The Use of Ultrasonography for the Guidance of Epidural Analgesia in Obstetric Anesthesia

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ABSTRACT

This review article describes the development of the use of ultrasound guidance for neuraxial blocks in obstetric anesthesia. Current evidence of the clinical utility and application, basic lumbar spine sonoanatomy and practical clinical approach of the ultrasound-guided technique for neuraxial blocks are presented and discussed. Suggested curriculum is intended to prepare anesthesiology residents for application of ultrasound guidance in epidural analgesia and obstetric anesthesia.

Keywords: Ultrasound for epidural analgesia, Ultrasound guidance for obstetric analgesia and anesthesia, Ultrasound for neuraxial blocks, Teaching of ultrasound imaging and technical skills in anesthesiology, Role of ultrasound in regional anesthesia.

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INTRODUCTION

Ultrasound skills for the guidance of regional anesthesia in both acute pain management and obstetric anesthesiology are used globally in modern practice of anesthesiology. Ultrasound skills are currently standard of practice for central venous access, highly recommended by the guidelines of both American Society of Regional anesthesia (ASRA), European Society of Regional Anesthesia (ESRA) for peripheral nerve blocks, as well as recommended guidance for obstetrics analgesia and anesthesia by the National Institute of Health and Clinical Excellence (NICE) of the

UK National Health Service.¹ Use of ultrasound guidance is a common practice for placement of peripheral nerve blocks worldwide, increasing their safety, ease of performance and decreasing complications. Ultrasound application in performing neuraxial blocks, epidural and spinal blocks for obstetric anesthesia and other surgeries is lagging behind, despite spinal and epidural anesthesia being the absolutely most widely used regional anesthetic techniques in current obstetrical anesthesia. This article will concentrate on the use of ultrasound in obstetrical anesthesia, and will discuss clinical evidence and methods of acquiring necessary skills.

Epidural needle insertion and catheter placement is historically a blind technique, where the epidural space is identified by palpation of anatomic landmarks and loss of resistance to saline or air technique when the needle passes through the ligamentum flavum. Palpation is inaccurate and depends on the anesthesiologist's level of experience; therefore failed blocks and complications are common. The most severe complication is development of the debilitating post-dural puncture headache (PDPH), which develops after about 50% of all accidental dural punctures.² The incidence of accidental dural punctures is stated as between 1 and 5%.^{3,4} PDPH can be debilitating and distressing for the patient to the point of requiring an epidural blood patch, which increases the risk of yet another accidental puncture as well as epidural abscess and meningitis.⁵

The most common complication of epidural block with or without catheter insertion is a failure to achieve an adequate pain control. Rates of failed epidurals are anywhere from 1.5 to 20%, depending on the experience of the anesthesiologist and/or the institution.⁶ Wrong estimation of specific lumbar spinal interspace is another possible complication of a blind technique. Studies have shown that anesthesiologist using the conventional palpation technique frequently estimates the specific lumbar interspace more caudally than visualized with ultrasound.⁷⁻¹⁰ This can lead to more frequent spinal cord trauma and possibility of permanent neurological deficit, since the conus medullaris not infrequently extends lower than the L1 level.⁸ Repeated attempts and re-directions of the epidural needle are also causing pain and discomfort to the patient in labor and may unnecessarily delay the pain relief.

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HISTORY OF THE USE OF ULTRASOUND FOR IMAGING OF THE LUMBAR SPINE

Bogin and Stulin were the first to describe ultrasound (US) facilitated imaging of the lumbar spine and the use of ultrasound for lumbar puncture in 1971.¹¹ In 1981, Cork RC et al described the use of US to localize the lumbar epidural space. They were first to define the basic components of US sonoanatomy: ligamentum flavum, spinal canal, laminae and vertebral bodies.¹² In 1984 Currie JM described the US guided measurement of the distance from the skin to the epidural space.¹³ His work was the basis for the use of US guidance to facilitate neuraxial blockade for labor and delivery analgesia. The method is commonly used for preprocedure scanning of obese or otherwise anatomically challenging patients to assess the depth of the epidural space.¹³

