Detection of residual disc hernia material and confirmation of nerve root decompression at lumbar disc herniation surgery by intraoperative ultrasound

Takeshi Aoyama[a], Kazutoshi Hida[a], Minoru Akino[b], Shunsuke Yano[a], Yoshinobu Iwasaki[a]

[a] Department of Neurosurgery, Hokkaido University Graduate School of Medicine, Sapporo, Hokkaido, Japan

[b] Department of Neurosurgery, Sapporo Azabu Neurosurgical Hospital, Sapporo, Hokkaido, Japan

Corresponding author:

Takeshi Aoyama

Department of Neurosurgery, Hokkaido University Graduate School of Medicine

Kita 15 Nishi 7, Kitaku, Sapporo, Hokkaido, 060-8638, Japan

taoya@sirius.ocn.ne.jp

Abstract

The aim of lumbar disc herniation surgery is the removal of herniated disc material (HDM) and complete decompression of the nerve root. As some patients present with residual HDM, we examined the ability of intraoperative utrasound (IOUS) to detect this material. Between February 2006 and June 2007, we used IOUS in 30 patients undergoing surgery for lumbar disc herniation. They were 17 men and 13 women; their age ranged from 22 to 63 years (mean 44.0). The level surgically addressed was L3/4 in 1-, L4/5 in 14-, and L5/S1 in 15 patients; they were operated in the prone position. After placing a 3 - 4 cm midline skin incision, partial hemi-semilaminotomy was performed. HDM was removed through a bone window; a surgical microscope was used during the operation. After removal was judged as adequate, IOUS was performed; 17 patients also underwent IOUS before removal of the herniated disc. For the acquisition of IOUS images we used LOGIQ 9 and 8c microconvex probes (GE Healthcare, USA). The normal anatomical structures were well-visualized. HDM was iso- to high-echoic compared to normal nerve tissue. In 3of 17 patients the dural sac and nerve root could not be distinguished from HDM before removal although in all 30 the decompressed dural sac, intradural cauda equina, and nerve root were well visualized. We posit that the echogenicity of nerve tissue was raised due to compression, rendering it similar to that of the herniated disc. In 2 patient IOUS detected residual disc material; the surgical procedure was resumed and sufficient removal was accomplished. IOUS monitoring is safe, convenient and inexpensive. It is also highly useful for the detection of residual HDM and the confirmation of adequate nerve root decompression.

Key words: echography, intraoperative, lumbar disc herniation, ultrasonography, ultrasound

Introduction

The symptoms of lumbar disc herniation derive from compression of the nerve root and/or dural sac due to herniation of the nucleus pulposus, tearing of the annulus fibrosus. Although 1% of the general population suffers from lumbar disc herniation, 46.3 individuals per 100,000 population per year undergo surgery. The goal of surgery for lumbar disc herniation is prompt decompression of the nerve root and/or dural sac. It can be difficult to determine intraoperatively whether sufficient removal of herniated disc material (HDM) has been accomplished. In some instances, residual HDM results in unsatisfactory pain improvement. The incidence of postoperative residual HDM remains unclear and some patients require re-operation.

In patients undergoing neurosurgical procedures, intraoperative ultrasound (IOUS) facilitates minimal invasive surgery and the detection of residual lesions. With improved image quality, its use has increased (Aoyama et al. 2005; Unsgaard et al. 2002) and the usefulness of IOUS in spinal surgery has been reported (Bonsanto et al. 2005; Hida K et al. 1995; Isu et al. 1993;

Kawakami et al. 1994; Kolstad et al. 2006; Mirvis and Geisler 1990; Quencer et al. 1984;Regelsberger et al. 2005; Yeh et al. 2006). However, IOUS is indicated only if there is a relatively large operative field, for example, to confirm decompression at posterior surgery for foramen magnum decompression (FMD) to treat Chiari malformation (Hida K et al. 1995; Isu et al. 1993; Yeh et al. 2006;), at laminectomy or laminoplasty for spinal degenerative diseases (Kawakami et al. 1994; Mirvis and Geisler 1990), and to ascertain an adequate operative field in space-occupying lesions such as spinal cord tumors or arachnoid cysts (Bonsanto et al. 2005; Kolstad et al. 2006; Quencer et al. 1984; Regelsberger et al. 2005).

We assessed whether IOUS is useful in patients undergoing surgery for lumbar disc herniation to confirm dural sac and nerve root decompression, and to detect the presence of residual HDM.

Materials and Methods

Between February 2006 and June 2007, IOUS was used in 30 patients undergoing lumbar disc herniation surgery in our department. The study was approved by the Institutional Review Board and Ethics Committee. Informed consent was obtained from all patients. They were 17 men and 13 women aged from 22 to 63 years (mean age 44.0 years; SD=13.9 years). Their symptom was sciatica due to nerve root compression. The level of lumbar disc herniation was L3/4 in 1 case, L4/5 in 14 cases, and L5/S1 in 15 cases; the herniation was medial in 11- and medio-lateral in 19 patients. Herniated disc were approached by a 3 - 4 cm midline skin incision and ipsilateral hemi-semi laminotomy. All surgical procedures were performed under a surgical microscope by an experienced surgeon. We used GE LOGIQ 9- and 8c microconvex probes (4 - 11 MHz) (GE Healthcare, USA). IOUS was performed when the surgeon judged that enough HDM had been removed. In 17 of the 30 patients IOUS was also performed immediately after laminotomy and removal of the ligamentum flavum prior to HDM removal. The operative field was cleared of debris and clots by washing with saline, filled with saline, and then the echo probes were introduced in the operative field. The length of the skin incisions, muscle dissection, and the areas of laminotomy were the same as in surgery without IOUS; the surgical field was not expanded for IOUS. Issues addressed in this study were 1) the display of normal structures, e.g. the dural sac, nerve root, disc, vertebral body, posterior longitudinal ligament(PLL), and of the herniated discs, 2) findings at the conclusion of surgery, i.e. successful nerve root decompression and detection of residual HDM.

