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Ultrasound-Guided Neuraxial Anesthesia

Jinlei Li[1] · **Ramya Krishna**[1] · **Yang Zhang**[2] · **David Lam**[1] · **Nalini Vadivelu**[1]

Abstract

Purpose of Review There has been a recent surge of interest in clinical applications of ultrasound, which has revolutionized acute pain management. This review is to summarize the current status of ultrasound utilization in neuraxial anesthesia, the most common type of regional anesthesia.

Recent Findings Ultrasound-assisted and ultrasound-guided neuraxial anesthesia has improved clinical accuracy and patient safety through landmark identification including proper vertebral level and midline, as well as via measurements on neuraxial space. Direct needle or catheter visualization during the entire procedure has not yet been achieved consistently.

Summary The recent introduction of ultrasound into neural anesthesia has clinical performance benefits and patient safety implications, with documented improvement on overall efficacy with higher first attempt success rate as well as less needle pass. More controlled studies are needed for the overall impact of ultrasonography in neuraxial anesthesia in obstetric and non-obstetric patients.

Keywords Neuraxial anesthesia · Obstetric neuraxial blockade · Ultrasound

Introduction

Neuraxial anesthesia has a long history of efficacy and safety in many types of surgery providing analgesia and anesthesia. The success rate with landmark alone is less than desirable and can be challenging in patients with distorted anatomy (history of back surgery, kyphosis, scoliosis), high body mass index (BMI), or during pregnancy. Fluoroscopy has improved the accuracy but is associated with radiation. The introduction of ultrasound into neuraxial anesthesia is new and has exhibited its positive impacts on the efficacy and accuracy of this common reginal anesthesia technique.

Neuraxial Anesthesia Prior to Ultrasound Era

With the continued development of medical technologies and desire for progress, medical practices and techniques have also evolved. Dr. Carl Koller, an ophthalmologist who injected cocaine solution on the cornea in 1884, was the catalyst in the development of regional anesthesia [1]. In 1885, James Corning begun experimenting with injecting cocaine between the spinous processes of the spine in dogs and human subjects and he would author the first publication describing the concepts of neuraxial blockade [2]. In 1891, Wynter and Quicke attempted to treat raised intracranial hypertension and were the first to aspirate cerebrospinal fluid from the subarachnoid space. Several years later in 1898, Karl August Bier performed the first operation under spinal anesthesia performed by injecting cocaine intrathecally [3]. Spinal anesthesia integration was briefly postponed with the introduction of ether anesthesia into clinical practice until in 1902 when Hopkins

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✉ Jinlei Li
Jinlei.li@yale.edu

Ramya Krishna
Ramya.krishna@yale.edu

Yang Zhang
Yang_Zhang@URMC.Rochester.edu

David Lam
David.Lam@yale.edu

Nalini Vadivelu
Nalini.Vadivelu@yale.edu

[1] Department of Anesthesiology, Yale University, New Haven, CT, USA

[2] Department of Anesthesiology and Perioperative Medicine, University of Rochester, Rochester, NY, USA

performed the first cesarean delivery with spinal anesthesia in the USA [4]. Between 1921 and the 1930s, the work by Fidel Pages of Spain and Achille Mario Dogliotti would lead to the development of clinically accepted technique for lumbar epidural anesthesia. In particular, Dogliotti would describe the "loss-of-resistance" terminology, which is related to the application of pressure with a syringe to identify the epidural space [5]. By 1941, Hingson, Edwards, and Southworth would develop and formalize the use of continuous caudal anesthesia [6].

In its current form, neuraxial anesthesia involves local blockade of innervation of the central nervous system involving spinal (subarachnoid), epidural, and caudal spaces.

The utilization of neuraxial anesthesia is common practice within all sub-specialties of anesthesia. The discovery of spinal opioid receptors in the late 1970s led to a widespread use of epidurally and intrathecally administered opioids, and the combination of opioids and dilute local anesthetics in providing labor pain relief became standard practice [7]. The use of neuraxial anesthesia in lumbar spine surgery is associated with lower intraoperative hypertension, tachycardia, and opioid consumption, as well as improved recovery times [8]. Moreover, neuraxial anesthetics have been shown to reduce the incidence of venous thrombosis and pulmonary emboli, transfusion requirements, and respiratory compromise after thoracic and abdominal surgeries [7]. Another benefit of neuraxial anesthesia is the ability to decrease requirements for general anesthesia and airway management, which bring about additional risks and complications especially in unique patient populations such as pediatrics and obstetrics. Nonetheless, neuraxial anesthesia as a solo modality may not be suited for all situations (e.g., difficult airway patients).

