Real-time Sonographic Imaging for Periradicular Injections in the Lumbar Spine

A Sonographic Anatomic Study of a New Technique

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Objective. We conducted this study to develop a sonographically guided approach to the spinal nerve of the lumbar spine and to assess its feasibility and accuracy by means of computed tomography (CT).

Methods. Fifty sonographically guided approaches at 5 levels (L1–S1) were performed on 5 embalmed cadavers, which were positioned prone. The spinal nerves of the lumbar spine were shown under sonographic guidance. In 1 cadaver, the most lateral aspect of the roof of the intervertebral foramen was defined as a reference point. Its position was computed as a distance from the tip of the spinal process (A), the midline (B), and the intervertebral disk (C). Subsequently, axial transverse CT scans were made to verify these distances. In a second part of the experiment, a spinal needle was advanced under sonographic guidance to the spinal nerves for each lumbar spinal level on 1 embalmed cadaver. The exact placement of the needle tips was checked with the help of CT. Results. This technique for a sonographically guided approach to the periradicular area proved to be feasible and accurate. Sonography and CT provided the same mean measurements of 4.0, 2.5, and 1.4 cm for distances A, B, and C, respectively. The Pearson correlation coefficient was 0.99 (P < .001) between sonography and CT. In the experimental study, all 10 needle tips were placed periradicular to the spinal nerves.

Conclusions. Sonographic guidance is a useful adjunct to increase the safety and efficacy of periradicular injections in the lumbar spine. Key words: feasibility; periradicular injection; sonography.

Injections therapies play a major role in the treatment of various pain conditions and are becoming integral parts of the multidisciplinary therapies required to improve and rehabilitate patients with pain.1,2 Periradicular injections in the lumbar spine are preferentially performed as computed tomography (CT)- or fluoroscopy-controlled interventions.3,4 Sonography is reliable and accurate in visualizing lumbar paravertebral anatomic characteristics,5 and the benefits of applying it in real time for different injection therapies have been shown in several studies.6-11 The aim of this study was to develop a new sonographically guided approach to the spinal nerves in the lumbar spine and to study its feasibility and accuracy by means of CT.
Materials and Methods

This study was conducted in 2 steps. The first part included a feasibility study to identify and depict the spinal nerves of the lumbar spine by using ultrasonographic imaging and to control these findings by means of CT. In a second step, an experimental study was conducted to show the exact needle placement and to confirm the concordance between the 2 different imaging methods.

Feasibility Study

After obtaining institutional approval, 1 radiologist, experienced in musculoskeletal sonography, performed sonographically guided posterior approaches to the spinal nerves in the lumbar spine on 5 prepared cadavers that had been donated to the Institute of Anatomy. To achieve a reasonable similarity to live patients, the cadavers were embalmed by a special procedure (ethyl alcohol/glycerin conservation). Sonographic examinations were performed with a standard sonographic device (HDI 5000; Philips Medical Systems, Bothell, WA) using a broadband curved array transducer working at 2 to 5 MHz and a broadband linear array working at 4 to 7 MHz.

Figure 1. A, Axial transverse anatomic image of the intervertebral foramen at level L4–L5; if indicates intervertebral foramen with part of the root sheath of the spinal nerve; js, joint space; sp, spinal process; ts, thecal sac with filum terminale; and vb, vertebral body. B, Axial transverse sonographic image of the intervertebral foramen at level L4–L5; A indicates distance from the reference point (rp) to the tip of the spinal process; B laterality; and C distance to the intervertebral disk. C, Axial transverse CT image of the intervertebral foramen at level L4–L5.

The cadavers were positioned prone, and bilateral sonographically guided approaches at levels L1–S1 were performed. To localize the different spinal levels, posterior paravertebral parasagittal sonograms were obtained. The spinous process and adjacent structures (lamina of the vertebral arch, zygapophyseal articulations, inferior and superior facets, transverse process, and vertebral isthmus) had to be clearly delineated by means of transverse sonograms at each level to identify the corresponding spinal nerves. After these were obtained, in 1 cadaver the most lateral bone portion was established as a reference point (Figure 1, A–C). Each sonogram was frozen, and measurements were computed by using the measuring functions of the sonographic device. Two distances were established.
(Figure 1, B and C, distances A and B) to assess this position on the transverse sonograms. Additionally, from this point, the distance to the intervertebral disk was established (Figure 1, B and C, distance C). All sonographic measurements were made in the center of the sonograms parallel to the axis of the ultrasound beam to achieve the best results.12

Subsequently, the resulting 30 measurements were verified by spiral CT (Synergy; GE Healthcare, Milwaukee, WI) and reformatted to 1-mm axial slices (Figure 1, A–C). The Pearson correlation coefficient was calculated to compare sonographic and CT measurements. All values are presented as mean ± SD.

**Experimental Study**

To verify these findings and to illustrate periradicular infiltrations, on 1 embalmed cadaver a spinal needle (20 gauge, 90 mm; Yale Spinal, Madrid, Spain) was advanced under sonographic guidance to the spinal nerves for each lumbar spinal level. The needles were inserted perpendicular to the skin, 3 to 4 cm lateral to the spinous process and exactly in line with the transducer and the echo plane. This enabled visualization of the entire needle, which appeared as a bright line-shaped echo pattern in the transverse sonogram (Figure 2A). If a needle deviated from its intended direction during the approach, the in-line technique allowed for an accurate repositioning under sonographic guidance. The exact placement of the needle tips was checked by CT (Figure 2B).

