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Anesthesiology Clin
26 (2008) 145–158

ANESTHESIOLOGY
CLINICS

Ultrasound-Facilitated Epidurals and Spinals in Obstetrics

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Regional anesthesia is currently the gold standard of practice for pain control in obstetrics, and it is unlikely that this will change soon. The search for improvements in the quality and safety of epidurals and spinals in obstetrics deserves therefore our closest attention.

Failures and complications of regional anesthesia can be related to many causes, one of the most important being the blind nature of such techniques. The practice of epidurals and spinals relies primarily on the palpation of anatomic landmarks that are not always easy to find. A good assessment of the spine includes a careful examination to be sure that the vertebrae are aligned, and to locate the iliac crests (Tuffier's line), lumbar posterior spinous processes, and interspaces. These landmarks identify the level of the spine at which the puncture will be performed and the optimal puncture site. Other important aspects of the spinal or epidural puncture, such as the angle of the needle during its insertion and the distance from the skin to the ligamentum flavum, cannot be assessed based on inspection and palpation. If a patient is overweight, has a curvature of the spine, or has any abnormal anatomy that is not visible or palpable, the spinal or epidural technique becomes not only blind, but also unpredictable. The somewhat unreliable nature of the technique can lead to complications, such as patient discomfort, trauma to various structures (nerves, vessels, ligaments, and bones), potential infectious risk from multiple attempts, failure, and accidental dural puncture with subsequent postdural puncture headache.

Failures and complications in spinals and epidurals can be minimized by optimal positioning of the patient, meticulous assessment of the anatomic landmarks, and refined technique. However, limitations still apply, notably

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doi:10.1016/j.anclin.2007.11.007 ***anesthesiology.theclinics.com***

the failure of clinicians to accurately determine the puncture level. When the accuracy of the puncture level determined by palpation is compared with that determined by MRI, clinicians are correct in their assessment only 30% of the time. Although they are only out by one space most of the time, this error in assessment can be as much as four spaces. The implications of such imprecision for the safety of the procedure are obvious, especially in case of spinal anesthesia [1,2].

Despite considerable improvement in the quality of needles, catheters, drugs, and delivery systems for epidurals and spinals, the technical aspects of the procedures have not evolved in the past 70 years. The techniques for identifying the epidural space currently in use were proposed by Dogliotti (loss of resistance) and Gutierrez (hanging drop) in the 1930s. The most common complication in labor epidurals, the accidental dural puncture, still occurs in up to 1.6% of cases, causing significant morbidity for the obstetric patient in the postpartum period [3].

Similar to the experience with peripheral nerve blocks, the ultimate advance in spinal and epidural techniques will only occur when we are able to have image-guided procedures. This will enhance precision and reduce complications, therefore improving patient outcomes and satisfaction. Ultrasound has recently been introduced into clinical anesthesia to facilitate lumbar spinals and epidurals [4,5]. The use of preprocedure ultrasound imaging or, eventually, real-time ultrasound guidance should improve not only clinical practice, but also teaching.

Spinal ultrasound is particularly challenging because the structures to be imaged are protected by a very complex, articulated encasement of bones, which affords a very narrow acoustic window for the ultrasound beam. In addition, the structures are located deeper than those we image when we use ultrasound for peripheral nerve blocks or the placement of central lines. There are, however, two useful acoustic windows for the assessment of lumbar spine sonoanatomy: One is accessed by using a transverse midline approach, the other by using a paramedian longitudinal approach [6,7]. The information from each of these two scanning planes complements the other. The ultrasound probe used for spinals and epidurals must be a low-frequency (2–5 MHz) curved probe. When compared with the high–frequency (10–15 MHz) linear probe, the low-frequency ultrasound penetrates deeper, which is more appropriate for this purpose. On the other hand, the image resolution is lower, which limits the precision of the assessment.

A thorough knowledge of the lumbar spine anatomy is necessary for the understanding of the sonoanatomy information being generated. The key elements visualized in the longitudinal and transverse approaches include boney structures and ligaments.

