

Review Article

Pre-Procedure Neuraxial Ultrasound in Obstetric Anesthesia

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ABSTRACT

Aim of review: To determine the current state of pre-procedure neuraxial ultrasound in obstetric anesthesia practice.

Methods: The PubMed and Scopus databases were searched for the keywords “neuraxial”, or “epidural”, or “spinal” or “ultrasound”, combined with “obstetric anesthesia”. A current review of original studies, systematic reviews, and meta-analysis within the past decade were included in the analysis.

Recent findings: Pre-procedure ultrasound imaging enhances successful neuraxial placement through determination of the optimal vertebral interspace, identification of the midline, location of the optimal insertion point, best angle for needle insertion, and accurate depth for needle advancement to the epidural or intrathecal space. In the experienced clinician, neuraxial ultrasound imaging can be of particular benefit in parturients with difficult anatomy and/or landmarks.

Conclusion: Neuraxial ultrasound imaging reduces the risk of failed or traumatic lumbar punctures and epidural catheterizations, the number of insertion attempts, and needle redirections. (Funded by the Departments of Medical Education and Anesthesiology, West Virginia University School of Medicine.)

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Obstetric patients present unique challenges in providing neuraxial (spinal or epidural) blockade. Neuraxial anesthesia offers analgesia and anesthesia for labor, vaginal delivery, cesarean section, and is considered the gold standard because of its limited effects on both the mother and fetus. Neuraxial analgesia/anesthesia relies primarily on the palpation of anatomical landmarks, which can be obscured in the setting of obesity, edema, and anatomical variation (1). Pregnancy is associated with generalized tissue edema, weight gain, and an exaggerated lordosis which can make palpation and identification of anatomic landmarks very challenging. Furthermore, the hormonal changes of pregnancy cause

ligaments to soften which can alter the tactile sensation of the dural ligament making the epidural space harder to identify. These changes narrow the epidural space causing the intrathecal space to become smaller increasing the risk for inadvertent dural puncture (2). Parturients may also have difficulty achieving and maintaining adequate flexion of the lumbar spine for neuraxial insertion because of the gravid uterus and/or severe pain from contractions (2). None-the-less, repeated needle insertions and redirections can further increase the pain and discomfort already experienced by the parturient in labor (1).

Ultrasound imaging for clinical procedures has gained increased popularity this past decade

Table 1. Available Data Obtained from Neuraxial Ultrasound

1. Accurate interspace identification
2. Establish midline
3. Estimate depth to the epidural space
4. Determine optimal interspace and best insertion space
5. Angulation of the Tuohy/Husted needle

Table 2. Improved Efficacy of Neuraxial Ultrasound

1. Reduces the number of epidural attempts, redirects and levels attempted
2. Decreases epidural catheter replacements
3. Improved analgesia
4. Higher maternal satisfaction

mainly because ultrasound imaging is relatively cheap, compact, readily available for point of care testing, involves no radiation, and supplements the relevant anatomical information already obtained using standard palpation techniques (1). Multiple clinical studies have determined that neuraxial ultrasound imaging can be used to identify the intervertebral space(s), the midline for insertion, determine the depth from the skin to the epidural space, the best needle insertion point, and the best angle for needle insertion (Table 1) (1-5). In 2013, a meta-analysis of multiple clinical studies involving neuraxial ultrasound concluded that ultrasound imaging can reduce the risk of failed or traumatic lumbar punctures and epidural catheterizations, as well as the number of insertion attempts and needle redirections (1).

Pre- Procedural Neuraxial Ultrasound versus Standard Blind Technique for Labor Epidural Insertion

Several clinical studies have reported that neuraxial pre-procedural imaging decreases the number of attempts required for epidural placement, determines the optimal puncture site and needle angulation, and accurately predicts the depth from the skin to the epidural space (2, 5). Superior epidural catheter function and fewer replacement rates are other reported benefits of ultrasound-guided epidural placement (Table 2) (2, 5). Multiple and difficult needle placement attempts as

well as altered hemostasis are all associated with increased risk for epidural hematoma (6). Furthermore, repeated multiple epidural and spinal attempts has been shown to be an independent risk factor for persistent post-surgical low back pain in non-obstetric surgical patients (2, 7).