The adequacy of IOUS images was of diagnostic value. Unlike magnetic resonance (MR)- and CT images, they are generated by the surgeon moving the echo probe. Their correct interpretation requires knowledge regarding the local anatomy. As the dural sac is located medially and represents a large portion of the operative field, its inspection is relatively easy. As the nerve roots branch ventro-lateral of the dural sac and run infero-laterally, the long axes of the dural sac and nerve root are not parallel. Therefore, after inspection of the dural sac on sagittal section, the echo probe should be tilted and rotated to accommodate the long axis of the nerve root. As the echogenicity of oozing blood pooling in the epidural space is equivalent to HDM, inspection of the nerve root is compromised. Sufficient hemostasis and aggressive irrigation of the operative field contribute to improving diagnostic accuracy.

Results

Images of normal structures

Normal structures were well displayed by IOUS. The image shown in Fig. 1 is of a patient with both lumbar disc herniation and lumbar canal stenosis. Therefore, the area of laminectomy was larger than usual. Cerebrospinal fluid (CSF) in the dural sac was low- and the cauda equina nerve was high-echoic. The posterior longitudinal ligament anterior to the dural sac was seen as a high-echoic structure. Although it was distinguished from the vertebral body and intervertebral disc, it was not distinguished from the dura mater and hypertrophic connective tissue adjacent to the HDM. The intervertebral disc was high- and the superior and inferior surface of the vertebral body was hypo-echoic. As the spongiosa of the vertebra was also hyper-echoic, care had to be taken not to confuse it with the intervertebral disc.

The nerve root was also well-visualized on both sagittal- (Fig. 2) and axial images (Fig. 3). To observe the nerve root on the sagittal image, the entire length of the nerve root in the area of laminotomy was visualized by turning and tilting the echo probe to accommodate the longitudinal axis. On the axial image, the structure of the nerve root branching from the ventral part of the dural sac and running laterally is observed by sweeping the echo probe in a rostral to caudal direction.

Images of herniated disc material and the affected nerve root

In 17 cases IOUS was performed before HDM removal. In 14, the nerve root compressed by HDM was well-demonstrated (Fig. 4) while in the other 3 the border between HDM and the nerve root was ambiguous, both were visualized as undetached structures (Fig. 5). The echogenicity of HDM was higher than of neighboring nerve tissue in 8 cases; it was equivalent in 9.

After HDM removal, the dural sac and nerve root were well-demonstrated in all 30 cases. The dural sac was enlarged and its echogenicity decreased due to the influx of low-echoic CSF. The space containing saline appeared ventral to the nerve root; its diameter was normalized, and the course of the affected nerve root was smooth and uncompressed (Fig. 6). In 2 of our 30 cases IOUS detected residual HDM although in the surgeon's judgment removal was complete. In these cases the operative process was re-launched

Postoperative course

All 30 patients reported cessation of their sciatic pain immediately after surgery. Nerve root decompression was also confirmed by computed tomography (CT) performed on the day after the operation. One patient required re-operation due to the reappearance of sciatic pain on the 4th postoperative day, however, it was due to re-herniation rather than residual HDM.

Discussion

Image description

At our hospital, all procedures addressing lumbar disc herniation are performed under a surgical microscope. Therefore, the length of the skin incision, muscle dissection, and the area of laminotomy are small and the operative field is only as large as the echo probe. IOUS facilitates the visualization of normal structures and HDM despite the small size of the operative field.

HDM has been reported as high-echoic (Koivukangas and Tervonen 1989). In our series, it was iso-echoic with neighboring nerve tissue in about half of the cases; this was due to the raised echogenicity of adjacent nerve tissue rather than a reduction in the echogenicity of the herniated disc per se. When the amount of low-echoic CSF is reduced due to dural sac compression, the echogenicity of the dural sac and the nerve root is raised. Therefore, the echogenicity of nerve tissue was raised to the level of HDM and this similarity in echogenicity rendered the border between HDM and the nerve root ambiguous.

In fact, in 3 cases both were visualized as undetached structures before HDM removal. However upon HDM removal, the influx of CSF into the decompressed portion of nerve tissue lowered the echogenicity. After HDM removal, the dural sac and nerve root were clearly discernible in all 30 cases. The degree of raised echogenicity due to compression depend on ratio of amount of nerve tissue and CSF in picture. And evaluation is judged by operator. Development of quantitative measurement, i.e. definition of reference point, equation in unit area is necessary in the future.