Anatomical elements identifiable by the longitudinal approach include:

- Sacrum
- Articular process

- Ligamentum flavum and posterior dura mater
- Anterior dura mater, posterior longitudinal ligament, and vertebral body

Anatomical elements identifiable by the transverse approach include:

- Spinous process
- Articular process
- Transverse process
- Ligamentum flavum and posterior dura mater
- Anterior dura mater, posterior longitudinal ligament, and vertebral body

With spinal ultrasound, only two patterns have to be recognized: one for the longitudinal paramedian approach, and the other for the transverse approach. This makes spinal ultrasound simpler to use than ultrasound for peripheral nerve blocks where different sonographic patterns have to be recognized. When using the longitudinal paramedian approach, a pattern appears that is commonly described in the literature as the ‘‘saw sign’’ (Fig. 1). As for the pattern of the transverse approach, I usually describe it as the ‘‘flying bat’’ (Fig. 2).

An accurate assessment of the sonoanatomy of the lumbar spine requires a systematic technique. For the longitudinal paramedian approach, the paramedian longitudinal scan is performed by positioning the ultrasound probe vertically, perpendicular to the long axis of the spine. The probe is initially placed over the sacral area, 3 cm to the left of the midline and slightly angled to target the center of the spinal canal. From this point, a continuous hyperechoic (bright) line representing the ultrasound image of the sacrum is visualized. The probe is then slowly moved cephalad until a hyperechoic sawlike image is seen (Fig. 3). The ‘‘saw’’ represents the articular processes (teeth of the saw) and the interspaces (spaces between the teeth), the latter consisting of the ligamentum flavum and posterior dura mater and, deeper in, the anterior dura mater, the posterior longitudinal ligament, and the vertebral

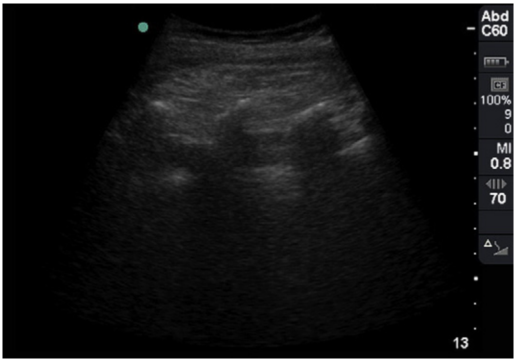

Fig. 1. Longitudinal paramedian view of the lumbar spine with the typical saw sign.

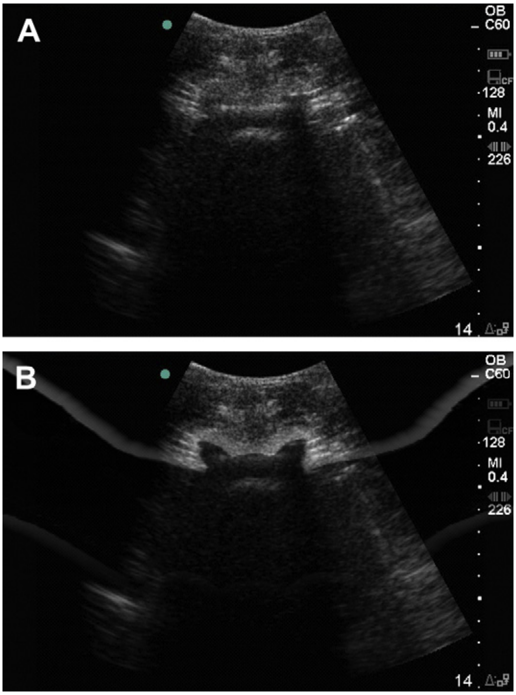

Fig. 2. Transverse view of a lumbar interspace shows a pattern that resembles a flying bat. (*A*) Actual image. (*B*) Artistic concept of the ''flying bat.''

body (Fig. 4). The exact level of each of the interspaces, L5-S1 to L1-L2, can then be marked on the skin to facilitate the rest of the examination.