This study was followed in 1992 by Wallace DH who used indirect ultrasonographic guidance for epidural anesthesia in pregnant patients.¹⁴ This was the basis of today 'off-line' ultrasound use for neuraxial blocks in obstetric anesthesia. In the years 2001 to 2004 total of 11 studies about sonography use for neuraxial blocks were authored by Dr Grau T et al who made a major progress in spinal sonography and performance of neuraxial blocks.¹⁵⁻²²

REVIEW OF THE ANATOMY OF LUMBAR SPINE

Lumbar vertebrae have two components: the body anteriorly and the arch posteriorly. Vertebral arch is composed of spinous process, transverse processes, pedicles, lamina and superior and inferior articular processes (Fig. 1).

The vertebral (spinal) canal is formed by the spinous process and lamina posteriorly, the pedicles laterally, and the vertebral body anteriorly.

Lumbar vertebrae are aligned vertically with articular processes and facet joints on both right and left para-medially from spinous processes and anteriorly from vertebral bodies (Fig. 2). Within the vertebral canal lies the thecal sac, formed by the dura mater and arachnoid mater. The thecal sac contains the spinal cord, cauda equina and cerebrospinal fluid.

The ligamentum flavum is a dense connective tissue ligament that bridges the gaps between laminae and interlaminar spaces. The spinous processes are connected at their tips by supraspinous ligament and along their length by interspinous ligament. The epidural space lies within the spinal canal but outside the thecal sac. The classic loss of resistance technique (LOR) is based upon the distinct change felt when the epidural needle passes through the solid fibrous ligaments into the epidural space.

Fig. 1: Anatomy of lumbar vertebrae. Note: 1. Lamina, 2. Spinous process, 3. Articular process, 4. Transverse process, 5. Pedicle, 6. Vertebral (spinal) canal, 7. Vertebral body

Fig. 2: Anatomy of lumbar vertebrae. Note: 1. Articular process (upper), 2. Transverse process, 3. Facet joint, 4. Spinous process, 5. Articular process (lower), 6. Facet, 7. Vertebral body, 8. Disk

Ultrasound imaging allows the anesthesiologist to visualize the structures within the vertebral canal: ligamentum flavum, epidural space and thecal sac, through the interlaminar spaces between the adjacent vertebrae that permits passage of ultrasound waves into the vertebral canal- acoustic windows. If an acoustic window between two vertebral laminae can be identified, it will likely permit the passage of a needle into the epidural or intrathecal space.

PRINCIPLES OF SCANNING

Ultrasound machine depth should be set to 7 to 8 cm for average size patients and 8 to 12 cm for most high body mass index (BMI) patients. The depth, focus and gain settings of the ultrasound machine need to be adjusted for each patient's scan as necessary to obtain the highest quality image.²³⁻²⁸

Patient needs to be positioned for the scanning in the same position the epidural block will be performed; this

Figs 3A to D: Typical views for sonography of the lumbar spine: (A) Curved-array, low frequency (2-5) MHz ultrasound probe is recommended, (B) paramedian sagittal view (PS), (C) paramedian sagittal oblique view (PSO) and (D) transverse view (T)

is either sitting or lateral decubitus position for obstetric analgesia. There are three basic ultrasound views for effective sonography of the lumbar spine (Fig. 3).

These planes are named after three basic anatomic planes of the human body (Fig. 4).

ULTRASONOGRAPHIC VIEWS OF THE SPINE

Pattern recognition is even more important for spinal sonography than for peripheral nerve blocks, because of the depth of the structures and limited acoustic windows which make visualization and identification more difficult. For beginner in ultrasound it is important to stress the following:

- Bony structures appear white (hyperechoic)
- Connective tissues, ligaments and fascias are also white (hyperechoic)
- Because of low acoustic impedance fluid and fat appear dark (hypoechoic).

