Feasibility of Ultrasound-Guided Lumbar and S1 Nerve Root Block: A Cadaver Study

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Objective: This study evaluated the feasibility of ultrasound-guided lumbar nerve root block (LNRB) and S1 nerve root block by identifying spread patterns via fluoroscopy in cadavers. Method: A total of 48 ultrasound-guided injections were performed in 4 fresh cadavers from L1 to S1 roots. The target point of LNRB was the midpoint between the lower border of the transverse process and the facet joint at each level. The target point of S1 nerve root block was the S1 foramen, which can be visualized between the median sacral crest and the posterior superior iliac spine, below the L5-S1 facet joint. The injection was performed via an in-plane approach under real-time axial view ultrasound guidance. Fluoroscopic validation was performed after the injection of 2 cc of contrast agent. Results: The needle placements were correct in all injections. Fluoroscopy confirmed an intra-foraminal contrast spreading pattern following 41 of the 48 injections (85.4%). The other 7 injections (14.6%) yielded typical neurograms, but also resulted in extra-foraminal patterns that occurred evenly in each nerve root, including S1. Conclusion: Ultrasound-guided injection may be an option for the delivery of injectate into the S1 nerve root, as well as lumbar nerve root area. (Clinical Pain 2019;18:59-64)

Key Words: Ultrasonography, Spinal injection, Lumbosacral Region, Spinal roots

INTRODUCTION

With advances in technology, imaging tools, such as magnetic resonance imaging, computed tomography (CT), and neuromuscular ultrasound, now provide higher-resolution and clearer images in the medical field. Ultrasound-guided injection is now attracting much attention from clinicians managing spinal pain.1-6 In cervical spinal interventions, ultrasound-guided techniques can ‘prevent’ intravascular injections, whereas fluoroscopy-guided procedures can ‘detect’ intravascular injections.7,8 In addition, ultrasound-based procedures do not entail radiation exposure and can be performed in a relatively small space, and with relatively little manpower.9

Using ultrasound, it is more difficult to obtain clear images in the lumbar area compared to cervical area because the spine is located relatively deeply, especially in obese patients. In an ultrasound-guided facet joint injection study, the accuracy of the procedure in an obese group with body mass indexes (BMI) of over 30 kg/m² was reportedly reduced to 62%.10 However, in non-obese patients, ultrasound-guided paravertebral procedures are reportedly associated with good accuracy and efficiency in the spinal area.12,5,9,11-16

Because the lumbar nerve root is located deeper than the target point of the facet and medial bundle branch, it is harder to perform ultrasound-guided injection at that site. Thus, the technique, and the feasibility and efficacy of ultrasound-guided lumbar nerve root block (LNRB) have not been well characterized, and most relevant studies were reported after 2011.14,17-19 Notably, the approaches used differ from study to study, including axial, paramedian sagittal, and paramedian sagittal oblique approaches and had several limitations. In a cadaver study reported by Gofeld et al.2 in 2011, the feasibility was good with a 91.3% intra-fora-
ternal contrast spread pattern, and needle placement in the ultrasound-guided procedure was correct in all cases (100%). In a prospective randomized clinical trial reported by Yang et al.,\textsuperscript{17} ultrasound-guided lumbar transforaminal epidural injections yielded an 85% success rate and shorter operation times than a fluoroscopy-guided procedure (518 s vs. 929 s). In another study, compared with a CT-guided technique, ultrasound-guided pararadicular injections also yielded good accuracy (90%) and shorter operation times (4.0 min vs. 7.6 min), and entailed less radiation.\textsuperscript{14} However, in those studies, the injection point was not clear (just described as the most medially visible shadow of the vertebral body between two adjacent transverse process)\textsuperscript{3} or the injection was performed in limited levels (L3~4 and L4~5).\textsuperscript{17} In addition, there has only been one case report of ultrasound-guided S1 root injection.\textsuperscript{20}

Therefore, it would be meaningful to confirm the feasibility of ultrasound-guided LNRB and S1 root injection in a study incorporating a clear description of the approach utilized. This study evaluated the feasibility of lumbar nerve root and S1 root injection using fluoroscopic confirmation.