For the transverse approach, a transverse scanning of each individual space can be performed once the interspaces are determined. This is accomplished by positioning the probe horizontally, perpendicular to the long axis of the spine, at the marked levels. With this approach, the midline of the spine corresponding to the spinous process is identified as a small hyperechoic signal immediately underneath the skin, which continues as a long triangular hypoechoic (dark) acoustic shadow (Fig. 5). The probe is then moved slightly cephalad or caudad to capture a view of an acoustic window (interspace). Within the interspace, on the midline, a hyperechoic band corresponding to the ligamentum flavum and the dorsal dura is visualized. A second hyperechoic band, parallel to the first band, corresponds to the anterior dura, the posterior longitudinal ligament, and the vertebral body. In addition, paramedian hyperechoic structures, corresponding to the articular and transverse processes, are also visualized via the acoustic window (Fig. 6).

The ultrasonographic assessment of the lumbar spine as described above helps the clinician determine the exact interspace for the puncture and the optimal insertion point. The determination of the optimal insertion point is

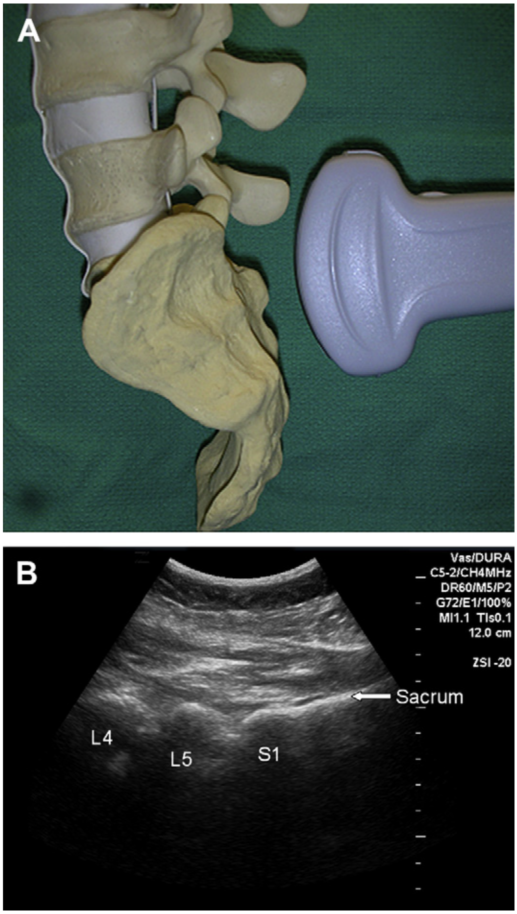

Fig. 3. Longitudinal approach, whether midline or paramedian, identifies the sacrum and the lumbar interspaces. (*A*) Orientation of the ultrasound probe. (*B*) Hyperechoic image of the sacrum and of the saw sign, which represents the articular processes of the lumbar vertebrae and the interspaces.

easily made with the transverse approach. Once the clear image of the interspace is obtained, the image is frozen. At that moment, with the probe kept steady, two marks are drawn on the skin, one coinciding with the center of the upper horizontal surface of the probe (midline) and the other coinciding with the middle point of the right lateral surface of the probe (interspace). The puncture site is determined by the intersection of the extensions of the two marks on the skin in the vertical and horizontal planes (Fig. 7). It is not easy to predict the angle at which the epidural needle should be advanced during placement. In the author's experience, a reliable technique is to ensure that the needle should follow the same angle at which the best image of the "flying bat" was captured. This technique is based on the premise that,

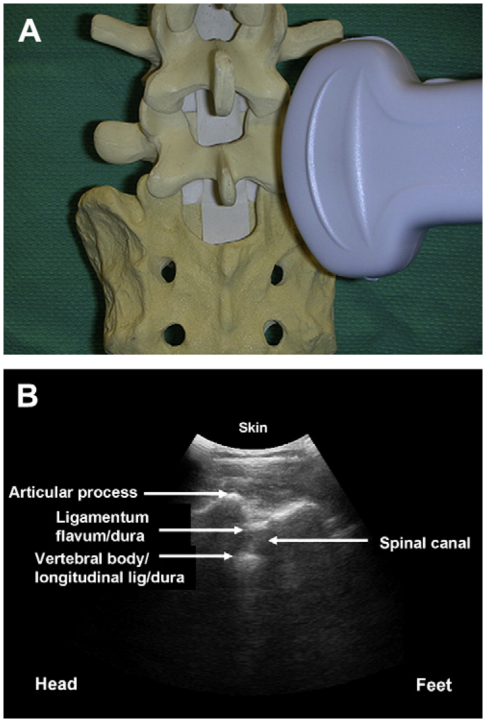

Fig. 4. Longitudinal paramedian approach with the typical saw sign. (*A*) Orientation of the ultrasound probe. (*B*) Hyperechoic image of the articular processes, the ligamentum flavum–posterior dura mater unit, and the anterior dura mater–posterior longitudinal ligament–vertebral body unit. The spinal canal can be seen between the anterior and posterior dura mater.

because the ultrasound beam penetrates without being distorted, it provides a good path for the needle to follow.

