

Ultrasound-Guided Lumbar Transforaminal Injections

Feasibility and Validation Study

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Study Design. Preclinical feasibility study.

Objective. Evaluation and validation of ultrasound-guided lumbar transforaminal injections.

Summary of Background Data. Lumbar transforaminal injections are routinely implemented in the interventional management of spinal radicular pain. Typically, these injections are administered under fluoroscopy or computed tomography. Although radiological guidance provides anatomical precision and accuracy, it is associated with radiation exposure and cannot be performed during outpatient visits or at bedside. Ultrasound-guided techniques have been previously described; however, the methodological generalizability remained unknown and validation against routine fluoroscopy has never been conducted on multiple spinal levels.

Methods. We addressed the procedural accuracy of ultrasound-guided lumbar transforaminal injections and proposed anatomically sound approach. Fluoroscopic validation was performed.

Results. Of the 50 planned injections, 46 procedures were performed. L5/S1 foraminal access was impossible in 4 cases (8%). Fluoroscopy confirmed the correct foraminal placement in all 46 injections (100%). The contrast-spread pattern was intraforaminal in 42 cases (91.3%) and extraforaminal (nerve root) in 4 cases (8.7%). When intraforaminal pattern was detected on anteroposterior image, lateral fluoroscopy demonstrated ventral epidural flow in all occasions. In 3 cases, intravascular injection was detected (6.5%).

Conclusion. Ultrasound-guided lumbar transforaminal injections are accurate and feasible in the preclinical setting.

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Lumbar transforaminal injection is a commonly performed procedure to treat spinal radicular pain. Typically, these injections are administered under fluoroscopy or computed tomography. Although considered relatively safe, several case reports of devastating neurological complications^{1–4} have been published. All reported events of permanent neurological damage were linked to the injections of nonsoluble particulate steroids. Current recommendations for safer and more accurate techniques include the adoption of radiopaque real-time and/or digital subtraction contrast injection prior to the instillation of a steroid.⁵ Other technical “pearls,” such as injection of a local anesthetic first^{4,6} and use of a water-soluble steroid,⁷ have been suggested.

A novel ultrasound-guided lumbar transforaminal approach described recently in the literature^{8,9} appeared in the current procedural terminology¹⁰ and was implemented in clinical practice. The absence of radiation exposure, equipment affordability, and bedside setting¹¹ favorably compare ultrasound with traditional radiological imaging. However, several concerns should be addressed, such as accuracy, reliability, and patient safety. The method of Galiano *et al*,⁸ for example, outlines so-called posterior foraminal approach when needle was directed toward the nerve root. It may lead to an inadvertent needle placement into the neuroaxial compartment without realization of the mishap. A definite sonographic landmark has yet to be described in published literature. We modified the original in-plane technique⁸ and developed a different, anatomically sound approach.

MATERIALS AND METHODS

The main outcome of the study was to confirm the feasibility of ultrasound-guided lumbar transforaminal injections on multiple levels. Specifically, accuracy of the spinal segment identification, patterns of the radiopaque contrast spread, and visibility of the defined target were evaluated.

Three female and 2 male unembalmed cadavers donated to the University of Washington Willard Body program were used. No institutional review board approval was required

because the personal health data, excluding biometrics, of the deceased were not disclosed to investigators.

Five transforaminal injections (L1/L2–L5/S1) were planned to be administered bilaterally on each specimen (10 injections per specimen). We intended to complete 50 injections in total.

Specimens were placed in prone position. Towel rolls were placed under the abdomen to alleviate lumbar lordosis. Paramedian sagittal sonography was performed at the level of transverse processes for the orientation purposes. The second scanning was performed in the short axis. The operator announced the level of injection. The injections were administered by using the C5-1 broadband curved array transducer and the CX-50 CompactXtreme ultrasound system (Phillips, Eindhoven, the Netherlands). The ultrasound transducer was positioned at the short axis paramedian view between 2 adjacent transverse processes, so the sonogram reflected the spinous process, lamina, and dorsal part of the vertebral body (Figure 1). If the exiting nerve was seen, the transducer was shifted caudally to avoid trespassing the nerve root. Twenty-gauge 5-inch Quincke-type spinal needles were inserted by using the in-plane approach, aiming to for the most medially visible shadow of the vertebral body. Once the needle touched the bone surface, 1 mL of iohexol (Omnipaque) 240 mg/mL was injected. Then anteroposterior and lateral fluoroscopy was performed.