In a systematic review and meta-analysis by Shaikh et al. (1) of randomized controlled trials to determine whether pre-procedural ultrasound imaging can reduce the risk of failed lumbar punctures or epidural catheterizations, the number of traumatic procedures, insertion attempts, and needle redirections when compared with standard blind technique, they determined ultrasound imaging can reduce the risk of failed procedures (risk ratio 0.21, 95% confidence interval (CI); 0.10 - 0.43, $P < 0.001$), lumbar punctures (risk ratio 0.19, 95% CI; 0.07 - 0.56, $P = 0.002$), epidural catheterizations (risk ratio 0.23, 95% CI: 0.09 - 0.60, $P = 0.003$), traumatic procedures (risk ratio 0.27, 95% CI: 0.11 - 0.67, $P = 0.005$), number of insertion attempts (mean difference -0.44 (-0.64 to -0.24), $P < 0.001$), and number of needle redirections (mean difference -1.00 (-1.24 to -0.75), $P < 0.001$) (1). Shaikh et al. (1) concluded ultrasound imaging can reduce the risk of failed or traumatic lumbar punctures and epidural catheterizations, as well as the number of needle insertions and redirections (Table 2).

Another demonstrated benefit of neuraxial ultrasound imaging is for novice resident training as a teaching tool. It has been shown to improve the epidural placement learning curve by increasing the epidural success rate, and reducing the number of epidural attempts and catheter replacement for failed labor analgesia (4, 5, 8).

Pre-Procedural Ultrasound for Combined Spinal Epidural (CSE) Technique

Pre-procedure ultrasound imaging has proven useful in the Combined Spinal Epidural (CSE) technique. Nassar and Abdelazim (3) compared 110 women scheduled for normal vaginal delivery, randomized into a palpation group, and an ultrasound guided group to detect the efficacy of pre puncture ultrasound before CSE to detect successful CSE procedure on the first attempt and to

reduce the number of attempts or punctures during insertion of the epidural catheter. They found the percentage of successful CSE procedures on the first attempt was significantly higher (67.3 %) in the ultrasound group compared to palpation group (40.0 %, $P = 0.04$). Additionally, the number of puncture attempts were significantly less in the ultrasound group (1.2 ± 0.6) compared to the palpation group (2.3 ± 0.8 , $P = 0.04$), and the number of redirections was also significantly less in the ultrasound group (1.4 ± 0.5) compared to the palpation group (2.8 ± 1.6 , $P < 0.001$). Only the time needed to identify the puncture site was significantly longer in the ultrasound group (3.0 ± 0.8 min) compared to the palpation group (0.4 ± 0.2 min, $P < 0.001$). Total procedure time (identification time + procedure performance time) was found to be longer in the ultrasound group (9.1 ± 1.5 min) compared to the palpation group (6.2 ± 1.2 min), however, it was not statistically significant ($P > 0.05$) (3). They concluded pre-puncture ultrasound for CSE increases successful CSE procedure on the first attempt, and reduces the number of attempts during CSE catheter insertion (3).

Pre-Procedure Ultrasound Technique

Ultrasound-guidance for neuraxial placement is most commonly performed before the procedure to establish landmarks and orientation. A low-frequency (2–5 MHz) curved array transducer (the same transducer used by obstetricians for fetal scanning of the uterus) is used for the procedure (5, 9, 10). This low-frequency probe allows deeper penetration of tissues to target the structures of interest, but sacrifices resolution and precision of the image. An initial depth setting of 7–8 cm is appropriate for most patients, but the depth, focus, and gain settings of the ultrasound machine should be adjusted as needed during the scanning process to produce an optimal image (10).

Pre-Procedure Step-by-Step Assessment of the Lumbar Spine

Ultrasound scanning of the lower back is usually performed both in the longitudinal (Figure 1