With the aid of a built-in caliper, the distance from the skin to the epidural space can be measured. This is helpful in determining the distance from skin to dura and assists the regionalist in needle placement and depth perception. With the current resolution offered by portable ultrasound machines, the captured image of the ligamentum flavum and posterior dura mater appears as a single unit. At present, the distance from the skin to the inner side (ie, the deepest border of this ligamentum flavum–posterior dura mater unit) is standardized to represent the actual needle depth (Fig. 8). The built-in caliper can also be used to measure the antero-posterior diameter of the dural sac, which might be useful information in the practice of techniques, such as spinal and combined spinal-epidural anesthesia.

Although it has been suggested that the paramedian longitudinal approach is the best acoustic window in spinal ultrasonography [6], the transverse approach is more useful in clinical practice, especially if the midline approach is to be used for the puncture, which is the norm. the author's experience,

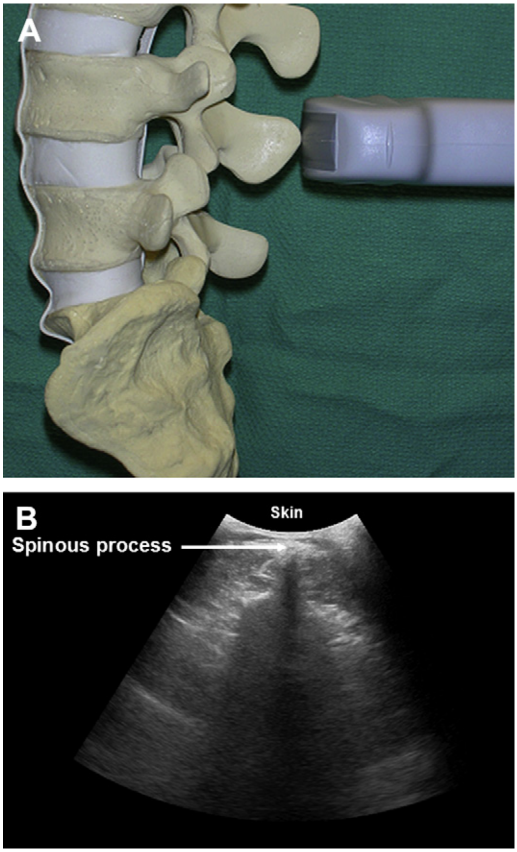

Fig. 5. Transverse approach at the tip of the spinous process easily identifies the midline of the spine. (*A*) Orientation of the ultrasound probe. (*B*) The tip of the spinous process appears as a small hyperechoic structure immediately beneath the skin, and determines a long vertical black hypoechoic shadow.

the paramedian longitudinal approach has been used to determine the level of the puncture. In some cases, especially where the quality of imaging is compromised or where there is a need of confirmation of a certain structure, the paramedian longitudinal approach is beneficial. It is therefore advisable that the anesthesiologist should be familiar with both approaches.

Based on the information provided by the ultrasound, anesthesiologists can determine the optimal insertion point, the estimation of the angle to be used, and the calculation of the distance from the skin to the epidural space. In addition to the loss of resistance, these are key factors in performing an uneventful puncture.