**MATERIALS AND METHODS**

This study was performed in accordance with the Declaration of Helsinki. This study was approved by the institutional review board. A total of 48 ultrasound-guided injections (L1 to S1, bilateral) were performed on 4 unembalmed cadavers who had no history of lumbar spine surgery (2 males and 2 females, mean age 79.7 years, and BMI 23.8 kg/m\textsuperscript{2}). An Accuvix XG ultrasound system (Medison Co, Seoul, Korea) equipped with a 2~7 MHz curved-array transducer was used for all procedures. The same operator performed all procedures. The cadaver was placed in a prone position with slight lumbar flexion using a soft pillow.

First, the transducer was positioned on the midpoint between the bilateral iliac crest with a transverse scan to the lumbar vertebra axis, then moved caudally until the sacrum and sacral foramen were visualized. Subsequently, the probe was moved cephalad to find the L5~S1 facet joint and L5 transverse process (Supplementary Video 1). The facet joint and the transverse process at each vertebra level appear sequentially as the probe was moved to the cephalic direction. After slightly moving the probe laterally to place the facet joint in the center of the view, the target level was

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**Fig. 1.** Schematic view for needle insertion. (A) At the level of the lower margin of the L5 transverse process. (B) L5~S1 facet joint was identified between the inferior articular process (filled arrow) and the superior articular process (unfilled arrow). (C) L5 nerve root injection. The target point level was identified as the mid-point between (A) and (B) cephalocaudally. The target depth was showed as the lower half between the lateral border of the L5 lamina (filled arrowhead) and the most medial border of the vertebral body (unfilled arrowhead). Arrow shows the needle approaching (D) S1 foramen (\textsuperscript{\#}) are shown bilaterally. Arrow shows the needle approaching. IC: iliac crest, S: spinous process, T: transverse process.
Table 1. Ultrasound-Guided Injection into Lumbar and S1 Roots (n = 48)

<table>
<thead>
<tr>
<th></th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>S1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra-foraminal spread</td>
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<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Intra-foraminal spread</td>
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<td>6</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Ventral spread only</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Ventral and dorsal spread</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Total: 7/48 (14.6%) for Extra-foraminal spread, 41/48 (85.4%) for Intra-foraminal spread.
dorsal sides. Seven of 48 cases (14.6%) revealed extra-foraminal spreading patterns, and it occurred evenly in each nerve root, including S1 (Table 1). Two of 48 cases (4.2%) showed intravascular injection.

**DISCUSSION**

This study is the first to show ultrasound-guided S1 nerve root injection procedure with fluoroscopy confirmation with high success rate (7 of 8, 87.5%). Also, it also validated the feasibility of ultrasound guided lumbar nerve roots (L1 to L5) injections, with similar overall rate of success (41 of 48, 85.4%) compared to previously reported studies (85~100%). In this study, all injections yielded typical neurograms. The rate of intra-foraminal contrast agent spreading (85.4%) was similar to that reported in previous studies (85~100%), including S1 root injection.2,14,17-19

Also, the procedure was performed using an in-plane approach with axial imaging, similar to that described by Gofeld et al.7 In contrast, Kim et al.18 and Loizides et al.19 have suggested a paramedian approach using sagittal imaging. In axial imaging, which is used method in this study, the visualization of structures deeper than the transverse process level is clearer than it is in sagittal imaging. Also, identification of the vertebral body is difficult and visualization of the needle tip also becomes harder when the needle tip advances deeper than transverse process level in sagittal imaging. In our opinion, an axial imaging approach can usually provide clearer visualization of the needle tip during the procedure and would be a more appropriate approach to maximize the advantages of the ultrasound-guided procedure with the exception of L5 root injection. In L5 root injection, visualization at vertebral body level is frequently difficult in both an axial and a sagittal view. In such cases in this study, the target depth was estimated from the lateral margin of the L5 lamina to be the same depth from the L4 level, and tried to keep the needle tip visible. To keep the needle tip visible during ultrasound-guided injection, the target point in this study was slightly shallower than that reported in previous studies. Previous studies have targeted the ventral area of the intervertebral foramen.2,18 The different target depths in this study may have caused a slightly lower intra-foraminal contrast agent spreading rate (85.4% in our study, 87.5% in Kim et al.,18 91.3% in Gofeld et al.7) and higher dorsal spreading pattern (7 of 48 in our study, 1 of 35 in Kim et al.,18 0 of 42 in Gofeld et al.7). Because sonoanatomy differs from patient to patient, especially in patients with scoliosis or spondylolisthesis, the target point should be adjusted based on each individual patient’s condition and the operator’s preference. The results of this study may be helpful when deciding on the injection target point.