Despite the general safe profile of neuraxial anesthesia, some risk and side effects still remain. One of the most common complications is postdural puncture headache [9]. Although the exact pathophysiology has not been confirmed, the leading belief is that if cerebral spinal fluid (CSF) leaks at a rate greater than its production (from a lumbar puncture or wet tap during epidural catheter placement), the body may attempt to compensate via meningeal vasodilation and blood volume expansion leading to headache [10]. As such, a general contraindication for neuraxial anesthesia includes intracranial hypertension [11]. Additional general precautions should be taken when neuraxial anesthesia is considered in patients who are hypovolemic, coagulopathic, allergic to local anesthetics, and have infections at the injection site. A broken needle in tract could constitute a major complication [12]. Other concerns include low accuracy and low success rate, with proper identification of the actual vertebral level only around 30% of the time by gross palpation [13], and success rate for epidural anesthesia placement with the traditional loss of resistance method around 74% [14].

Ultrasound in Neuraxial Anesthesia

History of Ultrasound-Assisted Neuraxial Anesthesia

The early study of echolocation by physiologist Lazzaro Spallanzani in 1794 helped catalyze the advancement of ultrasound into medicine, with the first credited use of sonography for medical diagnoses by Dr. Karl Dussik in 1942 [15]. The first ultrasound-guided lumbar puncture was not reported until 1971 [16]. Cork subsequently performed the first successful sonographic measurement of the epidural space in the 1980s, [17] and Bonazzi and de Gracia would later identify the ligamentum flavum in 1990s [18]. Despite continued improvements in technology, the routine use of ultrasound for neuraxial anesthesia was not formally accepted until 2008 when the National Institute for Health and Care Excellence recommended it for epidural catheterizations [19]. Compared to the traditional method of palpating bony anatomical landmarks, the process of performing a preprocedural scan was thought to facilitate faster and more accurate catheter placement. However, intraprocedural use of ultrasound in neuraxial anesthesia remains experimental and has not garnered widespread support.

Spine Gross Anatomy

The spine consists of 33 individual bones whose primary purpose is to support the human body. Coming down from the cervical spine, there is a natural S-shaped curve with muscles, tendons, and ligaments that track down along each bone. With the primary forms of neuraxial anesthesia involving the thoracic and lumbar spine, it is crucial to have a strong understanding of its anatomy and surrounding features. On the back of each vertebra, there are vertebral arches that have two supporting pedicles and lamina. Behind this structure lies the spinal canal, which contains the spinal cord, spinal nerves, blood vessels, fat, and ligaments that help hold the vertebrae together. The spinal cord has three covering membranes: the dura, arachnoid, and pia mater. These membranes accordingly split the canal into three distinct compartments: the epidural, subdural, and subarachnoid spaces which are the injection points for most neuraxial anesthesia techniques.

Given variations in patient body habitus and positioning techniques, there are several important landmarks used to locate the appropriate vertebral level where neuraxial anesthesia is to be performed. The ability to determine anatomical positioning and location using common landmarks is essential in performing neuraxial anesthesia, with or without the assistance of fluoroscopy or other methods of imaging. The C7 spinous process is the most prominent bony structure at the base of the neck. Another useful marker is an imaginary line between the lower edges of the scapulae which correlates with the T7 interspace. Determination of the iliac crest is extremely helpful as a line between the two crests (Tuffier's) generally denotes the L4/5 interspace. The S2 vertebral body which is the inferior border of the dural sac in adults can also be determined by utilizing the bilateral posterior superior iliac spines.

Spine Sonoanatomy

Although the bone is unable to be penetrated by ultrasound, its contour provides shadowing that is helpful for interpretation of spine anatomy. The vertebral canal is visualized through the soft tissue acoustic windows of the interlaminar and interspinous spaces provided by the surrounding bony structures [20••]. In evaluation of identifying structures of the spine, there are five basic ultrasound views. The transverse interlaminar/interspinous (TI) view and parasagittal oblique (PSO) view are generally the most important in clinical practice as they provide visualization of major neuraxial structures such as the ligamentum flavum, posterior dura, spinal canal, anterior dura, and posterior longitudinal ligament [20••]. The 5 views are described as follows:

1. Parasagittal transverse process view is found by placing the probe on the lower lumbar spine in a parasagittal orientation lateral to the midline. This will portray the transverse processes as "finger-like acoustic shadows" that are separate by the psoas major muscle. The erector spinae muscles will be superficial [20••].
2. Parasagittal articular process view follows a similar process to the transverse process orientation, then moving the probe medially. The articular processes can be distinguished by the superficial depth of the shadowing, presenting as "humps" [20••].
3. Parasagittal oblique (interlaminar) view (PSO) is found by tilting the probe lateral to medial orientation in the parasagittal articular process view. A "sawtooth" pattern will appear in which the upward slopes of the teeth correspond to the down sloping laminae with the gaps indicating the interlaminar spaces, subsequently providing an acoustic visualization into the vertebral canal.
4. Transverse spinous process view is found by placing the probe in a horizontal orientation with the center at the midline. When placed over a spinous process, the tip will appear as a hyperechoic cap with the erector spinae muscles laterally, presenting as its own dense shadow.
5. Transverse interlaminar/interspinous view (TI) is found by moving the probe in a caudal direction until the ultrasound beam strikes a space between spinous processes. Tilting the probe slightly more upward, the interspinous ligament will be visualized as a hypoechoic midline stripe. The hyperechoic spaces of anterior and posterior complexes will surround the intrathecal space [20••].

Patient positioning can have a large impact on target visualization with ultrasound for neuraxial procedures. While neuraxial techniques as a whole utilize various methods of patient positioning, implementing the use of ultrasound in these procedures makes patient positioning even more critical in producing a safe and effective anesthetic. Poor patient positioning during a spinal anesthetic may cause higher rates of spinal needle pass, resulting in an increase in back pain, postdural puncture headache, and epidural hematoma formation [21]. The goal of utilizing ultrasound during neuraxial anesthesia is to visualize and measure the measure midline and the distance/depth of the target space, and avoid multiple attempts, particularly in patients with difficult spinal anatomy [22].

As one considers patient positioning for neuraxial anesthesia, there are various factors that influence the success rate of the procedure. Often, the comfort of the operator, patient pathology and spinal anatomy, and type of neuraxial procedure play a large role in deciding how to position the patient. In general, it appears as though both the sitting and lying fetal positions are both acceptable for patients in order to open the interlaminar space, as well as improve patient comfort during ultrasound-guided neuraxial blockade [23]. When pursuing a thoracic ultrasound-guided neuraxial procedure, the sitting position may be preferred [24]. The adequacy of patient positioning can also be determined by the use of ultrasound. For instance, ultrasound measurements of the length of ligamentum flavum as it relates to accessibility of the subarachnoid space have been utilized to assess the impact of a dorsal table tilt in pregnant women [25]. Similarly, measurement of the length of the posterior longitudinal ligament in various patient positions has been used to optimize the window for both lumbar and thoracic epidural placement [26]. Porto et al. utilized an ultrasound simulation derived from healthy volunteers to assess various patient positions and efficacy of lumbar neuraxial blockade and found that the window of injection is larger in the sitting position as compared to the prone position, and that dorsal tilt had no effect. It is possible that when performing a prepuncture scan, one can identify these targets and adjust patient positioning to optimize first attempt success.

Ultrasound Transducer

The choice of ultrasound transducer or probe for landmark identification in neuraxial procedures can provide optimal acoustic windows to improve first attempt success rate. Understanding of spinal anatomy and depth influences choice of probe. For instance, given that the lumbar spine is located at a depth of 5–7 cm for non-obese patients, ultrasound imaging often requires low frequency curvilinear transducers. Curvilinear transducers also allow for a wider field of visualization, improving visualization of spinal structures and needle trajectory. However, the size and lack of exact localization of the ultrasound beam with curvilinear probes can prove to be problematic when considering utilizing the ultrasound probe in real time with needle insertion [27]. On the other hand, the sacrum is much more superficial, and therefore a high-frequency linear transducer can be utilized. Since spinal structures are more superficial in pediatric population, a high-frequency linear probe can be used in these patients as well [28]. Additionally, while the resolution of modern ultrasound probes is effective at visualizing the bony landmarks and ligaments, there is still difficulty in visualizing the nerves within the spinal canal [29]. Lower-resolution probes also limit the ability to clearly visualize vessels as compared to high-frequency transducers, resulting in a theoretically increased risk for intravascular injection [9].