Ideally, on ultrasound images structures that are difficult to inspect directly, are visualized easily and safely. In some cases with medial lumbar disc herniation, excessive pulling of the dural sac is necessary to detect residual HDM; IOUS detects HDM with ease through the dural sac. In patients with lateral lumbar disc herniation, also known as extreme lateral herniation, intraoperative inspection is difficult. As none of the patients in our series manifested lateral herniation, we do not have knowledge whether IOUS is useful for the detection of residual material in patients with lateral- and far-lateral herniation.

Surgical endpoint and postoperative course

Even in cases where the surgeon judges that all HDM has been completely removed, IOUS can be used to ascertain the absence of residual HDM. It can be difficult to decide whether hypertrophic connective tissue adjacent to the herniated nucleus pulposus, the so-called “post-extraction bulging disc” (Koivukangas and Tervonen 1989), should be removed. If only stiff tissue is detected on IOUS images, the surgical procedure can be finished without removing the post-extraction bulging disc. In the medial part, sufficient dural sac decompression is confirmed by the influx of CSF and the suspension of the cauda equina in the subarachnoid space. In the lateral part, sufficient decompression of the nerve root is confirmed by its smooth, uncompressed course and the visualization of a saline-filled space ventral to the nerve root.

Residual HDM was detected by IOUS in 2 of our 30 cases although the experienced surgeon had judged removal to be complete. Both patients had medial lumbar disc herniation. The intraoperative detection of this type of herniation is difficult (Koivukangas and Tervonen 1989). Meanwhile one of our 30 patients required re-operation. We were able to obtain sufficient nerve root decompression and IOUS detected no residual HDM. This was also confirmed by CT performed on the 1st postoperative day. In this case, the recurrence of sciatic pain was due to re-herniation rather than insufficient decompression or overlooked residual HDM. IOUS can confirm decompression of the nerve root and dural sac, and detect residual HDM, however it cannot predict re-herniation of the nucleus pulposus.

Limitation of intraoperative ultrasound for lumbar disc herniation surgery

As mentioned above, sometimes HDM is not well described before removal. However it doesn't mean that HDM is not exist, nerve tissue could well described if it is not compressed. And the efficacy of IOUS is not denied by preoperative vagueness, postoperative IOUS can confirm the end point of surgery.

Another problem is whether lateral or far-lateral lumbar disc herniation could be observed by IOUS. Structures hidden by the bone edge for a few millimeters are discernible on ultrasound images (Raynor 1997). Enlarged laminotomy in the lateral direction is necessary to remove lesions in the lateral portion and we suggest that IOUS can detect residual HDM even in patients with lateral or far-lateral herniation. Further study should be taken to solve this problem.

Intraoperative ultrasound for spinal surgery

The use of IOUS in spinal surgery has been reported as early as 1980 (Dohrmann and Rubin 1982; Knake et al. 1983; Rubin and Dohrmann 1983). However, to our knowledge only one paper has been published on possible diagnostic applications in lumbar disc herniation (Koivukangas and Tervonen 1989). It is possibly due to the fact that majority of spine surgeons (of both neurosurgeons and orthopedic surgeons) have not been familiar with ultrasound techniques, and have misconception that its resolution is inferior in quality. Our experience reported in this paper is encouraging and explores the usefulness of IOUS with the improved ultrasound techniques in use today, especially utilizing smaller probes and better spacial resolution.

Conclusions: The usefulness of IOUS at lumbar disc herniation surgery is discussed. IOUS monitoring is safe, convenient and inexpensive. It is also highly useful for the detection of residual HDM and the confirmation of adequate nerve root decompression.

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Figure Legends

Figure 1

Structures shown on IOUS images. The echogram was obtained after L3 hemilaminectomy in a patient with L3/4 disc herniation.

After removing the lamina and ligamentum flavum, the cavity is filled with physiological saline. Precipitated blood is shown as hyper-echoic. In the dural sac, the cauda equina and CSF are hyper- and low-echoic, respectively. The posterior longitudinal ligament is seen as a hyper-echoic structure. It can be distinguished from the vertebra and the content of the dural sac. However, differentiation from the dura mater and hypertrophic connective tissue adjacent to peri-herniated disc material is difficult.

The disc is hyper-echoic and the upper and lower surface of the vertebral body is hypo-echoic. As the spongiosa of the vertebra is also hyper-echoic, careful analysis is required to differentiate between the vertebral body and intervertebral disc.

Hypertrophic connective tissue persisting after removal of the herniated disc material is called “post-extraction bulging disc”.

Abbrevations: PLL, posterior longitudinal ligament

Figure 2

Ultrasound image, sagittal view. Tilting and rotating the echo probe visualizes different structures.

A The cauda equina is seen in the dural sac.

B Visualization of the nerve root. The nerve root arises ventro-lateral of the dural sac and runs laterally. It is well-demonstrated by tilting and rotating the echo probe. In patients undergoing removal of a lumbar disc hernia, the nerve root must be carefully inspected.

C Schema of the operative field (transverse section). Lines A and B indicate the cut plane (see Figs. 3A,B, D). The dural sac is visualized by tilting the echo probe medially (dotted line A), the nerve root by lateral tilting (dotted line B). Note that the longitudinal axes are not parallel. Therefore, to inspect the nerve root along its entire length after inspection of the dural sac, the echo probe should be rotated and tilted to accommodate its long axis.