In a previous study done at Mount Sinai Hospital, the accuracy of the insertion point has been shown to be very high. When the preprocedural scanning is done with the above technique, there is no need to reinsert the

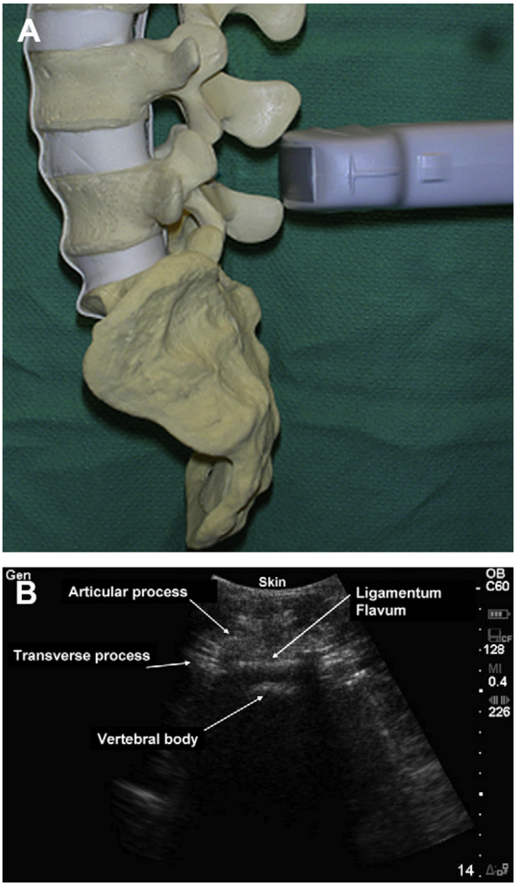

Fig. 6. Transverse approach at a lumbar interspace shows the typical "flying bat" sign. (*A*) Orientation of the ultrasound probe. Arrow indicates (*B*) Ligamentum flavum–posterior dura mater unit and anterior dura mater–posterior longitudinal ligament–vertebral body unit are seen as hyperechoic structures on the midline. Articular processes and transverse processes are seen as paramedian hyperechoic structures and determine corresponding acoustic shadows.

epidural needle in 91.8% of the patients, and no need to even redirect the needle in 73.7%. In our experience, the successful identification of the epidural space is accomplished with two or fewer redirections in 96.7% of the cases [7]. The precision of the estimation of the distance to the epidural space is also remarkable. In our series of 60 obstetric patients, we found that the mean difference between the distance estimated by the ultrasound and the actual needle depth was 0.01 (±0.345) cm, with a 95% limit of agreement for the difference between the two measurements being −0.666 to +0.687 cm. The epidural space depth determined by ultrasound was 4.66 (±0.68) cm (range 3.43–6.91 cm), whereas the one determined by the actual needle was 4.65 (±0.72) cm (range 3.5–6.5 cm) [7].

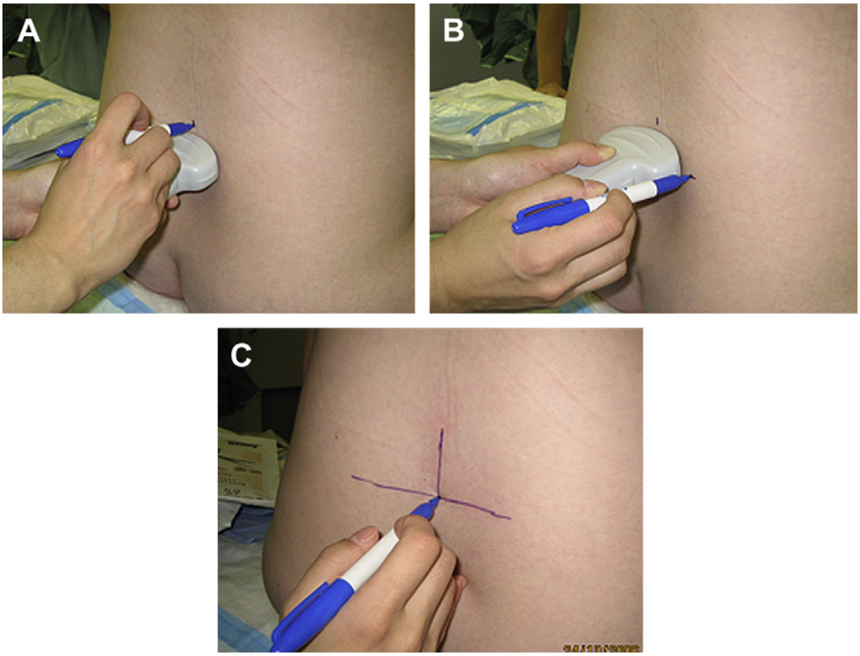

Fig. 7. The insertion point is determined by the intersection of the extensions of the two marks on the skin in the vertical and horizontal planes, one for the midline, the other for the interspace.