Preprocedural Scan and Ultrasound-Assisted Neuraxial Anesthesia

Given that ultrasonography has been relatively underutilized in neuraxial anesthesia, training and performing ultrasound neuraxial anesthesia can prove to be a challenging task to take on. One avenue that has been shown to be effective is to conduct an ultrasound scan prior to needle insertion. The scan can be done to visualize spinal anatomy and determine needle trajectory, and a mark can be made where the needle should enter. Once this is done, the ultrasound probe is placed down, and the remainder of the procedure is performed in the traditional loss of resistance to air or saline method [30]. Utilizing preprocedural scanning has a higher rate of success of identifying the appropriate vertebral level desired and identifying the depth of neural structures [20••]. Shaik et al. conducted a systematic review comparing ultrasound-assisted versus traditional method neuraxial blockade and observed a 79% reduction in procedural failure rate when utilizing the ultrasound to perform a preprocedural scan [31]. Preprocedural scanning has primarily shown to be helpful when the pretest probability of difficult neuraxial procedure is high. For instance, preprocedural scanning has been utilized when the patient has difficult spinal anatomy and the assessment of common landmarks proves difficult [2]. While some studies attest that there is no difference in success rates with preprocedural scanning versus a landmark based technique, these studies are conducted on those with easily palpable landmarks [32].

There are several limitations of assessing the utility of preprocedural scanning. For one, those practitioners more inclined to utilize imaging guided techniques are more likely adept at ultrasound visualization. Teaching and incorporating preprocedural ultrasound can prove to be difficult in a field where the success rate of neuraxial blocks is generally high, such as in patients with easy anatomy [33]. Additionally, there is concern that the addition of preprocedural scanning will add additional time to performing the procedure [2, 34]. However, the added time should be balanced against an increased patient comfort when utilizing a preprocedural scan [35].

There are also pitfalls in the use of preprocedural scanning. For instance, after the operator performs an ultrasound scan and marks the patient, the operator is required to determine the exact middle of the ultrasound probe from which the beam is originating, and current curved linear array probes do not have accurate markings for this [2]. The target structures should be visualized without distortion of the image, which can be difficult in patients with abnormal spinal anatomy or obesity. Finally, needle insertion should follow a similar trajectory to the prior ultrasound beam, all while the patient remains completely still. Training in both the use of spinal ultrasonography and subsequent neuraxial anesthesia could help overcome many of these pitfalls.

Real-Time Scan and Ultrasound-Guided Neuraxial Anesthesia

There have been several novel studies and case reports detailing the use of ultrasound in real time for needle placement during neuraxial anesthesia [36–39]. This practice generally requires placing the ultrasound probe in the location and orientation that allows simultaneous visualization of neuraxial target structure/space, and the needle. Several cases have detailed this being done with multiple operators—one holding the ultrasound probe and the other performing the neuraxial procedure [40]. Alternatively, other case reports detail a single-operator technique [19, 41]. Additionally, while patients in these case studies were positioned in several ways (prone, lateral, sitting), many of the operators positioned the probe in the lateral sagittal position to obtain the most ideal visualization of neuraxial structures. Often, the needle was placed midline, and was followed in real time with the ultrasound [42]. Other proceduralists attempted an in-line approach resulting in a paramedian approach, where the needle was placed caudal to the probe and angled cephalad [19]. A report by Chin et al. describes an initial attempted preprocedural scan in a patient with difficult spinal anatomy with lack of success in performing a spinal anesthetic. Transitioning to a real-time approach led to a successful block [37]. Grau et al. compared the efficacy of real-time ultrasound combined spinal-epidural (CSE) placement to that of a preprocedural scan. All ten patients receiving real-time ultrasound spinals or CSE were successfully anesthetized on the first attempt (single skin puncture with or without redirection of the needle) [40]. Chong et al. showed a similar increase in successful first attempts compared to a landmark based technique (87 vs. 43%) [43]. These results show promise for using of real-time ultrasound while performing neuraxial procedures.

There are several limitations to the use of real-time ultrasound in neuraxial procedures. For instance, the space visualized by the ultrasound is quite limited given the acoustic shadows of the spinal canal. Maintaining an ideal ultrasound image while attempting to place a spinal or epidural therefore could be predictably difficult. This constraint has been overcome with the use of multiple operators; however, it is unclear how feasible this is in practice. Additionally, several cases report the use of novel loss of resistance techniques to assist in single-operator procedures, but access to these devices could be difficult [44]. Finally, understanding the real-time changes in neuraxial anatomy when placement of an epidural or spinal requires experience. For instance, Grau et al. noted that while intrathecal injection was easily visualized in real-time, epidural catheter placement was not as easily performed [40].