Abbrevations: CE, cauda equina; DM, dura mater; IVD, intervertebral disc; NR, nerve root

Figure 3

A,B Axial IOUS image obtained at a level before (A) and after (B) branching of the nerve root. After removal of the lamina and ligamentum flavum, the cavity is filled with saline. The images shown were obtained after removal of the herniated disc. The nerve root branching from the dural sac and running in a lateral direction is visualized by sweeping the echo probe from rostral to caudal. The ipsilateral nerve root is well-visualized, however, the contralateral nerve root is usually not because the bone window is small. As we applied the Love method, removal of the medial portion of the bone was not necessary.

C Schema of scanning by IOUS. The area visualized with the sector probe is shown as a fan-shaped gray area.

D Schema of the relationship between the axial section and the position of the nerve root. The level imaged in Figs. 4A and 4B is indicated by lines A and B.

Abbrevations: DS, dural sac; SP, spinal process; CNR, contralateral nerve root; INR, ipsilateral nerve root

Figure 4

Intraoperative findings of a patient of L4/5 disc herniation.

A IOUS image (sagittal view) obtained before removal of the herniated disc.The HDM is high-echoic and continues to the intervertebral disc. The nerve root is compressed strongly in the dorsal direction by the HDM.

B IOUS image (axial view) obtained before removal of the herniated disc.

C IOUS image (sagittal view) obtained after removal of the herniated disc.

The nerve root is not compressed and its course is smooth.

D IOUS image (axial view) obtained after removal of the herniated disc.The nerve root is round and not compressed.

Abbrevations: HDM, herniated disc material

Figure 5

IOUS images shown in A (sagittal view) and B (axial view) were obtained before HDM removal; images shown in C (sagittal view) and D (axial view) were acquired after HDM removal.

A,B The border between the dural sac, the nerve root, and the HDM is indicated by a dotted line. The increase in the echogenicity of the compressed dural sac renders its differentiation from herniated disc material difficult.

C,D After removal of the HDM. The dotted lines indicate the border between the dural sac, the nerve root, and the post-extraction bulging disc. Upon post-decompression inflow of CSF into the dural sac, the echogenicity decreases and the demarcation between the dural sac, nerve root, and HDM or post-extraction bulging disc becomes apparent.

Figure 6

IOUS images shown in A (sagittal section) and B (axial section) were obtained after HDM removal. The images shown in C (sagittal section) and D (axial section) are of a different patient.

In A and C, the diameter of the nerve root is normalized, the nerve root is not compressed, and its course is smooth. In B and D, there is a space filled with saline around the nerve root. Sufficient decompression and the absence of HDM are confirmed by clear visualization of the involved nerve root and its smooth course.