It is very important to adopt and develop a systematic approach to scanning, using standard set of views. Systematic assessment facilitates the learning of pattern recognition and increased the overall efficiency of ultrasound guided neuraxial blockade.²⁸⁻³⁴ Here, we present the technique described by Chin et al.^{28,34}

1. Prepare the equipment:
 - A. Ultrasound machine, curved array low frequency probe (2-5 MHz)
 - B. Marking pen
 - C. Ultrasound gel
 - D. Towels or gauze
 - E. Gloves
2. Position the patient in a sitting position (lateral is possible as well). Place the probe in a transverse position to the long axis of the spine at the middle of the patient's lower back—approximately at the intercrystal (Touffier line), L3-L4.
3. Optimize the image by adjusting the:
 - A. Depth

Fig. 4: Anatomic planes of the human body: sagittal, transverse and coronal. Median or mid-sagittal plane illustrates plane running through the midline

- B. Frequency
 - C. Focus
 - D. Gain and Time-gain compensation (TGC)
4. Mark the midline: Probe is aligned strictly transversely to the spine structures—RT and LT sides are mirror images from the center of the probe. Sliding the probe cephalad and or caudad direction, alternating Spinous Transverse Process and Transverse Interspinous views, mark the midline over several interspaces (Figs 5 and 6).
 5. Identify the lumbosacral junction and intervertebral levels: Obtain the parasagittal transverse process view (Fig. 7) by placing the probe parasagittally about 3 to 4 cm from the midline. Finger-like acoustic shadows of the transverse processes or 'trident sign' will be visible. Slide probe medially toward the midline to obtain the parasagittal articular process view (camel humps)—line of hyperechoic facet joints—vertebrae connected by superior and inferior articular processes (Fig. 8). Identify the short lamina of L4/L5 (L5 lamina), slide the probe caudally, until the continuous white

Fig. 5: Transverse spinous process view (SP)

Fig. 8: Paramedian sagittal oblique view

Fig. 6: Transverse interspinous view. TP—transverse process, APJF—articular process/facet joints, PC—posterior complex—ligamentum flavum, epidural space and posterior dura, AC—anterior complex—the anterior dura, posterior longitudinal ligament, posterior aspect of the vertebral body or the intervertebral disk

Fig. 7: Paramedian sagittal transverse process view

(hyperechoic) line of sacrum is visible. Slide the probe in a cephalad direction, centering on each lamina and marking it – the lamina/interspace will correspond to

the center of the long side of the probe. This is called ‘counting up’ approach. Mark the L1-L5 levels.

6. Estimate the required needle direction: The probe is rotated transversely at the desired level (e.g. L4-5 or L3-4) and transverse laminar view is obtained. The estimated best needle insertion angle or direction is identified by optimizing the image – tilting the probe in slight cephalad or caudad directions until the best view of anterior AC and posterior PC complexes is obtained.
7. Estimate the depth from the skin to the epidural space/dura: Anterior complex, or AC, since the dura and epidural space are visualized as a single hyperechoic line. Use the ultrasound calipers to measure the distance. The true depth will differ slightly depending on how much pressure on the ultrasound probe is used for scanning.
8. Mark the optimal needle insertion point: This is best done by marking all four midpoints of the long and short edges of the probe. Put the probe aside. The optimal needle insertion point is where the lines intersect.
9. Re-apply the probe and check that you have a good view of the anterior complex from the marked insertion point. Put the probe aside.
10. Use the marked insertion point, estimated angle of insertion and estimated depth to place an epidural catheter under sterile condition.

This technique is proposed for the ultrasound guided epidural catheter placement, or preprocedure scan; so far, the most widely used technique, requiring only one provider. The placement of the catheter under a real time ultrasound is technically difficult, and usually two providers with advanced skills are required. It is best done from the Parasagittal Oblique View, when the probe is placed in a parasagittal articular view and then tilted slightly in medial direction, until acceptable image of AC and PC is obtained. From 2005 to 2010 a pre-loaded epidural syringe ‘Episure

AutoDetect LOR Syringe' (Indigo Orb) was available on US market. This needle allowed one anesthesiologist to hold the probe in one hand and the syringe in another. The syringe was spring loaded and able to identify the loss of resistance when the tip of the needle reached the epidural space. Studies to compare the Episure AutoDetect syringe with the classic glass syringe for identification of the epidural space in parturients brought mixed results.^{35,36} The Episure AutoDetect syringes are currently not on the US market as of July 2013.