**Results**

**Feasibility Study**

Fifty bilateral sonographically guided approaches on 5 embalmed cadavers were performed. Ten of 50 positioning attempts were not feasible because of reduced imaging conditions in some of the embalmed cadavers, resulting from pockets of air trapped during the conservation process as confirmed by CT. Using the advantages of online imaging with multiple angles of view, it was possible to show the intervertebral foramen in all other cases. The panoramic view option of modern sonographic devices allowed simultaneous depiction of all adjacent structures (Figure 3).

A comparison of sonographic and CT measurements revealed a correlation coefficient of 0.99 (P < .001). Sonography provided mean measurements of 4.0 ± 0.6, 2.5 ± 0.5, and 1.4 ± 0.3 cm for distances A, B, and C respectively. The CT measurements were 4.0 ± 0.7, 2.5 ± 0.5, and 1.4 ± 0.2 cm. Individual measurements showed mean differences of 0.02 ± 0.2 cm for distance A, 0.01 ± 0.1 cm for distance B, and 0.03 ± 0.1 cm for distance C. The specific values of sonographic and CT distances are shown in Figure 4.

**Experimental Study**

The experimental study confirmed that all 10 needle tips were placed within the dorsal third of the intervertebral foramen in the periradicular area (Figure 2, A and B).

**Figure 2.** A, Sonographic image of periradicular infiltration showing delineation of the needle (n), needle tip (nt), tip of the spinal process (sp), intervertebral foramen (if), and vertebral body (vb). B, Computed tomographic image of periradicular infiltration showing delineation of the needle and intervertebral foramen.
Periradicular injections are preferentially performed as CT- or fluoroscopy-controlled interventions. Such injection therapies can be performed predominantly onsite in appropriately equipped clinical institutions. Injection therapies play a major role in the treatment of various pain conditions and are becoming an integral part of the multidisciplinary therapies required to improve and rehabilitate patients with pain.

Several benefits of sonography as a useful adjunct during various forms of injection applications have been shown: imaging of the individual anatomic parts, real-time needle guidance, visualization of the spread of local anesthetics, minimal risk of complications, dose reduction of local anesthetics, and shortening of onset time. Recently, Greher et al described a sonographically guided technique for lumbar facet nerve blocks.

To expand the application of these techniques and to make them feasible for offsite administration as well, we developed a sonographically guided approach to the spinal nerves of the lumbar spine and studied its feasibility and accuracy using CT verification.

We performed an in-line approach in which the needles were advanced strictly parallel to the long axis of the transducer to keep them in the echo plane. This is a feasible and well established sonographically guided infiltration technique, originally developed and described for the psoas compartment block. This technique provides real-time monitoring of the inserted needle along its entire length. In fact, the needle appears as a single distinct line-shaped echo pattern, as opposed to only a few dotlike reflections when other techniques are used. Nevertheless, precise and careful handling of the transducer is mandatory to achieve the best visualization of the entire needle.

Of 50 approaches, 10 could not be performed because of reduced imaging conditions caused by trapped air in the embalmed cadavers. In the remaining approaches, the intervertebral foramen could be clearly delineated. Some difficulties can be encountered in exactly depicting the periradicular area in the upper lumbar spine. It should be noted that the isthmus is more straight in the upper lumbar spine (L1–L3). Furthermore, the laminae of the vertebral arch in the upper lumbar spine become narrower; accordingly, the spaces between the transverse processes are small, and the vertebral isthmus can appear like a straight fissure. The lesson learned from this experiment is that it is important to follow a systematic process in depicting the vertebral isthmus and, consecutively, the periradicular area. First of all, the spinal level should be determined. This is not shown in this report because it can be obtained easily from
sagittal sonographic images of the spinous processes. Subsequently, the transducer can be rotated, and the corresponding spinous process can be traced until the lamina can be delineated. The lamina should be shown in its entire length for assessing its lower margin. The next slit occurring laterally is the joint space, and then the lateral facet will be visible. Starting from this image, the intervertebral foramen and corresponding spinal nerve can be traced (Figure 3).

A comparison of sonographic and CT measurements showed that the reference points corresponded very well. The most likely explanation for deviations between the sonographic and CT distances is minor measurement errors, which are typical for curved array transducers. With a broadband linear array, measurement errors can be minimized. Even though this transducer in fact has good near-field clarity, only a limited penetration depth can be resolved for the purpose of adequately imaging facet joint structures. Sonographic imaging proved to be reliable and accurate in placing the needle for periradicular approaches. This has to be emphasized for 2 reasons: (1) a freehand technique was performed (no needle guides or other aids were applied), and (2) no specially designed and hence more expensive needles (as available for interventional sonography) were used.

In summary, the described technique for a sonographically guided approach to the periradicular area proved to be feasible and accurate. No additional technical aids (eg, guides) or specially designed needles were applied to achieve accurate sonographic guidance. However, a systematic process, knowledge of sonographic imaging of the lumbar paravertebral region, and practice in handling a transducer in combination with a needle are required. With these necessary skills, the described technique is simple to perform.

We conclude that, because of the benefits of sonography (imaging of the individual anatomic parts and real-time needle guidance), the efficacy of periradicular injections may be increased. This new sonographically guided technique supports a wide application range with accurate and reproducible needle placement. Also, the lack of exposure to ionizing radiation, in contrast to CT- and fluoroscopy-based procedures, may further benefit a wider application of this proposed sonographically guided technique.

References

Periradicular Injections in the Lumbar Spine