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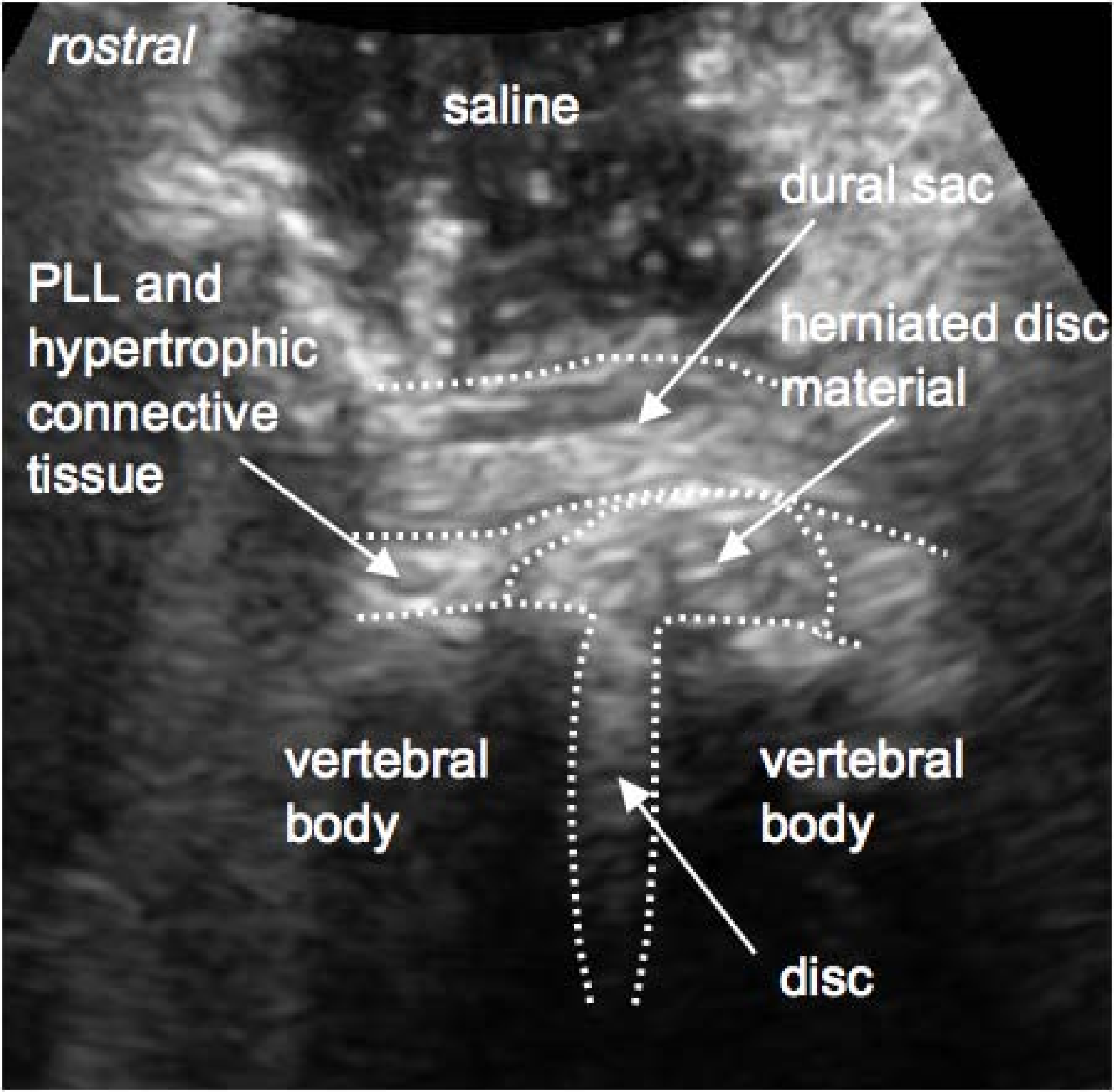
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