ADVANTAGES AND DISADVANTAGES OF ULTRASOUND GUIDANCE IN NEURAXIAL BLOCKS FOR OBSTETRIC ANESTHESIA

A literature search was performed in PubMed database to review studies for the advantages and disadvantages of the US guided neuraxial blocks specifically in obstetric anesthesia. The search was limited to studies conducted from 1971 until the present on human subjects 18 years and older. Search terms included: epidural or neuraxial, ultrasound, ultrasonography, ultrasonographic and spinal sonography. During the period from 2005 to 2010, there has been an increasing number of both anesthesia and emergency medicine publications describing investigation and practical use of spinal sonography for the ease and better accuracy of neuraxial procedures. Also, ultrasound equipment both improved technically and became more affordable and available in most developed countries. In 2008 The National Institute for Health and Clinical Excellence (NICE) of UK issued guidelines on ultrasound-guided neuraxial – epidural and spinal procedures for both obstetric and nonobstetric anesthesia.¹ Ultrasound machines remained too expensive, less mobile and not commonly available until 2009 to 2010. This might reflect a small number of publications and only few case reports published before 2008.¹⁵⁻²⁴ The reports focused on the advantages of the use of spinal sonography to facilitate difficult or presumed difficult epidural catheters' placement in morbidly obese patients, patients with significant scoliosis and patients with history of previous lumbar spine surgery.

Ultrasound guided regional anesthesia has since become a standard for all anesthesiology residencies. Teaching of US guided procedures to anesthesiology residents has led to increased number of studies and articles on efficacy of the use of US in anesthesiology. Several studies were published on the benefits, decreased complication rates and decrease in time to perform labor epidural placements in training institutions.^{25,26} Despite this widespread use of ultrasound in anesthesiology there are some studies pointing out the disadvantages of the use of ultrasound in obstetric anesthesia,

mainly indicating increased cost.³³ Cost of ultrasound machine and need for two providers for real time placement of epidural catheters are main limitations of the US guided technique. Placement of epidural catheter facilitated by US requires advanced training of an anesthesiologist, since there is a long learning curve associated with lumbar ultrasound.³³ There is also a cost of the medical fee, CPT code 76942 paid by insurance companies for the use of ultrasound in this setting. This cost is eventually passed onto the patients.

Spinal ultrasound is not easy to learn, requires advanced training and instruction. There is a long learning curve associated with lumbar spine ultrasound and the teaching methods are not standardized and vary extensively from institution to institution and between the countries. The deficiencies in teaching and training are more pronounced in the clinical setting of obstetric anesthesia, when patients are in labor and time is of essence. The literature reviewed for advantages and disadvantages of ultrasound guided neuraxial blocks in obstetric anesthesia are summarized in Table 1.

Advantages of the use of ultrasound for epidural placement are the following:

1. Preprocedure or 'off-line' ultrasound helps visualize the anatomy, select the correct intervertebral space, measure the depth from skin to the epidural space and help to plan the insertion angle for needle trajectory.
2. Real time 'on-line' ultrasound allows visualization of the epidural needle placement.
3. Both preprocedure and real time ultrasound visualization of the epidural space are helpful in aiding an epidural catheter placement or subarachnoid block in a morbidly obese patient and patient with an altered anatomy, mainly previous lumbar spine surgeries and kyphoscoliosis.
4. Visualization of epidural space with ultrasound is a valuable teaching tool for residents and shortens the learning curve and improves the success rate.
5. Improved block success – reduces rates of failed epidural placement resulting in inadequate analgesia, lower rate of postdural puncture spinal headaches (PDPH).

