ULTRASONIC MEASUREMENT OF THE LUMBAR SPINAL CANAL

THE ORIGIN AND PRECISION OF THE RECORDED ECHOES

R. KADZIOLKA, M. ASZTÉLY, K. HANAI, T. HANSSON, A. NACHEMSON

From the Departments of Orthopaedic Surgery and Radiology, Sahlgren Hospital, University of Göteborg, Sweden

It has been shown that it is possible to determine the width of the lumbar spinal canal using ultrasound. Measurement with this technique on segments of cadaveric lumbar spine revealed that the ultrasonic echoes originated from the boundaries between the dural sac and the surrounding tissues at the level of the intervertebral disc. The width of the lumbar spinal canal as reflected by the ultrasonic echoes was about one millimetre less than the width of the dural sac as determined from a mould.

A new method of demonstrating the lumbar spinal canal was introduced by Porter, Wicks and Ottewell in 1978. An ultrasonic grey-scale B-scanning technique was used and the width of the spinal canal was measured from the picture of the echoes reflected from the canal. This method could be a valuable, simple, safe complement to other methods currently in use for the determination of the size of the spinal canal.

The present investigation was undertaken to clarify the structural origin of the recorded echoes and to determine the precision of the measurements.

MATERIAL AND METHODS

Ten fresh segments of lumbar spine (L1–5 or L2–5) were excised during routine necropsies. The segments were cleaned of all surrounding soft tissue except the ligamentous structures and the remaining parts of the cord and cauda equina excised from the spinal canal, care being taken not to damage the dural sac, which thus was left intact within the canal. The spinal canal was then plugged at its distal opening and placed in an upright position.

The canal was filled with a two-component silicone rubber (RSKO with hardener RSV, manufactured by H Röck Comp, Kircheim-Teck, BRD). This rubber is initially a liquid but sets at room temperature (20 to 25 degrees Celsius) within 15 minutes, becoming highly elastic and resistant to permanent deformation. No changes in size of the set rubber occur within the first 48 hours, but after seven days a shrinkage of up to 0.1 per cent may occur. These properties were tested by filling a bent tube with the silicone rubber. After setting, the rubber was pushed out of the tube and the mould that was removed regained the precise measurements of length and width of the casting tube.

The silicone rubber for use in the investigation was mixed with barium sulphate to provide radiographic contrast. No pressure was used in filling the canal and care was taken to avoid air bubbles within the rubber. The rubber was then left to set for up to 12 hours at room temperature. While the silicone rubber was still in the spinal canal the level of each vertebral disc was marked with needles on the corresponding part of the rubber mould. Anteroposterior and lateral radiographs of the segments were then taken (Figs 1 and 2).

Fig. 1
Anteroposterior and lateral radiographs of one segment of lumbar spine. The dural sac is filled with silicone rubber mixed with barium sulphate.

Fig. 2

Using slight pressure on its distal end the silicone rubber mould was then extruded from the canal (Figs 3 and 4). Each mould was then cut into slices four to five millimetres thick. The sagittal diameter of each slice and the right and left oblique diameters at 15 degrees from the sagittal diameter, were determined to the nearest 0.1 millimetre using a micrometer (Fig. 5). During these procedures care was taken to avoid any drying of the spinal segments, especially the dura.

Measurements of the spinal canal were made using pulsed
The silicone rubber mould of a dural sac. Figure 3—Anteroposterior view. Figure 4—Lateral view. Figure 5—The silicone rubber mould of the dural sac in slices four millimetres thick. The three dotted lines on the slice marked a represent the measured left and right sagittal diameter and the oblique diameters. The x-marked specimens are slices at the level of an intervertebral disc.

ultrasound emitted from a 2.25 megahertz transducer, and a static ultrasound scanner (Pho/Sonic-SM, Searle). The spinal segments were fixed in a water bath in a position that corresponded to that of a subject lying prone. The transducer was kept at a height above the segments that corresponded to the skin level. Scanning then took place in the longitudinal direction with the transducer 10 to 20 millimetres from the midline of the segment and inclined at an angle of 15 degrees to the sagittal plane (Porter et al. 1978). Small movements of the transducer in the longitudinal direction made it possible to obtain echoes from the spinal canal. Measurements were made of the matrix at both sides of the midline.

To determine from which level the echoes originated, metal markers were inserted at different positions in the spinal canal. In some specimens complete intervertebral discs, together with the dural sac, were excised and replaced by a piece of rubber of the same height to act as a spacer between the end-plates to maintain the interbody distance. Ultrasound measurements were then again performed.

Ultrasound measurements were then compared with the width of the spinal canal as determined from the lateral radiographic projection of the spinal segment, duly corrected for magnification; and with the three diameters determined from the slices of the mould.