The sonoanatomy described above represents the normal findings with this new technology. Ultrasound technology has major benefits when it comes to dealing with parturients with altered anatomy. Two of these conditions are worth highlighting: obesity and scoliosis.

Obese patients can introduce some degree of difficulty to the use of spinal ultrasound. Image quality depends on how much fat tissue exists between the skin and the tip of the spinous process. In addition, if the distance to the ligamentum flavum is too great, the sharpness of the image can be compromised, but appropriate visualization is still possible (Fig. 9). In some patients, the tip of the spinous process is located more than 5 cm from the skin. The ligamentum flavum can be as deep as 8 cm, with extremes of 11 to 12 cm. One important detail while scanning obese patients is to estimate the degree of compression that the subcutaneous tissue allows. This is easily demonstrated on the ultrasound screen by compressing and relieving the subcutaneous tissue with the ultrasound probe. If the distance from the skin to the epidural space is measured during the compression of the subcutaneous tissue, such measurement will considerably underestimate the actual needle depth. One should therefore relieve the pressure on the skin, freeze the image, and measure, thereby ensuring a much better correlation between the measurements determined by both ultrasound and

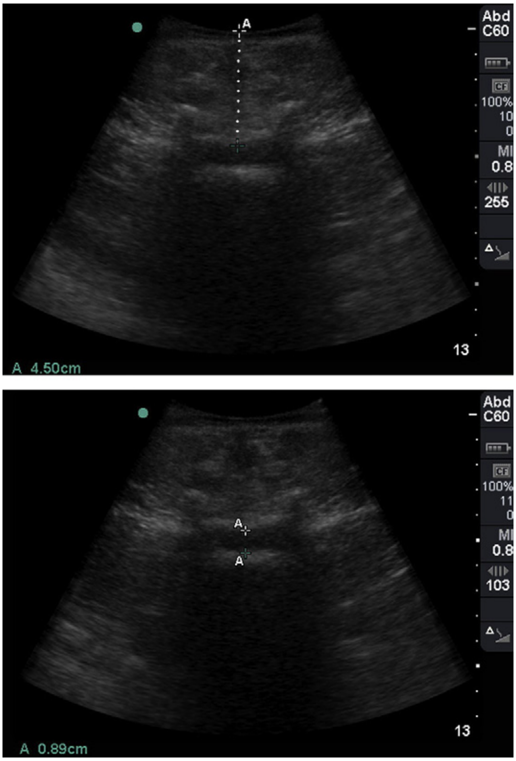

Fig. 8. Estimation of the needle depth (*dotted line*) by ultrasound with the aid of the built-in caliper. The author recommends positioning the caliper at the inner side (ie, the deepest border of the ligamentum flavum–posterior dura mater unit) (*top image*). The built-in caliper can also measure the antero-posterior diameter of the dural sac (*bottom image*). (*A*) Position of caliper.

needle. The vast majority of obese patients have the epidural space located at a maximum of 8 cm from the skin if the puncture is done at the optimal insertion point. The clinical implication of this information is that with the aid of ultrasound, an extra-long spinal or epidural needle is not likely necessary. Preprocedural scanning is helpful in determining the need for special needles. In some cases, the quality of the image obtained at 8 cm from the skin can be compromised in the transverse approach. In these cases, the distance from the skin to the ligamentum flavum can be double-checked with the longitudinal paramedian approach, which offers a sharper image of the ligamentum flavum and dura mater in this subset of patients. Measurements obtained with the midline approach and the paramedian approach are slightly different, either a few millimeters longer or shorter, depending on how much subcutaneous tissue fills the paraspinal groove. An additional advantage of ultrasound in these patients is its usefulness for positioning the patients appropriately. By viewing real-time ultrasound, minor changes in