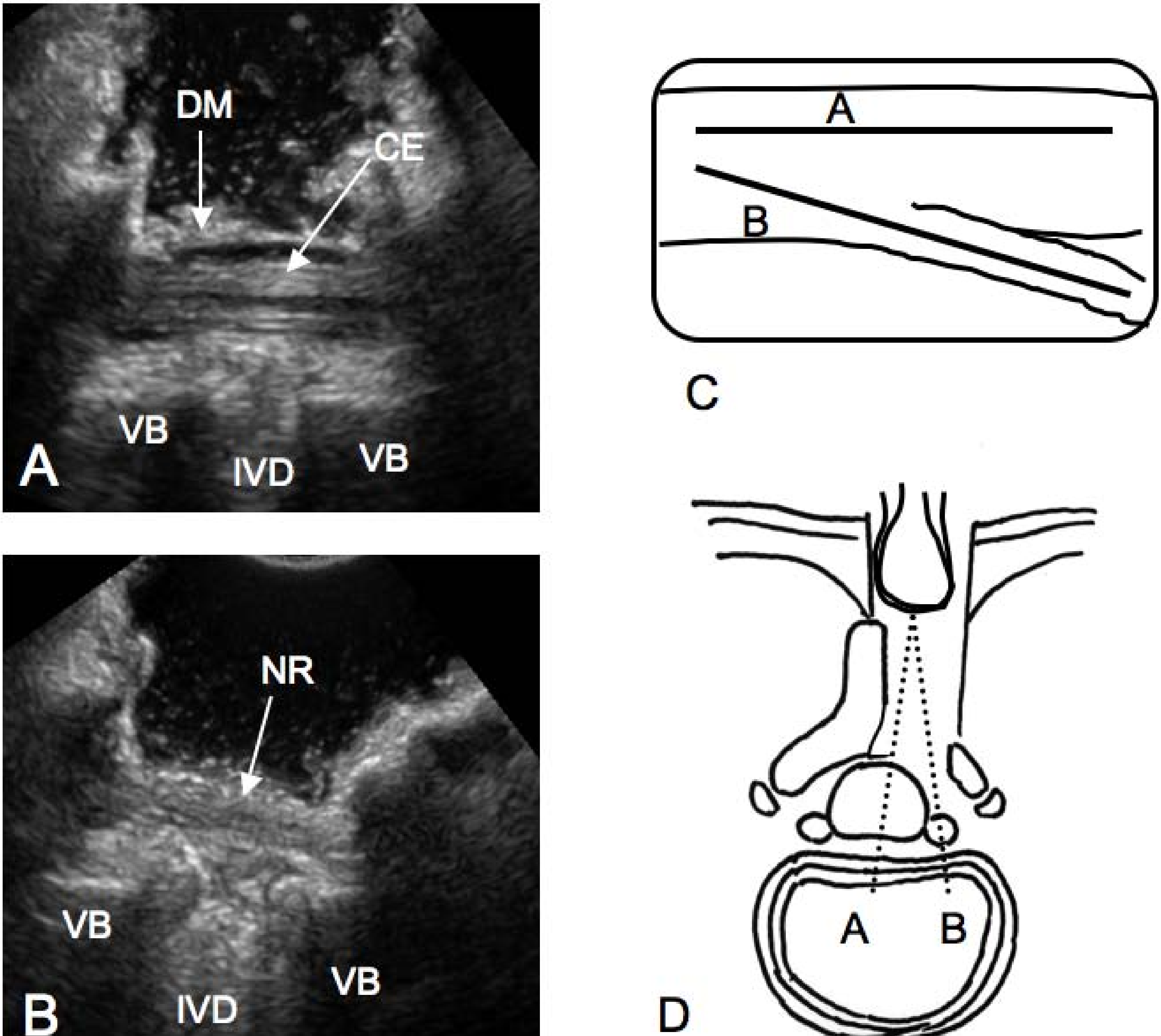
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