings are limited because of the standardization of the patient demographics, as well as the clinical and imaging parameters before treatment and at each follow-up visit in the case records of the patients undergoing injection at our institution. In addition, we could not entirely exclude from our study patient participation in other treatments, such as medications or physical therapy during the follow-up periods. Second, whether or not the injectate was properly injected into the targeted area during

US-guided SNRB was not verified with FL. This method may have affected the results. Third, the treatment procedures were conducted by the same physician. Therefore, the study's results may have reflected the experience of one practitioner, which may have limited the generalization of the study's findings. Additional studies may be required with the improved limitations in the future.

Conclusions

The US-guided SNRBs had similar treatment outcomes for pain reduction and functional improvements to that of the FL-guided CIESIs, but they lacked the associated risks of radiation exposure. In addition, intravascular injections were only observed in (seven) patients who underwent the FL-guided CIESIs. Therefore, given the data obtained in our retrospective study, US-guided SNRB is deserving of consideration for the conservative management of lower cervical radicular pain. In addition, the US-guided SNRB may enable the identification of atypical vessels at unexpected locations proximal to the intervertebral foramen, thereby avoiding injury. Although these advantages may support the stability of the US approach, confirmation of the absence of critical vessels that are small in size may still be impossible with the current US technology. Despite real-time monitoring of the injections, US may not reliably detect microscopic intravascular injections that may lead to neurological injury. Therefore, applications of the lidocaine test and non-particulate steroids are recommended to support the US-guided approach.

Compliance with ethical standards

Conflict of interest The authors have no conflict of interest for this study.

Ethical statement Procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent This study was a retrospective comparative review of chart data. Patient privacy and data confidentiality were maintained throughout the research process. The institutional review board of the corresponding author's affiliated university approved the study. The approval included a waiver of informed consent, because the study did not include direct contact with the study population, and all patient identifiers were removed from the data set on the initial collection.

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