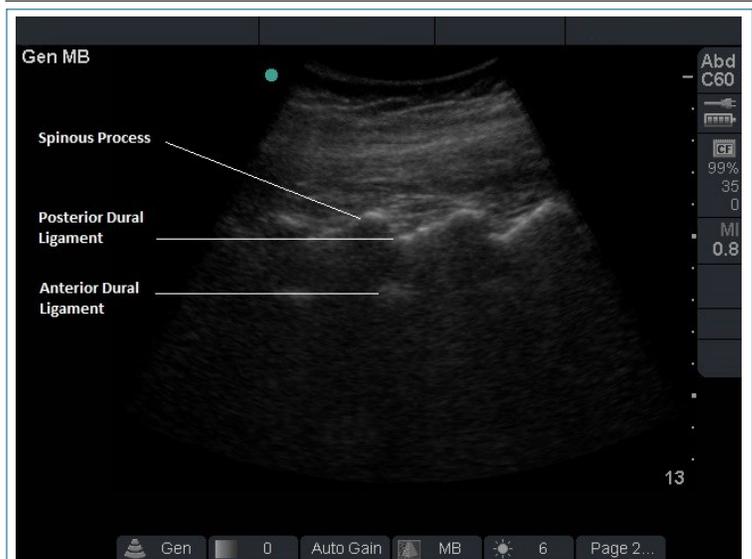


Figure 1. Ultrasound Image in The Longitudinal L3-L4 Median Plane.

The ligamentum flavum, epidural space, and posterior dura appear together as the “posterior complex”; the anterior dura, anterior longitudinal ligament, and posterior aspect of the vertebral body appear together as the “anterior complex” (see text for details); Blue dot is oriented in the cranial direction.



Figure 2. View of The Ultrasound Probe in The Skeletal Longitudinal Plane.

and Figure 2) and transverse planes (Figure 3 and Figure 4).

Longitudinal paramedian oblique view

The structures identified in this view include the

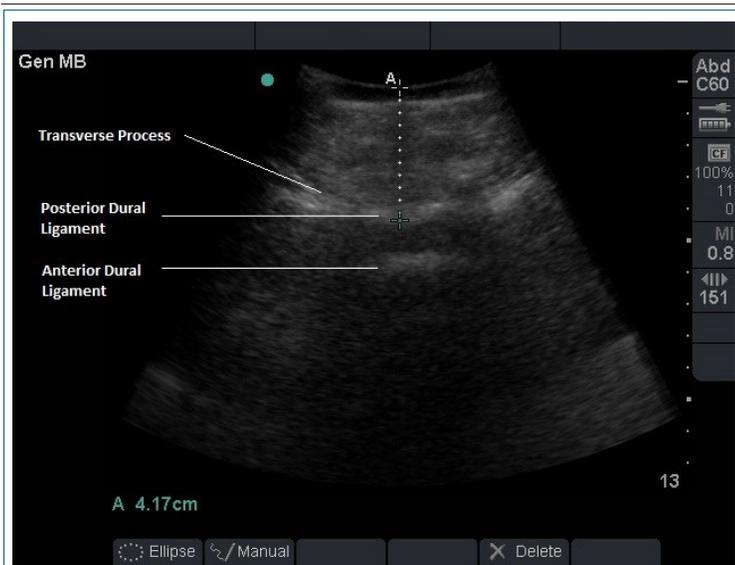


Figure 3. Ultrasound Image in The L3-L4 Transverse Plane. The ligamentum flavum, epidural space, and posterior dura appear together as the “posterior complex”; the anterior dura, anterior longitudinal ligament, and posterior aspect of the vertebral body appear together as the “anterior complex”.

as a single linear hyperechoic structure, which is termed the posterior complex (10). Similarly, the anterior dura, anterior longitudinal ligament, and posterior aspect of the vertebral body or the intervertebral disc also appear as a single linear hyperechoic structure and is collectively referred to as the anterior complex (10). The transducer is positioned vertically 1–2 cm lateral to the spinous process and the ultrasound beam is directed obliquely toward the midline. The spinal canal is visible between the interlaminar spaces. The delineating structures are the ligamentum flavum and dura mater posteriorly and the posterior vertebral body cortex and posterior longitudinal ligament anteriorly. The epidural space appears as a thin hypoechoic line between two hyperechoic lines produced by the ligamentum flavum extending between the laminae and the posterior dura mater located at a deeper level.