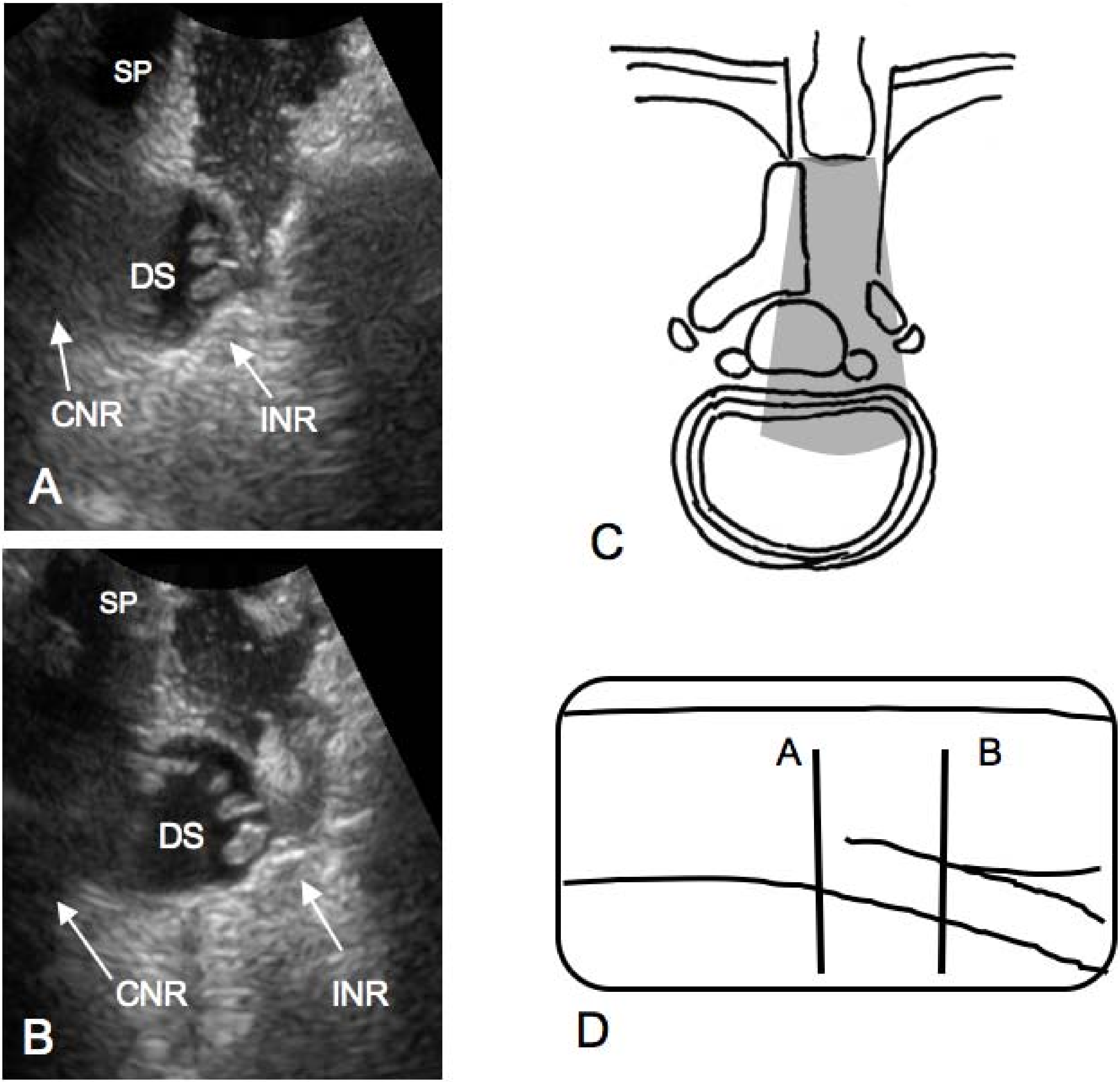
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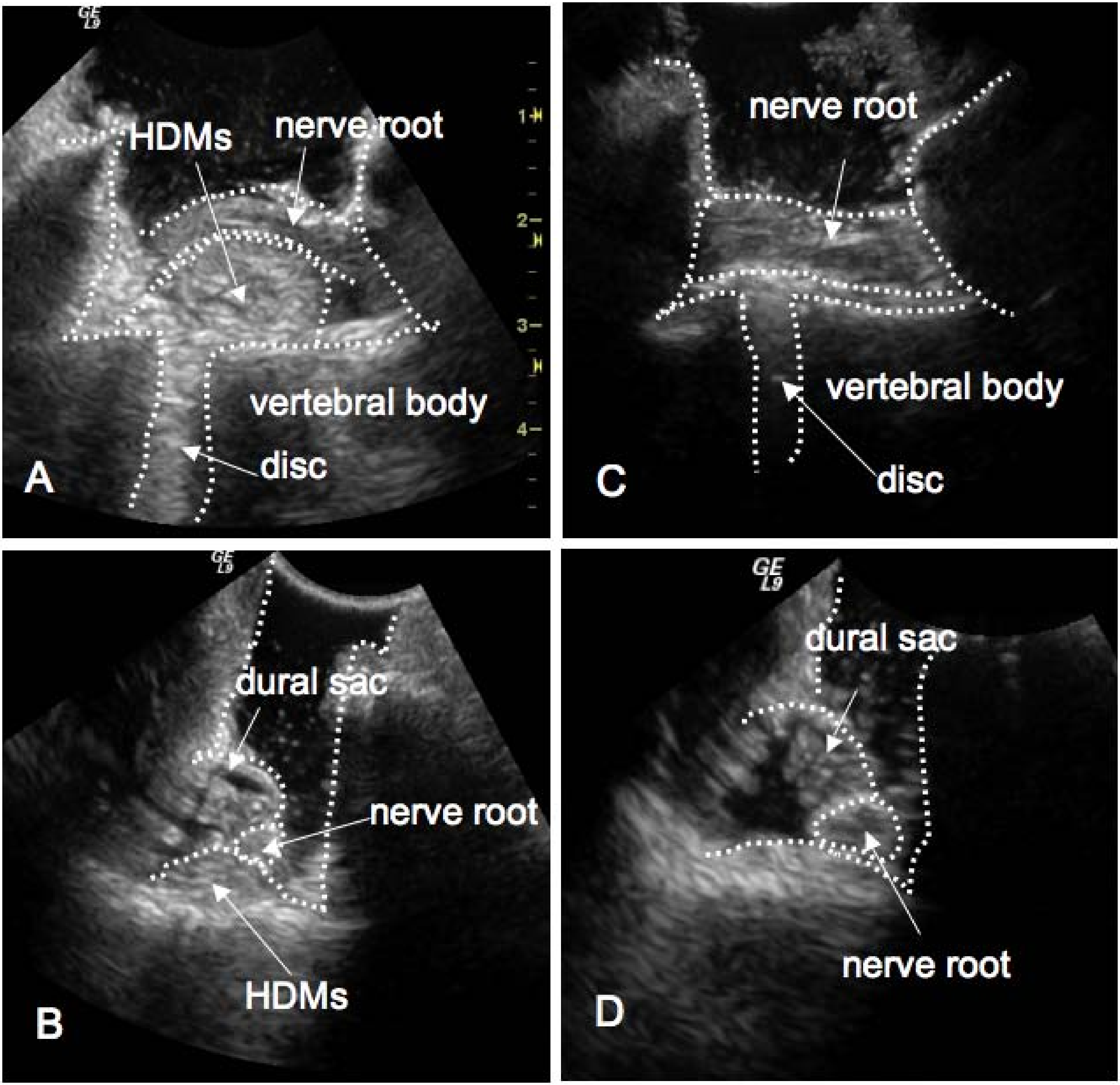

