HIGH-RESOLUTION ULTRASOUND OF THE PUDENDAL NERVE: NORMAL ANATOMY

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ABSTRACT: Introduction: In this study we aimed to determine whether high-resolution ultrasound (US) can identify the pudendal nerve and its terminal branches. We also attempted to identify the best approach for visualizing these structures. Methods: Normal anatomy of the pudendal nerve was evaluated in 3 cadavers and 20 healthy volunteers proximally at the level of the ischial spine and distally with low-frequency (2–5-MHz) and high-frequency (12–7-MHz and 17–5-MHz) transducers. Two musculoskeletal radiologists performed the examinations and evaluations. Volunteers were placed in 3 different positions, which allowed different approaches (posterior, medial, and anterior transperineal). A 0–3 scale was used to assess nerve visibility. Results: Visualization of the pudendal nerve at the ischial spine was best when using a medial approach (P < 0.004); the terminal branches were seen best with the anterior approach (P < 0.002). Conclusion: High-resolution ultrasound (US) can identify the pudendal nerve and its terminal branches.


The pudendal nerve arises from the sacral plexus. It is formed by the second, third, and fourth sacral nerve roots. The nerve exits through the greater sciatic foramen and crosses the ischial spine, the sacrospinous ligament, and the sacrotuberous ligaments.1,2 It then re-enters the pelvis through the Alcock canal, and, at the level of the perineum, it normally gives 3 terminal branches—the inferior rectal nerve, the perineal nerve, and the dorsal nerve of the penis or clitoris.1–5

Direct peripheral nerve visualization is now possible with high-resolution ultrasound6 for large fascicular nerves7 and for small monofascicular nerves.8 Visualization of peripheral nerve allows diagnosis of different conditions that alter morphological features.6–14

Diagnosis of pudendal neuralgia is essentially clinical, and no specific clinical signs or complementary tests are reliable.15 Therefore, investigating the use of ultrasound (US) for visualization of the pudendal nerve may be valuable not only for diagnostic purposes but also for US-guided nerve block. Pudendal nerve block under US guidance has been performed using only low-frequency probes without a clear visualization of the nerve and its terminal branches.3–5 With convex probes, visualization of the pudendal nerve was obtained in less than half of the patients, which is a potential limitation of the technique.3

On the basis of anatomical studies, the pudendal nerve has a diameter of approximately 4–5 mm at the level of the ischial spine.3–4 Therefore, we proposed that it may be visible with high-resolution US. The purpose of our study was to determine whether high-resolution US can identify the pudendal nerve and its terminal branches and also to identify the best approach for visualizing these structures.

METHODS

The study was conducted in accordance to the standards of the committees on human experimentation of the institutions involved and in accordance with the Helsinki Declaration of 1975.

Anatomical Correlation. The anatomical correlation portion of this project was approved through the anatomical donations program at the University of Barcelona. The anatomy of the pudendal nerve was examined in 3 human cadavers (1 male and 2 females: 42, 52, and 66 years old, respectively) dissected by an anatomist with 20 years of experience. Dissections extended from the lumbosacral plexus to the perineum. Concomitant osseous pathology at the level of the pelvis and perineum was excluded (fractures, metastasis, osteophytes). The gluteus muscles were identified and removed. The lesser sciatic foramen and the sacrotuberous ligament were exposed. The pudendal nerve and artery near the ischial spine and under the sacrotuberous ligament were isolated and inspected visually by the anatomist and by a musculoskeletal radiologist with 5 years of experience in musculoskeletal imaging and dissection. The contralateral side of a cadaver was used as an anatomical correlation to visualize the nerve using broadband (frequency band: convex 5–2 MHz, 12–7 MHz, and 17–5 MHz) linear-array transducers. We then obtained one-to-one qualitative comparison by performing the US evaluation before dissection.

US In Vivo Examination. US imaging of the pudendal nerve was performed bilaterally in 20 healthy

Abbreviation: US, ultrasound
Key words: Alcock canal, perineal nerves, pudendal nerve, sacrotuberous ligament, ultrasound, anatomy
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US of Pudendal Nerve
volunteers (15 women and 5 men: median age 33 years, age range 22–56 years) with commercially available US equipment (iU22; Philips, Eindhoven, The Netherlands) using broadband transducers (frequency band: convex 5–2 MHz, linear 12–7 MHz, and 17–5 MHz).