Longitudinal median view

This view visualizes the spinous processes and identifies the vertebral levels. The structures identified include the sacrum, articular process, ligamentum flavum and posterior dura mater, anterior dura mater, posterior longitudinal ligament, and vertebral bodies (Figure 1 and Figure 2). The transducer is placed on the midline, along the spinous processes, in the longitudinal direction. The spinous processes are seen as a series of hyperechoic lines with upward convexity and posterior acoustic shadowing. The sacrum is seen as a flat continuous hyperechoic line compared to the more convex spinous processes. Counting the spinous processes or laminae upward from the sacrum is more accurate than clinical estimation using the traditional method via the intercrystal line (10). Moving up the superior edge of the sacrum, the L5-S1 interspinous space can then be identified. The L5 spinous process is a useful landmark, as it is often smaller and more pointed than the other spinous processes, which are increasingly flat and wide from L4 to L1. In each interspinous space, the ligament is visible as a hyperechoic structure. If the interspinous space is sufficiently wide, the epidural space and spinal canal can be seen.

Transverse median view

In this view, the spinous process, laminae, articu-



Figure 4. View of The Ultrasound Probe in The Skeletal Transverse Plane.

sacrum, articular process, ligamentum flavum and posterior dura mater, posterior longitudinal ligament, anterior dura mater, and vertebral bodies (Figure 1 and Figure 2). The ligamentum flavum, epidural space, and posterior dura appear

lar process, transverse process, ligamentum flavum, posterior dura mater, anterior dura mater, posterior longitudinal ligament, and vertebral body can be identified (Figure 3 and Figure 4) (2). The transducer is placed on the midline, along the spinous processes, in the transverse direction. The spinous process is seen as a convex hyperechoic line with posterior acoustic shadowing. On either side of, or deep to the spinous process, the laminae produce two horizontal hyperechoic lines with posterior acoustic shadowing. Two oblique hyperechoic lines correspond to the transverse processes. Positioning the transducer between two spinous processes eliminates the acoustic shadowing, thus allowing visualization of the spinal canal, which is bounded by two hyperechoic parallel lines. The epidural space is above the dura mater, which is seen as a hyperechoic line. The deepest line is the posterior longitudinal ligament and posterior cortex of the vertebral body. The direction and angle of the probe used for transverse plane visualization that provides the best image is the same angle and direction that should be used for epidural and spinal needle placement (Figure 4) (5). Once an optimal view has been obtained, the depth from skin surface to the posterior complex may be measured using the electronic caliper built into the ultrasound machine (5, 10).

Real-Time Ultrasound Visualization

Real-time ultrasound-guidance for neuraxial procedures is not commonly utilized by practitioners, but may become more popular in the future, as technology and needle guide devices are developed (2). Currently, ultrasound probe dimensions as well as the need to use two hands in securing and placing the needle renders real-time ultrasound needle placement technically challenging for the single user (9). However, automated loss-of-resistance syringes and needle guide systems have facilitated performance by the single operator (2, 11-13). Belavy et al. (14) has attempted the use of 3-D/4-D systems in cadavers, which may come to clinical realization in the near future (2). A single-operator real-time technique using an on-screen overlay and fixed-needle guide has been described (12). More data is required before real-time ultrasound visualization can be recom-

mended for routine clinical use.

Neuraxial Ultrasound for Obesity and Difficult Landmarks/Anatomy

Anesthesiologists are increasingly confronted with abnormal spine anatomy, obesity, scoliosis/kyphosis, and previous back surgery (2). Over one-third of adults (34.9%) in the United States are obese (15). Likewise, more than half of pregnant women are overweight or obese, and 8% of reproductive-aged women are extremely obese (2, 16). Obesity frequently obscures anatomic landmarks, and anesthesiologists can experience difficulty in appreciating the midline and vertebral interspaces (2). Multiple attempts are often required and excessive adipose tissue can increase the incidence of false-positive loss-of-resistance during epidural placement. Furthermore, obese patients are more likely to experience longer procedure times, a higher incidence of accidental dural puncture, a higher incidence of epidural venous puncture, and higher overall failure and complication rates during neuraxial anesthesia placement (2, 17, 18).

In non-obese parturients with BMI's ranging from 25.1 to 39.9, Vallejo et al. (5) found that the Pearson correlation coefficients comparing the actual needle depth (ND) versus ultrasound depth (UD) to the epidural space in the longitudinal median and transverse planes were (0.914 and 0.909, respectively). In comparing the distance from the skin to the epidural space at the level of L3-4 in obese women (BMI at delivery of 33-86 kg/m²), Balki et al. (18) found that the Pearson correlation coefficient between the ultrasound depth (UD) and the actual needle depth (ND) was 0.85 (95% confidence interval: 0.75-0.91), with a concordance correlation coefficient of 0.79 (95% confidence interval: 0.71-0.88). In morbidly obese parturients, Singh et al. (19) determined that the use of an epidural depth equation prior to US visualization for epidural catheter placement resulted in even higher Pearson correlation coefficients of 0.905 (95% CI: 0.873 to 0.929) in the longitudinal median plane and 0.899 (95% CI: 0.865 to 0.925) in the transverse plane.