In the event of an intravascular contrast spread, the injections were repeated by using 20-gauge Coudé (curved) versions of the blunt nerve block needle (Epimed, Johnstown, NY).

The vertebral level of injection, position of the needle tip, contrast flow pattern, and aberrant contrast spread were registered.

RESULTS

All cadavers had skin-to-vertebra distance of 6 to 9 cm measured on the ultrasound examination. L5/S1 in-plane injections were deemed impossible in 2 specimens, that is, on 4 vertebral levels (8%). In those cases, L5 vertebral body



Figure 1. Axial sonogram of lumbar vertebra. S indicates spinous process; L, lamina; V, vertebral body; arrowhead, target for injection.

could not be visualized. Therefore, total 46 injections were administered.

Fluoroscopy confirmed the foraminal placement in all 46 injections (100%). As expected, the needle tip was located at the ventral part of the intervertebral foramen on the lateral view and under the pedicle (6-o'clock position) on the anteroposterior view. The cephalocaudal tip position was varied between the lower part of the cephalad vertebra and the upper part of the caudad vertebra (Figure 2). The contrast spread pattern was intraforaminal in 42 cases (91.3%) and extraforaminal (nerve root) in 4 cases (8.7%). All intraforaminal injections cases demonstrated ventral epidural flow of the injected radiopaque contrast agent on the lateral fluoroscopy (Figures 3 and 4). The correct spinal level was identified in all 46 cases (100%). As stated, in 2 L5/S1 cases, the vertebral body could not be detected. We nevertheless attempted injections and fluoroscopy confirmed erroneous L4/5 or sacral placement, most probably related to a deviation of the needle tip by the L5 transverse process. Therefore, on the basis of predetermined imaging inclusion criteria (lamina and vertebral body must be seen), we decided to exclude those L5/S1 cases from the final analysis.

All 4 injections with extraforaminal spread occurred in a 104-year-old female cadaver. Intrathecal contrast injection was administered. The obtained myelographic image detected multilevel severe spinal stenosis, which could explain the aberrant extraforaminal contrast flow.

While using a 20-gauge Quincke-type spinal needle, intravascular venous pattern was detected in 3 cases (6.5%) (Figure 5). The intravascular injections occurred at the left L1/2, L2/3, and the right L5/S1 levels. The L2/3 injection resulted in both epidural and intravascular contrast flow. Repeated injection with a 20-gauge Coudé needle revealed no intravascular uptake.

DISCUSSION

A modified in-plane technique aiming vertebral body as a sonographic landmark has not been previously described. When the needle is resting at the bone, no further advancement into the neuraxial compartment is possible. The injection administered in this position of the needle tip resulted in the transforaminal epidural flow in most cases. The methodology

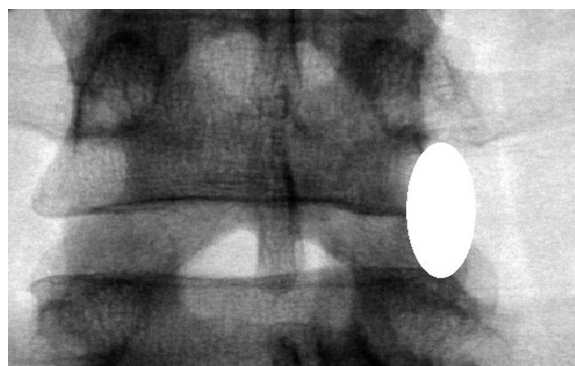


Figure 2. Anteroposterior fluoroscopy with typical distribution of the observed needle positions (white eclipse).

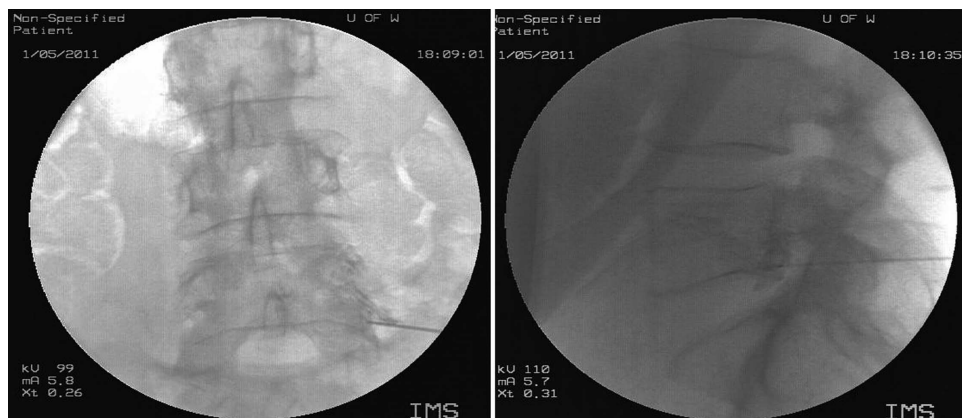


Figure 3. Anteroposterior (left) and lateral (right) fluoroscopy of the needle position and the contrast flow at L5/S1 level.