Several techniques can be used to perform a spinal injection, such as the blind technique, CT-guided injection, fluoroscopy-guided injection, and ultrasound-guided injection. Each technique has associated benefits. With fluoroscopy-guided injections, the clinician can confirm the dye spreading pattern. For example, intra-foraminal, which imply that the contrast spread to epidural space at the level of posterior longitudinal ligament area, and extra-foraminal, spreading along the distal nerve root. This confirmation may be important when developing the subsequent treatment plan. In our opinion, the most important benefit of ultrasound-guided injection in spinal procedures is that it can provide real-time visualization of the tissue surrounding the needle tip, particularly arteries with the Doppler mode. Due to this advantage, ultrasound-guided injection may facilitate the prevention of intra-arterial injections. In this study, there were two intravascular contrast spreading patterns because the present study was performed in unembalmed cadavers; therefore, the vessels were not examined with the Doppler mode. In living patients, Doppler imaging can efficiently provide relevant information about vessels around the lumbosacral spine.20 Notably, ultrasound-guided injection has the disadvantage that clearly confirming the cephalocaudal spread pattern of contrast agent in the epidural space is difficult via the procedure, while it is possible with fluoroscopy-guided injection. In a previous study, which investigated ultrasound-guided cervical root injection, a crescent pattern of contrast agent spreading in the ultrasound image was related to peri-radicular contrast spreading in fluoroscopy, and was associated with significantly better outcomes with regard to cervical radicular pain reduction.21 However, in the lumbar area the resolution and quality of ultrasound imaging is lower than it is in the cervical area. Thus, the local spreading pattern could not be identified clearly in the lumbar area. When confirming the spreading pattern is more important, fluoroscopy-guided injection would be advantageous.
The visualization of the lumbar structure was clear in this study because the body mass index of the cadaver was within a normal range and there was no definite spinal deformity (e.g., scoliosis, spondylolisthesis, or sacralization). The ultrasound guided lumbar medial branch block in obese patients (BMI > 30 kg/m²) was successful in only 62% of cases,⁹ even though the target point of the medial branch block was located superficially compared to that of ultrasound-guided LNRB. This imply that ultrasound guided lumbar root injection may be more difficult to perform in obese subjects. Also, if the patient undergoing ultrasound-guided LNRB is believed to have a severe spinal deformity, the results of other imaging studies, such as X-ray, should be checked to specify the exact target level.

Identifying vessels using Doppler ultrasound is an important benefit in ultrasound-guided injection. High frequency ultrasound can detect small arteries sensitively in Doppler mode.³,⁸,²² In ultrasound-guided LNRB, a relatively lower frequency transducer is used compared with that used during a cervical nerve root injection, which effects the resolution and sensitivity of ultrasound. To our knowledge, there have been no reports of the sensitivity of Doppler ultrasound to detect the vessels surrounding the lumbar vertebra. Since Doppler ultrasound is a valuable tool for estimating the blood flow in the ovarian artery with a 1~2 mm diameter,²²,²³ Doppler ultrasound may have a potential to provide information about vessels in the lumbar vertebral area. However, avoiding vessels during ultrasound-guided procedures can be affected by many factors (e.g., spinal deformities, clinician’s skill, and the resolution of the ultrasound machine). Therefore, further studies in real patients will be necessary.

The accuracy of ultrasound-guided injection is good, and can be similar to that of CT-guided and fluoroscopy-guided procedures. Additionally, the operation time is shorter, there is no radiation exposure to patients and the operator, and it requires less space than CT or fluoroscopy-guided procedures.²,¹³,¹⁴,¹⁷,¹⁹ In the present study, the accuracy of ultrasound-guided injection was approximately the same as it was in previously reported studies.²,¹⁴,¹⁸ Ultrasound-guided injection may be an option for the delivery of injectate into the S1 root, as well as lumbar nerve root area.

CONCLUSION

Ultrasound-guided S1 nerve root, as well as lumbar nerve root injection, is feasible and valid treatment option considering that it showed similar success rate to fluoroscopy-guided process with less harm to patients in non-obese cases. Also, in-plane approach using axial imaging can visualize exact needle tip during the procedure, which can enhance treatment accuracy.

DISCLOSURE STATEMENT

The authors declare that there are no conflicts of interest.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.35827/cp.2019.18.2.59.

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