Given the high Pearson correlation coeffi-

cients with ultrasound (especially in experienced hands), pre-procedure ultrasound-guidance can be particularly valuable in cases where obesity, technical difficulty is anticipated and as a rescue to the blind technique when technical/anatomic difficulty is encountered. Chin et al. (20) examined the effect of using ultrasound to guide spinal anesthesia in obese orthopedic patients with poorly palpable spinous processes, and moderate to severe lumbar scoliosis or previous lumbar spine surgery, and showed successful dural puncture was achieved after the first needle insertion in 65% of cases in the ultrasound group compared to only 32% in the landmark group. The efficacy and safety of pre-procedure neuraxial ultrasound has been clearly demonstrated in multiple clinical studies (Table 2) (5, 21-24).

Popularity of Pre-Procedure Ultrasound Use in Obstetric Anesthesia

Anesthesiologists have not embraced the use of pre-procedural ultrasound imaging for neuraxial blockade to the same degree as they have for peripheral nerve blockade. In peripheral nerve blockade, ultrasound-guidance has nearly replaced nerve stimulation techniques and become the gold standard for regional analgesia in many centers. However, ultrasound-guidance continues to be slowly embraced for neuraxial blockade. Reasons include difficulty in performing procedures under real-time imaging where direct visualization of nerve bundles and the spread of medication around the target nerves are not possible, and the high success and low complication rates when these procedures are performed utilizing the traditional blind landmark-based techniques (2, 25).

The number needed to treat (NNT) to prevent one additional bad outcome with the use of pre-procedural ultrasound imaging compared to the traditional blind landmark-based technique has been calculated to be between 16 to 26 parturients (1, 5). Given this high number needed to offer benefit, many clinicians would opt to utilize the traditional blind technique instead.

Arzola et al. (25) looked at parturients with normal anatomy comparing the use of pre-procedural spinal ultrasound in anesthesia trainees to

the traditional blind technique based on anatomical landmarks in women with easily palpable lumbar spines and observed no improvement in the time to perform epidural catheter insertion, the number of interspace levels attempted, and the number of needle passes. He did find, however, that the total procedural time was longer in the pre-procedural ultrasound group. Likewise, Ansari et al. (26) determined that when performed by experienced anesthetists in both ultrasound and landmark techniques, the use of ultrasound does not appear to increase the success rate of spinal anesthesia, or reduce the procedure time, nor number of attempts in obstetric patients with easily palpable spines.

Contrary to Arzola et al. (25) and Ansari et al. (26), two studies by Vallejo et al. (5) and Grau et al. (7) demonstrated ultrasound-guided epidural imaging not only increases success rate for trainees but also improves their learning curve. Perlas et al. (27) performed a systemic review and meta-analysis of ultrasound-assisted lumbar neuraxial ultrasound for spinal and epidural anesthesia and concluded pre-procedural ultrasound imaging provides accurate measurement of the depth of the epidural and intrathecal space, improves efficacy of neuraxial anesthesia, increases accuracy of identification of lumbar interspaces and location of the midline, and can improve neuraxial anesthesia safety. Perlas et al. (27) concluded there is significant evidence supporting the role of neuraxial ultrasound in improving the precision and efficacy of neuraxial anesthetic techniques (Table 2).

Future studies are needed to determine the optimal means of incorporating neuraxial ultrasound imaging for lumbar punctures into obstetric anesthesia clinical practice.

Conclusion

Pre-procedure ultrasound imaging allows for greater accuracy and fewer needle passes by providing reliable and accurate information for successful neuraxial placement such as determination of the midline, deciding the optimal vertebral interspace level in those with normal and difficult anatomy, finding the optimal insertion point, locating the best angle for needle insertion, and accurately determining the proper

depth for needle advancement, which can enhance the patients overall comfort, experience, and satisfaction.

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