Two musculoskeletal radiologists with differing expertise (7 and 2 years of experience in musculoskeletal imaging and ultrasound, respectively) performed the US examinations. Volunteers were placed in 3 different positions that allowed different approaches (posterior, medial, and anterior transperineal) to visualize the nerve.

For the posterior approach, each volunteer was placed in the prone position. In this position, the ischial spine, the sacrotuberous ligament, and the internal pudendal artery, which accompanies the pudendal nerve, can usually be delineated by US (Fig. 1). This approach is commonly used by anesthesiologists for nerve block.3–5

For the medial approach, the volunteer was placed prone with the legs slightly opened. The probe was placed on an axial plane at the level of the ischial tuberosity, then moved up and rotated by approximately 45°. In this position the probe should be almost perpendicular to the sacrotuberous ligament. From this position the examiner can look for the nerve, which is expected to be oblique to the ligament (Fig. 2).

For the anterior approach, the volunteer was placed in the gynecological position, and the ischial tuberosity was located by palpation with hips and knees flexed. Moving the probe posteriorly, the pudendal nerve and artery were sought. Moving the probe anteriorly, at the level of the perineum, the distal branches of the nerve were sought and located (Fig. 3).

The pudendal nerve was considered to be identified when a fascicular structure at the ischial spine was visible. Identification of the fascicular echotexture is normally used to identify large- and medium-sized nerves on US.6–13 At the level of the ischial spine, an artery accompanies the nerve; color Doppler was used when appropriate to differentiate nerve from small vessels. Monofascicular structures visible throughout different planes reaching the rectum, the perineum, and the vestibular bulb were considered the distal branches. The appearance of a monofascicular structure visible throughout different planes is a typical feature of small peripheral nerves on US.6–13 Mean cross-sectional areas of the nerves were obtained using the tracing function of the US equipment and registered (measured within the hyperechoic rim).

Images were independently analyzed by the same radiologists who performed the examinations (A.T. and E.F.). Anonymous static images and video-clips were used for the evaluation. Both static images and video-clips were used to increase diagnostic confidence in imaging evaluation. US examinations were repeated after 1 month to assess inter- and intraobserver agreement. Images were transferred to an external workstation equipped with 32-bit OsiriX software (version 3.6). Images were reviewed randomly, and each radiologist was
blinded to the observations of the other. A semi-quantitative scoring (visibility index) system for the visibility of the pudendal nerve (0 = total masking; 1 = insufficient visibility; 2 = sufficient visibility; 3 = optimal visibility) was used. Total masking was used when the nerve was not visible, insufficient visibility when the nerve was not visible sufficiently to allow diagnostic considerations, sufficient visibility when it was possible to make a diagnosis, and optimal visibility when the nerve was perfectly visible. This score was similar to 1 already adopted for the sciatic nerve and adapted from brachial plexus magnetic resonance imaging (MRI). The mean result for both observations was recorded. The visibility of the pudendal nerve was evaluated at different levels in a craniocaudal direction. The levels considered were: the level of the ischial spine; the area below the ischial spine (the Alcock canal); and the perineum. At the level of the perineum, the 3 terminal branches (inferior rectal nerve, perineal nerve, and dorsal nerve of the penis or clitoris) were considered separately. The sum of the scores given to each approach for each position considered was divided by the maximum sum that could be obtained, thus obtaining a percentage visibility index.

**Statistical Analysis.** Differences among image quality scores and differences among the visibility scores of the 3 approaches were globally evaluated with the Friedman test. Post hoc analysis for direct comparison between pairs of sequences was performed using the sign test. Intra- and interobserver agreement were calculated using Cohen kappa statistics. SPSS software (release 13.0 for Windows; SPSS, Inc.) was used for analysis. \( P < 0.05 \) was considered statistically significant.