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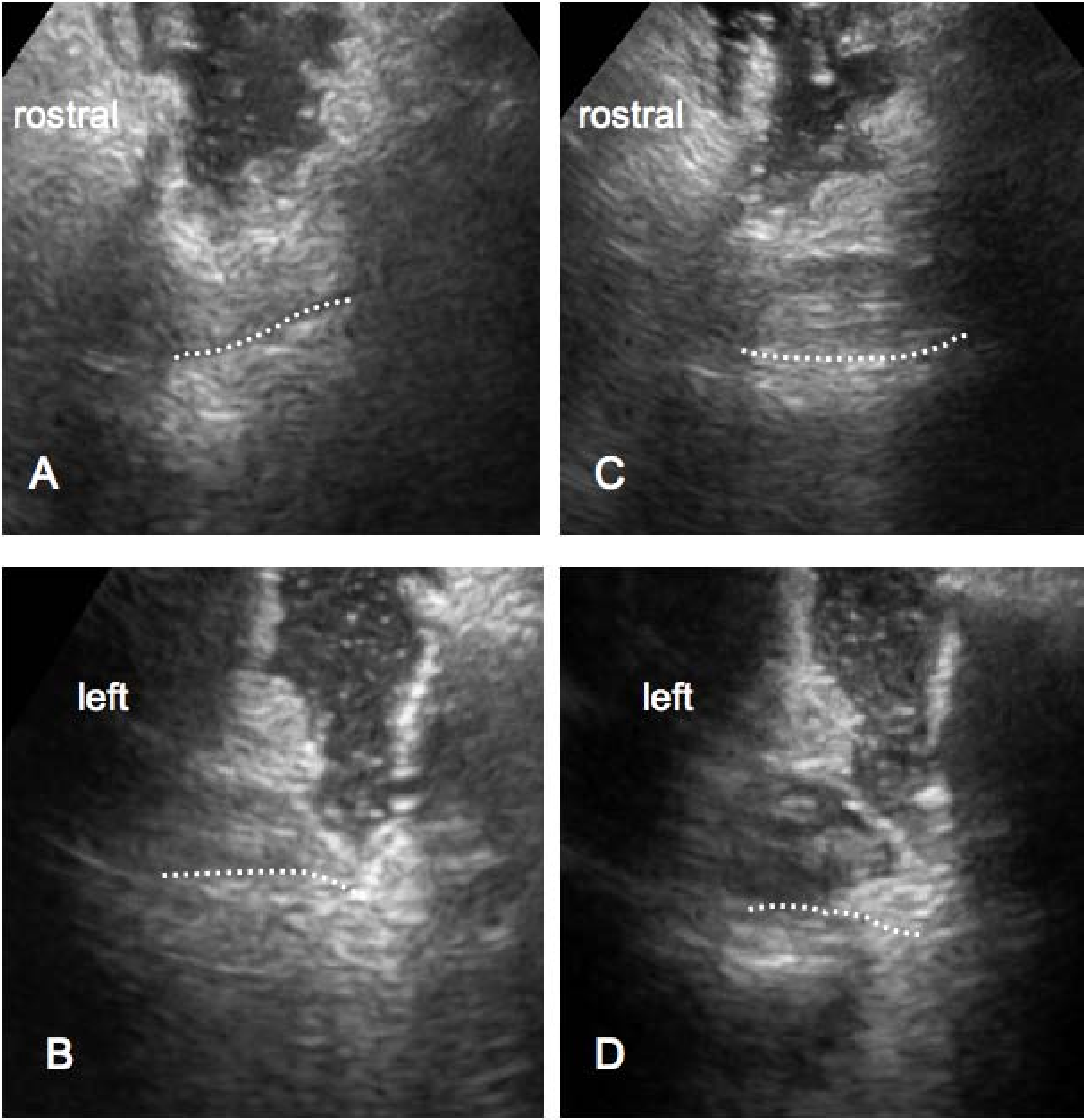
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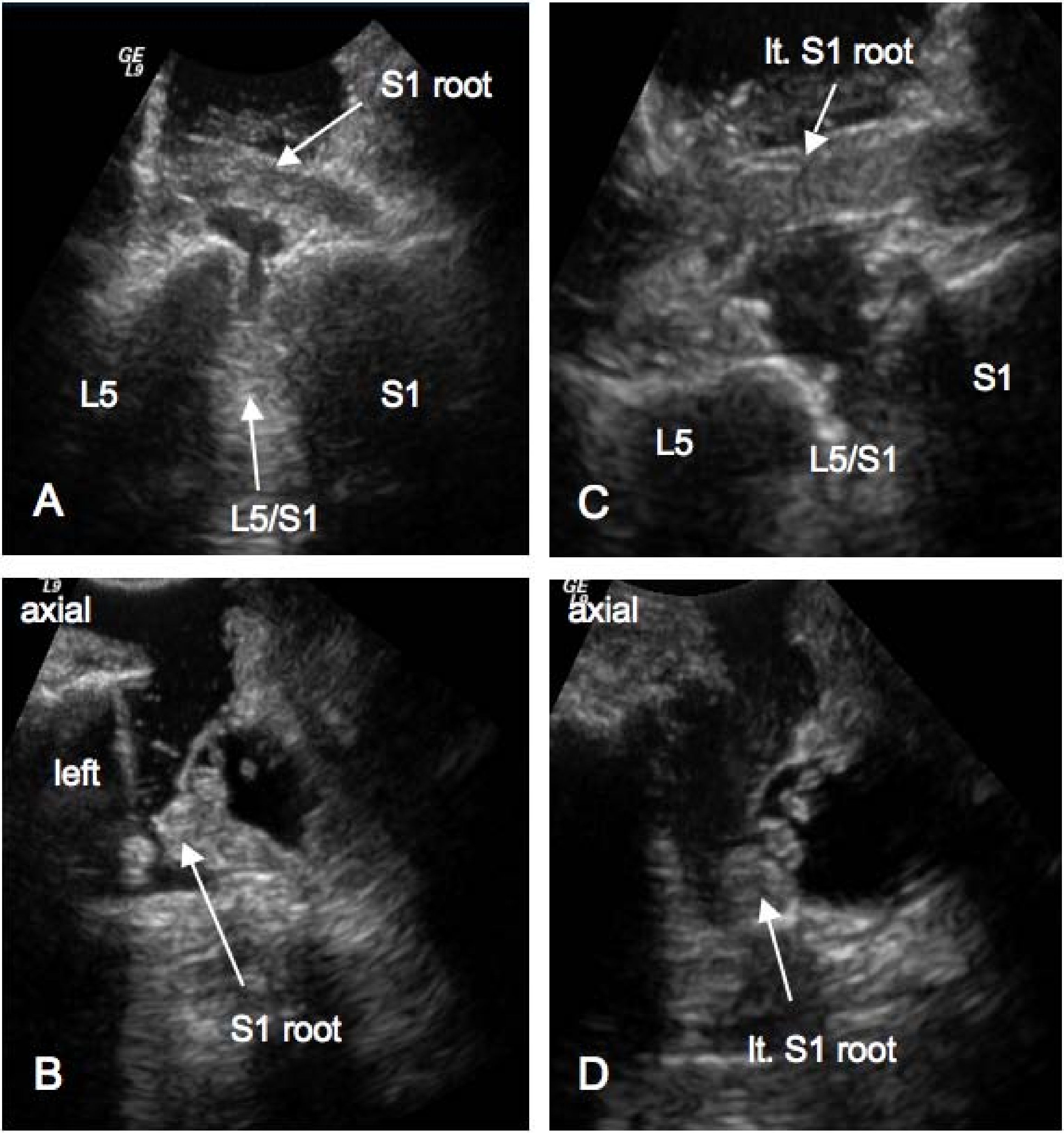
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