Disadvantages of the use of ultrasound for epidural placement include the following:

1. Need of expensive equipment
2. Lack of trained providers in both EU and US
3. Two providers necessary for real-time ultrasound guided epidural catheter placement
4. One-provider real time US technique is currently not available (Autodetect epidural needles (Episure) are not available on the market).

These are multiple drawbacks to broader use of spinal sonography worldwide. The technique requires ultrasound

*The Use of Ultrasonography for the Guidance of Epidural Analgesia in Obstetric Anesthesia***Table 1:** Advantages and disadvantages of ultrasound guided neraxial blocks in obstetric anesthesia

<i>Author/Year</i>	<i>Study objectives</i>	<i>Methodology</i>	<i>Findings/Results</i>	<i>Relevant evidence</i>
Currie JM ¹³ (1984)	Tested the accuracy of US measurement of the depth of extradural space	Single-arm prospective cohort study; 75 patients requesting extradural analgesia; US blinded by second operator; correlation coefficient	Provided accurate readings of the depth of the extradural space in 43 cases	Initial evidence that US benefits/facilitates extradural block
Wallace et al ¹⁴ (1992)	Use of epidural anesthesia using sonographic guidance to locate epidural space correctly	Single-arm prospective cohort study; 36 obese patients scheduled for elective repeat cesarean delivery; linear regression analysis	Satisfactory epidural anesthesia was accomplished in all obese patients with indirect sonographic guidance	Needle depth could be predicted with US in difficult cases
Grau et al ¹⁵ (2001)	Evaluated the visibility of all anatomical structures and compared the distances measured by US and during puncture	Prospective study; 100 pregnant women, admitted for childbirth and undergoing epidural block; correlation coefficient	Correlation between distances measured by ultrasound and puncture needle was high ($r = 0.79$); patient acceptance of the procedure was very good	Show ultrasound ability to determine site and direction of epidural puncture
Grau et al ¹⁶ 2001	Investigated whether prepuncture US examination of the spinal anatomy is beneficial in expected cases of difficult epidural anesthesia	Prospective randomized study; 72 patients with abnormal anatomical conditions scheduled for epidural anesthesia, 36 per group; Chi-square test, Bland-Altman analysis	In US group results were optimal skin puncture site, ideal direction of needle advancement and skin-to-epidural space distance	Use of ultrasound facilitates epidural anesthesia by pre-puncture findings of spinal anatomy in difficult cases
Grau et al ¹⁷ (2001)	Investigated the influence to the tissue alterations of pregnancy on epidural technique	Prospective cohort study; 60 patients receiving epidural block for conventional or cesarean delivery; Chi-square test, student's t-test	US enabled assessment of landmarks for puncture	Benefit of ultrasound is to identify important structures for epidural anesthesia
Grau et al ⁶ (2001)	Evaluated usefulness of US in facilitating localization of the epidural space	Case control study; 80 patients with cesarean delivery, US ($n = 40$), control group ($n = 40$); US measured epidural space by single operator; Chi-square test and student's t-test	Bony landmarks, including the spinous and transverse processes, and facet joints can easily be identified by US	Use of US is beneficial for localization of epidural space. There is significant reduction in puncture attempts. Preparation time was not significantly altered. US of the epidural space does not cause discomfort
Grau et al ¹⁸ (2001)	Assessment of 3 ultrasound planes (transverse, median and paramedian) for assessment of the visibility of epidural space	Case control study; 60 patients and 40 healthy volunteers; US measurement of the epidural space and its surrounding structures; student's t-test	In the paramedian plane, the permeable window was larger ($p < 0.001$) than in the median approach. The visibility of the ligamentum flavum ($p < 0.0001$), dura mater ($p < 0.0001$) and cauda equina ($p < 0.0001$) was significantly higher	The longitudinal paramedian plane provides information about the epidural space depth in excellent imaging quality
Grau et al ¹⁹ (2001)	Evaluation of the usefulness of color Doppler assessment in the screening of the trajectory of the epidural needle	Case control study; 20 volunteers; ultrasound examination of L3/4 interspace; vascular structures were identified by pulsation (B mode) and blood flow (Doppler)	Vessel detection was possible in 50% of the B-mode images and in all of the 4-MHz Doppler images. Vessels were perceptible from a diameter of 0.5 mm/veins were the predominantly visible structures	Prepuncture Doppler imaging can provide the anesthesiologist with information regarding the position of vessels in the needle trajectory. This might help to reduce complications in regional anesthesia