**RESULTS**

**Anatomical Correlation.** At dissection, visual inspection of the pudendal nerve showed that the caliber of the nerve was approximately 3 mm at the level of the ischial spine. The artery was located anterior to the nerve. It was possible to identify the nerve and the sacrotuberous ligament with US, but not the artery, because it was collapsed. Using convex probes, it was not possible to locate the nerve. With high-resolution probes the nerve was best identified using the medial approach. One-to-one comparison between cadaveric specimens and US images showed that the pudendal nerve could be identified with high-resolution probes (Fig. 4a–c). Results of the visibility index of the 3 approaches on cadavers reported in Table 1 show that the best approach was the medial one. On cadavers, US identification of the terminal branches was not possible due to the difficulties in separating small monofascicular nerves from small vessels, and therefore this analysis was not included in the table.

**US In Vivo Evaluation.** Examination time was 30 minutes: 25 minutes of imaging time for the 3 approaches and 5 minutes for patient positioning. None of the volunteers reported pain or...
discomfort during the procedure or during the following 30 minutes. On volunteers, color Doppler was useful to differentiate small vessels from monofascicular structures at the level of the perineum. At the level of the ischial spine, color Doppler was useful to confirm that the fascicular structure visualized was not a vessel (e.g., the internal pudendal artery).

The pudendal nerve around the ischial spine was visible in 100% of the volunteers. The inferior rectal nerve and the perineal nerve were visible in 75% of volunteers. The dorsal nerve of the penis or clitoris was visible in 100% of volunteers. Examples of the visibility of the pudendal nerve are provided in the figures (Figs. 5–9).

The difference among the visibility indices of the 3 approaches was highly significant ($P < 0.001$, Friedman test). The visibility indices of the medial approach were significantly higher ($P < 0.004$, sign test) than those of the remaining approaches, regardless of the probe. The terminal branches were better visualized with the anterior approach ($P < 0.002$).

### Table 1. Visibility index on cadavers at different levels*: at the ischial spine and below the ischial spine (Alcock canal).

<table>
<thead>
<tr>
<th>Approach using 5–2 MHz</th>
<th>Pudendal at the ischial spine</th>
<th>Pudendal below the ischial spine</th>
<th>Visibility index†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior</td>
<td>0.5</td>
<td>0.4</td>
<td>15%</td>
</tr>
<tr>
<td>Medial</td>
<td>0.8</td>
<td>0.6</td>
<td>23%</td>
</tr>
<tr>
<td>Anterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Approach using 12–7 MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medial</td>
<td>2.8</td>
<td>2.8</td>
<td>93%</td>
</tr>
<tr>
<td>Anterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Approach using 17–5 MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medial</td>
<td>2.8</td>
<td>2.9</td>
<td>95%</td>
</tr>
<tr>
<td>Anterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Each level was evaluated with 3 different probes—convex 5–2 MHz, linear 12–7 MHz, and 17–5 MHz.
†Percent ratio between the sum of the visibility scores and the maximum attainable score (see text).
The results of the visibility index of the 3 approaches on volunteers are reported in Table 2. The mean cross-sectional area of the pudendal nerve was $5.9 \pm 1.3 \text{mm}^2$. The mean cross-sectional areas of the terminal branches were $0.6 \pm 0.2 \text{mm}^2$ for the inferior rectal nerve, $0.6 \pm 0.2 \text{mm}^2$ for the perineal nerve, and $1.1 \pm 0.3 \text{mm}^2$ for the dorsal nerve of the penis or clitoris. Intra- and interobserver agreement was good ($k = 0.88$ and $k = 0.81$, respectively).

**DISCUSSION**

Diagnosis of pudendal neuralgia due to pudendal nerve entrapment is essentially clinical, and no specific clinical signs or complementary tests are able to correctly diagnose this disease (Nantes criteria). However, a combination of criteria can suggest the diagnosis, and positive diagnostic anesthetic pudendal nerve block supports the clinical suspicion (fifth criteria). It has been shown that it is possible to block the pudendal nerve using US guidance or fluoroscopy. However, both approaches have some disadvantages. Pudendal nerve injection under US guidance has been performed using low-frequency probes and, therefore, direct nerve visualization was difficult due to the relatively low spatial resolution. On the other hand, fluoroscopic guidance does not allow pudendal nerve visualization and uses ionizing radiation. In particular, ionizing radiation may be harmful for young female patients of a reproductive age. For these reasons, a diagnostic procedure that can directly identify the pudendal nerve may be helpful clinically. Direct visualization of the pudendal nerve and its terminal branches has not yet been performed with high-resolution probes.