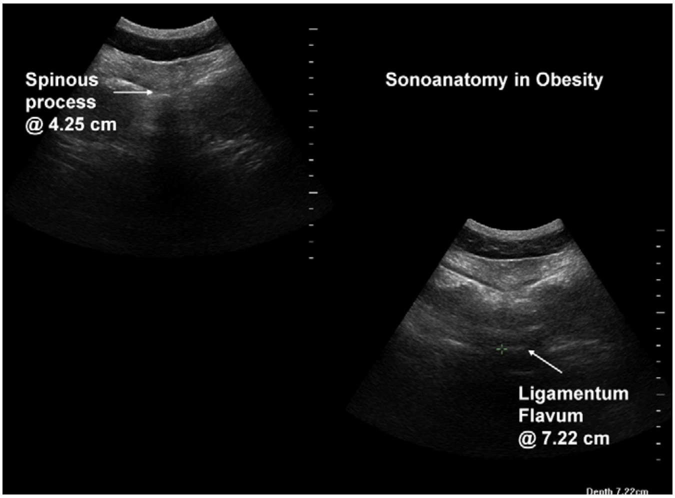

Fig. 9. Sonoanatomy of the lumbar spine of an obese patient. Note that the tip of the spinal process is 4.25 cm from the skin and 7.22 cm from the ligamentum flavum–posterior dura mater unit. If significant compression of the subcutaneous tissue is applied during the ultrasonographic assessment, a significant underestimation of the distance will occur.

patient position can make huge differences in opening up interspinous spaces and ensuring minimal spinal rotation or lateral flexion.

Patients who have scoliosis also present challenges. Scoliosis is not only associated with lateral curvatures of the spine on the longitudinal plane, but also with different degrees of rotation around the longitudinal axis. These abnormalities are frequent causes of difficult epidurals and spinals. In many cases, accurately determining the optimal puncture site is impossible without the use of the ultrasound. This is especially true in overweight patients in which the palpation is compromised. The abnormal interspace shows asymmetry of the bony structures, with asymmetric articular processes. In addition, one of the typical parallel hyperechoic lines corresponding to the ligamentum flavum and the vertebral body is either incomplete or missing (Fig. 10). When possible, these abnormal interspaces should be avoided and a space with preserved anatomy should be sought. In the past, a radiograph was needed to determine the optimal space in patients with scoliosis. Today, with the use of ultrasound, this can be avoided. Additionally, corrective surgery for scoliosis can obliterate potential spaces and the use of ultrasound can assist the anesthesiologist in optimal site selection.

Abnormal anatomy can be present in patients for reasons other than obesity and scoliosis. Patients with previous spine surgery may have extensive destruction of bony and soft tissue, with substitution by scar tissue. However, even in the presence of extensive spinal surgery, it is almost always possible to identify a space with preserved anatomy and therefore

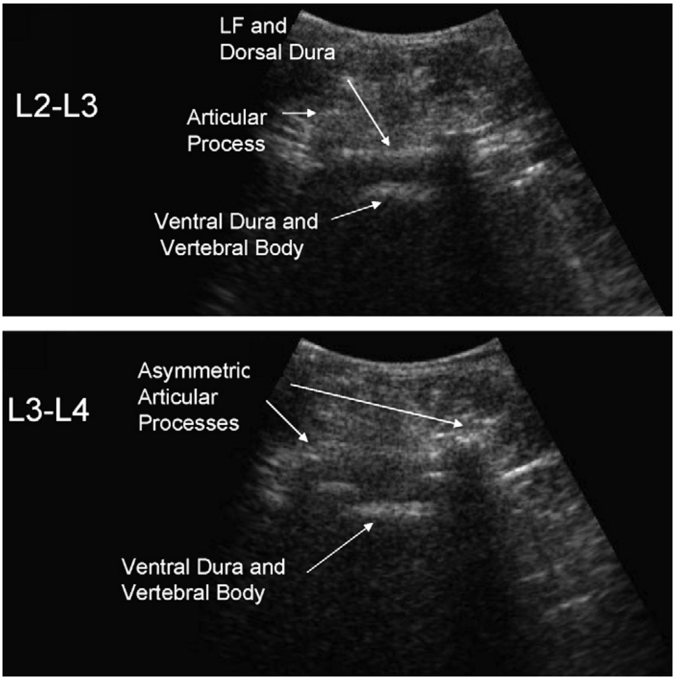

Fig. 10. Sonoanatomy in severe scoliosis. Sonoanatomy is typical and normal at L2-L3, while at L3-L4 articular processes are grossly asymmetric and the ligamentum flavum is not seen.