RESULTS

When the lumbar spine was investigated with ultrasound, two horizontal echoes occurred opposite each other in each segment where there was an intact dural sac (Figs 6 to 8). Removal of the dura made the echoes appear more irregular and indistinct. Excision of the dura and the intervertebral disc, leaving the interbody distance intact, made the first, dorsal echo more indistinct (Fig. 9) while the second ventral echo

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Ultrasound investigation of a spinal segment in which the dura and the intervertebral disc have been excised but the intervertebral distance kept unchanged. The echoes became indistinct and some of the ultrasonic energy passed through the gap of the excised disc (arrow).
became even more irregular and indistinct; this was because some ultrasonic energy passed through the segment at the level of the gap (Fig. 9). The metal markers inserted into the spinal canal caused reflection of ultrasonic energy only when located at the apex of the intervertebral discs; elsewhere within the canal they caused no detectable echo.

At all levels and irrespective of which diameter was used for comparison, the ultrasound measurement of the width of the spinal canal was less than that of the silicone rubber mould, and thus of the dural sac, at the height of the intervertebral disc.

**DISCUSSION**

Ultrasound echoes are caused by reflection of the energy at the boundaries between two different media with different acoustic impedance. The bigger the difference in impedance the stronger the echo. From the anatomy of the lumbar spine it seemed probable that the strongest echoes would be reflected from the dorsal and ventral sites of maximal containment of the cerebrospinal fluid by the dura.

As can be seen from the lateral radiograph, the dural sac is not directly adherent to the bone at the posterior aspect of the vertebral body but separated from it by the epidural space (Fig. 6). This space is filled with fat and areolar tissue and a plexus of veins. If the ventral measureable ultrasound echo had arisen at the boundaries of this space and the bone, as proposed by Porter et al. (1978), the distance between the echoes would have been one to four millimetres greater than the distance we did in fact find in this study. Since, with a few exceptions, the distance was smaller than the width of the dural sac by 0.5 to 1.0 millimetres our findings strongly indicated that the echoes reflected the width of the dural sac (Fig. 10). The changes from distinct,

---

**Figure 10**—Analysis of measurements at the 36 positions investigated. The difference in millimetres is expressed as the mean and standard deviation between: **A**, the sagittal diameter of the dural sac and the lateral diameter of the spinal canal measured from the radiographs; **B**, the sagittal diameter of the dural sac and the ultrasound measurement from the left side; **C**, the left oblique diameter of the dural sac and the ultrasound measurement from the left side; **D**, the sagittal diameter of the dural sac and ultrasound measurement from the right side; **E**, the right oblique diameter of the dural sac and the ultrasound measurement from the right side. The horizontal line represents the size of the dural sac determined from the silicone rubber mould. **Figure 11**—The same differences expressed as percentages.

The absolute and percentage differences between the three diameters determined from the slices of the mould, the diameter of the spinal canal determined from the lateral radiographs and the ultrasound measurements at the 36 positions investigated are presented in Figures 10 and 11. In these comparisons, the diameters of the radiographs and the moulds were those determined at the level of the intervertebral discs. There were no statistically significant differences in these figures when the four different vertebral levels were compared separately.
regular and easily definable echoes into indistinct and
irregular ones after excision of the dura further
suggested that the measurable echoes originated from
the boundaries of the dural sac. The fact that reflection
of the energy from the inserted metal markers only
occurred when they were placed at the level of the
intervertebral disc also seemed to confirm that the
measurable echoes from the spinal canal were caused at
the level directly behind the disc. The existence of a
ventral echo, however atypical, after excision of the disc
(but with interbody distance unchanged) could imply
that this echo also reflected the spinal canal just above
and below the disc.

The ultrasound measurement did not always
correspond exactly with one of the three measured
diameters of the mould of the dural sac. Almost
complete agreement, however, was obtained when the
mean diameter of the dural sac was calculated from
several diameters measured in the same plane as the
ultrasound emissions and this mean used for comparison
with the ultrasound measurement (Fig. 12).

As pointed out by Eisenstein (1977) and also noted
in the present study the shape of both the bony spinal
canal and the dural sac changes with vertebral level.
Nothing in our results reflected this difference in shape,
nor was there a better or worse agreement between the
ultrasound measurement and the width of the dural sac
at different vertebral levels.

The precision of measurement with the ultrasound
technique was somewhat lower than in myelographic
investigations and gave less information on the shape of
the dural sac.

This study therefore confirms the work of Porter et
al. in 1978 showing that it is possible to visualise parts of
the spinal canal by an ultrasonic technique. The echoes
that were strongest and most easily measured were
found at the boundaries of the spinal liquor, and
occurred at the level of the posterior part of the
intervertebral disc. The dural sac was measured with an
accuracy varying between 90 and 95 per cent.

This work was supported by research grants from Grete and Einar Ask er's Foundation and the Swedish Medical
Association.

REFERENCES

Eisenstein SM. The morphometry and pathological anatomy of the lumbar spine in South African negroes and caucasoids with specific reference