Visualization of the pudendal nerve was reached in less than half of the patients using convex probes. Limitations to direct visualization of the pudendal nerve may have been related to the small diameter and deep anatomical position, to the adipose and connective tissue that wrap the nerve and hamper its sonographic depiction, and to the presence of multiple anatomical variants, including proximal bifurcation.

We were able to fulfill 2 objectives in this study. We demonstrated that high-resolution US

<table>
<thead>
<tr>
<th>Approach using 5–2 MHz</th>
<th>Pudendal at the ischial spine</th>
<th>Pudendal below the ischial spine</th>
<th>Inferior rectal nerve</th>
<th>Perineal nerve</th>
<th>Dorsal nerve of penis or clitoris</th>
<th>Visibility index†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior</td>
<td>0.3</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5%</td>
</tr>
<tr>
<td>Medial</td>
<td>1.2</td>
<td>1.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19%</td>
</tr>
<tr>
<td>Anterior</td>
<td>1.1</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>17%</td>
</tr>
<tr>
<td>Approach using 12–7 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Medial</td>
<td>2.8</td>
<td>2.7</td>
<td>1.8</td>
<td>1.7</td>
<td>1.1</td>
<td>84%</td>
</tr>
<tr>
<td>Anterior</td>
<td>2.1</td>
<td>1.8</td>
<td>2.1</td>
<td>2.2</td>
<td>2.9</td>
<td>92%</td>
</tr>
<tr>
<td>Approach using 17–5 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Medial</td>
<td>2.5</td>
<td>2.3</td>
<td>1.5</td>
<td>1.6</td>
<td>1.2</td>
<td>76%</td>
</tr>
<tr>
<td>Anterior</td>
<td>1.4</td>
<td>1.6</td>
<td>2.0</td>
<td>2.0</td>
<td>2.9</td>
<td>82%</td>
</tr>
</tbody>
</table>

*At the level of the perineum, the 3 terminal branches (inferior rectal nerve, perineal nerve, and dorsal nerve of the penis or clitoris) were considered separately. Each level was evaluated with 3 different probes—convex 5–2 MHz, linear 12–7 MHz, and 17–5 MHz.

†Percent ratio between the sum of the visibility scores obtained (see text).
can identify the pudendal nerve and its terminal branches, and we clarified the best approach to visualize these structures.

The medial approach was most suitable for visualization of the pudendal nerve around the ischial spine. In this position, the US beam is oriented in a mediolateral direction, and we noted that the thickness of the subcutaneous tissue and the gluteus maximus muscle are reduced in comparison to the classical posterior approach. We believe that this is the reason why it was possible to identify the nerve using high-resolution probes.

The anterior approach allowed better visualization of the small terminal branches. The inferior rectal nerve and the perineal nerve were identified in 75% of volunteers. We believe that these data are concordant with the anatomical literature. Indeed, these 2 nerves were found to form a plexus around the rectum, anal sphincter, and perineum in 5 of 28 cadaveric specimens. To reinforce this hypothesis we noted that the mean cross-sectional area of the dorsal nerve of the penis or clitoris was larger than the mean areas of the inferior rectal nerve and perineal nerve.

We acknowledge some limitations of this study. The first is that the radiologists involved in the study have extensive experience in peripheral nerves. Moreover, in cases of pudendal neuralgia, a repeat evaluation of a patient group is needed to determine whether there is any difference in the size or anatomy of the nerve in the patients.

Finally, we acknowledge that the examination time to identify the nerve and its terminal branches may be relatively long in the context of a daily busy clinical practice. In this study we found that high-resolution US can identify the pudendal nerve around the ischial spine in every volunteer and that US can identify all the terminal branches of the pudendal nerve in up to 75% of volunteers.

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