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<i>Author/Year</i>	<i>Study objectives</i>	<i>Methodology</i>	<i>Findings/results</i>	<i>Relevant evidence</i>
Grau et al ⁶ 2002	Assessment of the clinical use of US for localization of the epidural anesthesia	Randomized prospective study; 300 patients, in each group (n = 150) 85 conventional delivery and 65 cesarean sections; Chi-square test, Bland-Altman analysis	US for structure detection results in reduced number of puncture attempts, less side effects, higher patient satisfaction	The clinical use of ultrasound for epidural catheter placement may improve regional anesthesia. The use of ultrasound resulted in superior quality in all measured endpoints
Grau et al ²¹ (2003)	Evaluation of the teaching possibilities of US as a diagnostic approach to the epidural region	Prospective, randomized, nonblinded study; two groups of five residents performing first 60 epidurals; Chi-square test, student t-test	Using US the learning curves started at a mean level of 86% and rose up to a mean success rate of 94% after 60 epidurals. In comparison, the learning curve without US started at 60% and reached a maximum of 84%	Demonstrates the value of ultrasound imaging for teaching and learning obstetric epidural anesthesia
Grau et al ²² (2004)	Evaluation of real-time US control for epidural anesthesia	Prospective randomized study; 30 patients scheduled for cesarean section, 10—control, 10—online imaging, 10—offline imaging	Real-time ultrasonic scanning of the lumbar spine provides an accurate reading of the location of the needle tip and facilitates the performance of combined spinal-epidural anesthesia	Use of ultrasound is effective in identifying epidural structures
Vallejo et al ³¹ (2010)	Evaluation of the measurements of the epidural space depth	Prospective, randomized, nonblinded study; 379 patients requesting labor epidural analgesia, US group = 189 and control group = 181; Pearson's correlation coefficients, multivariate linear regression	US planes have high correlation with actual clinical depth to the epidural space; US was successful in 186 patients vs 171 with no US respectively	Ultrasound for the guidance of epidural analgesia has higher success rate
Gambling DR ³² (2011)	Analysis of the literature on impact of ultrasound use on ease and comfort of epidural anesthesia and success rate	Review article	Cost-beneficial, decreased time, feasibility of use, effectiveness of lumbar US	Risk analysis for lumbar ultrasound during pregnancy should be performed. The issue of ultrasound biosafety needs to be considered before use of US in pregnant patients

equipment, which is expensive and not available in developing countries, not even in all US hospitals with obstetric wards. The use of ultrasound for visualization of spinal anatomy requires an experienced anesthesiologist with special training in ultrasound. Until a safe and cost-beneficial technique will be developed for only one provider to be able to perform both scanning and needle placement in 'real time', the technique requires two providers, which is economically and practically burdensome for most but largest teaching institutions.

CONCLUSION

At this time ultrasound guided technique of epidural and spinal blocks for obstetric patients should not replace the

traditional landmark and palpation technique of neuraxial anesthesia for all patients. The traditional technique is easy, economically advantageous and has minimal risks and complications when performed by well-trained providers. Ultrasound guidance performed as preprocedure scanning is invaluable in facilitating placement of difficult epidural and spinal blocks, such as in morbidly obese patients, patients with severe scoliosis and patients with history of previous spinal surgeries and instrumentation. Spinal sonography is also an invaluable tool in teaching anesthesiology residents the basic, as well as complicated and altered spinal sonoanatomy. More work needs to be done in developing a standardized teaching approach for residents and practitioners to increase the use of ultrasound guidance

for performance of neuraxial blocks for obstetric anesthesia, as well as increase of its efficacy and more widespread use.

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