make regional anesthesia, such as a spinal, still possible. A promising application of ultrasound is for detecting abnormal sonoanatomy of the ligamentum flavum and thus to possibly avoid accidental dural puncture. In comparing patients with history of previous accidental dural puncture with patients who also had epidurals but without dural puncture, investigators at Mt. Sinai Hospital have found a much higher than normal incidence of abnormal ligamentum flavum on ultrasonography in the group with dural puncture. Although no clear explanation can be offered for these findings at present, it has been the author's practice to avoid the puncture of spaces in which the ligamentum flavum is either not seen or appears abnormal on ultrasound. The author hypothesizes that widespread use of ultrasonography may decrease the number of accidental dural punctures.

The advantages of ultrasound in assisting the placement of epidurals and spinals have been discussed in a few publications. Grau and colleagues [8] have determined that, compared with the epidurals done with the conventional palpatory method, ultrasound-assisted blocks are associated with fewer attempts during the procedure, greater efficacy, and higher patient satisfaction. This has been shown to be true not only in patients with spines that are considered easy for placement, but also in subgroups of patients with spines considered difficult for placement, such as patients with scoliosis, accentuated lordosis or kyphosis, or obesity [9].

The limitations of ultrasound use are confined to time, cost, and technical limitation. However as experience develops, many of these can be overcome with the promise of improved reliability.

The advantages of the use of ultrasound-assisted epidurals and spinals go far beyond routine clinical practice. Ultrasound is an accurate and extremely helpful teaching tool. Grau and colleagues [10] have shown that the learning curve for administering epidurals can be significantly improved when these procedures are done under ultrasound. As compared with the standard palpatory method, the ultrasound-assisted technique is associated with a higher success rate at all stages of the learning curve.

The use of sonoanatomy of the spine may well be a breakthrough in the practice of regional anesthesia. Research possibilities with this new tool are phenomenal. The author recently attempted to correlate the antero-posterior diameter of the dural sac with the spread of spinal anesthesia in cesarean deliveries [11]. Although not successful on the first attempt, it is believed that preprocedural scanning will allow for a better understanding of the physiology and pharmacology of epidural and spinal anesthesia.

Another fascinating possibility is the development of a ‘‘difficult spine score,’’ similar to what has been developed for difficult intubation. Preprocedural assessment of the patient’s spine will allow better planning and will, it is hoped, lead to better outcomes and greater patient satisfaction.

Finally, despite the obvious technical difficulties, it has been suggested that real-time spinal ultrasound can actually be used to guide the needle insertion [12] and even to detect position of vessels in the needle trajectory with the aid of Doppler [13]. Although these possibilities are fascinating, they do face important limitations. In the case of real-time ultrasound, an assistant is needed to capture the image of the interspace with a paramedian longitudinal approach while the primary anesthetist performs the needle insertion via midline approach. In the case of detection of vessels, the limiting factor is the extremely low blood flow in the epidural vessels, which makes imaging more difficult.

In summary, the preprocedural ultrasonographic assessment of the lumbar spine provides valuable information for the placement of spinals and epidurals, by determining:

- The exact interspace (level) at which the puncture will be performed, which is especially important in spinal anesthesia
- The best interspace (the clearest sonoanatomy)
- The ideal insertion point
- The angle of the puncture
- The depth of the epidural space
- Any abnormalities of the anatomy (eg, scoliosis)

This fascinating new tool will considerably improve the technical aspects of spinal and epidural techniques, with the following possible benefits:

When used as a teaching tool, it facilitates the learning curve and increases safety.
It shortens the duration of the procedure.
It increases the comfort of the procedure.
It decreases the number of attempts and the subsequent trauma.
It decreases the number of accidental dural punctures.
It forecasts difficult epidurals (similar to difficult intubations).
It transforms difficult epidurals into easy epidurals.
It helps the clinician in choosing the best equipment for the spinal/epidural.

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