developed during the experiments was centered on improving success and eliminating potential complications. All needle placements were done at the correct vertebral level, and in 91.7% ensued in a ventral epidural contrast-dye spread confirmed by fluoroscopy. The intravascular injection rate was 6.5%. This is comparable with the incidence reported in a clinical study.¹² Another publication rated occurrence of this event as high as 11.2%.¹³ The sample size ($n = 761$) in the article by Furman *et al*¹³ was substantially larger than that in this study. In any case, the difference may not reflect potential superiority of the ultrasound-guided injections. When no contrast-enhanced fluoroscopy is used, inadvertent intravascular injections cannot be recognized in a procedural setting. Clinical comparative imaging research may be needed to answer this question.

Notably, the lumbar nerve root and blood vessel imaging is a function of depth and echogenicity of the surrounding tissues. Therefore, poorly visualized nerve may be traversed by needle. Use of a blunt Coudé needle may prevent nerve root trauma and intravascular injection.

It seemed that the vertebral body and the intervertebral disc have different acoustic properties. While the bone has hyperechoic signal, the disc appearance is rather hypoechoic. This phenomenon was previously published.¹⁴ However, the observation was valid only in the younger specimen. Aged, degenerated discs are heavily calcified and cannot be differentiated from bone by the sonographic examination.

Ultrasound-guided lumbar transforaminal injections are deemed controversial among interventional pain physicians. According to current beliefs, ultrasonography may not guarantee needle placement at the correct level, accurate spread of the injectate, and prevention of the intravascular injection. Our work at least partially addressed these concerns: precise needle placement was feasible and the correct vertebral levels can clearly be identified. Use of a blunt-tip needle may reduce inadvertent intra-arterial injection, but probably not intravenous injection, which may lead to false-negative results. The procedure, however, can then be repeated under fluoroscopy.

Previous publications^{8,9} already confirmed the feasibility of the ultrasound-guided transforaminal injections. However, the approach described by Galiano *et al*,⁸ if applied in the clinical setting, may result in needle advancement into the neuroaxial compartment without notice. Perhaps, in order to prevent such advancement, Galiano *et al*⁸ advised halting needle progress when it reached the dorsal foraminal opening laterally to the superior articular process. It is unlikely that an injectate will extend to the ventral epidural compartment (the recommended location for transforaminal injection) when the needle was placed dorsally and laterally. Most likely, it will spread onto the exiting nerve root. No contrast dye injection was used in the study of Galiano *et al*⁸ to confirm epidural spread. We experimentally tested the possibility of the neuroaxial injection by using the previously described

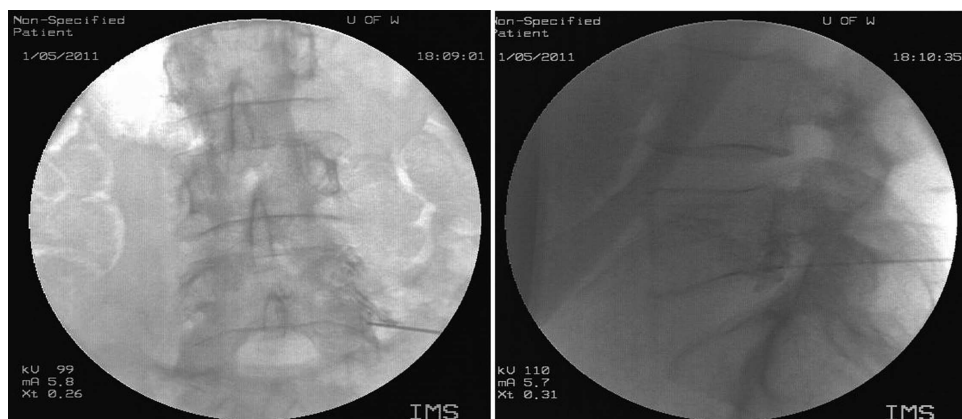


Figure 4. Anteroposterior (left) and lateral (right) fluoroscopy of the needle position and the contrast flow at L4/L5 level.

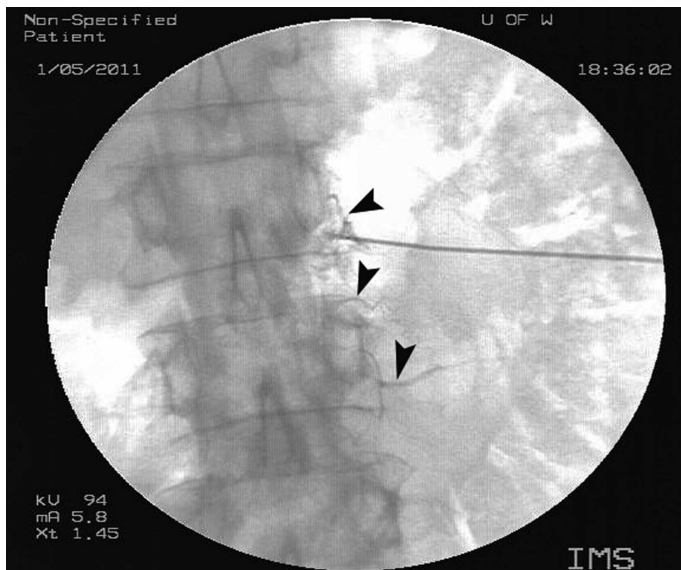


Figure 5. Anteroposterior fluoroscopy demonstrated aberrant (vascular) contrast flow.

technique. Once the needle tip approached the level of the articular processes, its further progress was shadowed by bony structures and the needle entered the neuroaxial space (Figure 6).

Sato *et al*⁹ used an out-of-plane technique and demonstrated feasibility and accuracy of the L5 nerve root injection. In 3 cases (3.8%), injection was not successful because of L5 articular process protruded laterally. Approach of Sato *et al*⁹ may be considered for the L5/S1 injections, because the technique used in this study showed poor accessibility of the L5/S1 foramen *via* the in-plane method.

At this stage, ultrasound-guided transforaminal injections may be furnished at the practitioner's discretion, when the dorsal vertebral body is visible at the foraminal level. Only water-soluble corticosteroids should be injected, and if the

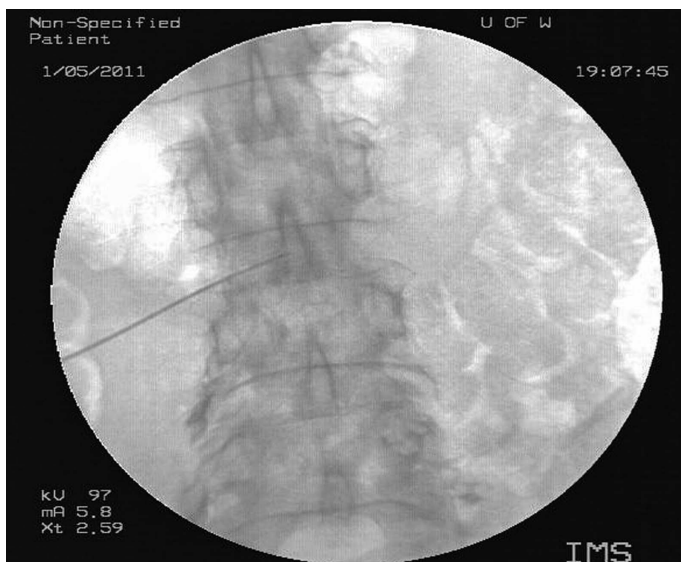


Figure 6. Anteroposterior fluoroscopy demonstrated potential severe complication—inadvertent neuraxial needle placement.

result of the procedure was disappointing, practitioners may consider repeating the injection by using fluoroscopy or computed tomography. Blunt-tip Coudé needle may also be helpful in avoiding direct nerve trauma and intravascular injection.

Ultrasound-guided lumbar transforaminal injections were accurate and feasible in the preclinical setting. Clinical correlation was required for dissemination of this novel technique in routine practice.

➤ Key Points

- Previously described ultrasound-guided transforaminal injection technique was modified.
- A modified in-plane technique aiming vertebral body as a sonographic landmark prevents further advancement into the neuraxial compartment.
- This method has advantages of a bedside procedural setting and spares patients and personnel from radiation exposure.
- Ultrasonography provides reliable setup in localizing foramina and performing transforaminal lumbar injections.
- Water-soluble steroids should be used when practicing this technique.

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