Limitations in Ultrasound Utilization for Neuraxial Anesthesia

Ultrasound is moderately effective in visualizing needle trajectory during ultrasound-guided neuraxial blocks. The obstacle in neuraxial procedures is that spinal structures are at some depth, and entering the spinal target must be achieved at a steep angle [19]. This trajectory precludes accurate visualization of the tip of the needle because of limitations in ultrasound technology, independent of the type and manufacturer of ultrasound machines [45]. There have been several methods that preclude the need for accurate needle visualization during ultrasound-guided neuraxial blocks. Several case reports detail the use of the anatomical changes to indicate accurate movement and position of the needle. Chin et al. notes that while the authors were not able to visualize the needle as a hyperechoic structure, they could appreciate the trajectory of the needle clearly on ultrasound [22]. Liu et al. describes a similar pattern; clear needle tip visualization was difficult in certain patients, but the trajectory of the needle could be appreciated by movements of the surrounding tissue [36]. Anatomic changes secondary to placement and injection of fluid into the subarachnoid space or subdural space can also provide accurate assessment. Anterior displacement of the posterior dura and widening of the posterior epidural space has been utilized as markers for epidural injection [6]. Tsui et al. were able to differentiate epidural versus intrathecal injection during a caudal anesthetic by visualizing a mosaic pattern on color flow doppler during injection [46].

An additional layer of difficulty is created by the lack of echogenicity of spinal needles. Conroy et al. performed ultrasound-guided spinal anesthetics in 100 patients, and utilized a 22G Quincke needle instead of a 25G Whitaker needle, more commonly used in practice, due to easier visualization of the 22G needle [39]. Brinkmann et al. utilized a novel highly echogenic needle in performing a real-time epidural placement in a porcine phantom and was able to visualize the needle tip at steeper angles [44]. Even though visualization of epidural catheter in children may be achieved under ultrasound, it has proved challenging in adults due to the depth of the catheter and lack of echogenicity; therefore, clinicians frequently rely on secondary indications mentioned previously [47]. Despite these described difficulties in visualization, ultrasound improves correct identification of the correct interspace when compared to landmarks alone, as verified by MRI, CT, or fluoroscopy thereafter [5, 13, 48].

Additional Imaging Options for Neuraxial Anesthesia

It is also of interest to understand the placement of both epidural and spinal anesthetics under other imaging modalities. The utilization of real-time imaging such as fluoroscopy and CT has been substantially proven to be a valuable tool in performing consistent injections of neuraxial anesthetics especially in difficult anatomies and injection sites such as cervical facets [49]. Without the use of fluoroscopically guided needle placement, there has been found to be substantial risk for error as high as 52% as seen by a study by Renfew in 1991 [50].

A study at Dartmouth-Hitchcock Medical Center has shown that the use of fluoroscopy for thoracic epidural placement resulted in a successful placement of the epidural in 98% of patients, as compared to 74% undergoing the traditional loss of resistance method [14]. The authors also stated that in the cases undergoing fluoroscopy, the epidural catheters were more likely to be in the correct position; there was a decreased length of post anesthesia care unit (PACU) and total hospital length of stay. Additionally, there was no difference in the use of adjunctive pain control in either arm of the study or numeric pain scores. Another study done by Kim et al. describes the methodology for performing c-arm assisted thoracic epidural catheter placement in 24 American Society of Anesthesiologists (ASA) I-II patients [51]. Similar to ultrasound, fluoroscopy is also useful in patients with difficult spinal anatomy. A case study done in Saudi Arabia demonstrates the use of fluoroscopy for epidural placement in a patient with ankylosing spondylitis, after traditional methods of spinal anesthesia placement were attempted without success. Similarly, a case study by Eidelman et al. demonstrated the use of fluoroscopy in successfully performing spinal anesthesia in a woman with a BMI of 54 [52].

Despite the substantial utility of this modality, fluoroscopy and CT requires the use of radiation which with continued use can lead to radiation induced injuries to the skin, underlying tissues, as well as cancers. The radiation exposure to patients must be a consideration in these cases, and its risks must be outweighed by the benefits of utilizing fluoroscopy for neuraxial procedures. Patient positioning can also be of concern. The studies mentioned previously had patients in the prone position; patients must be able to tolerate this position for successful fluoroscopic evaluation. The amount of time required for the use of fluoroscopy must also be considered. The duration of time clinically depends on availability of a c-arm, an X-ray compatible table, time positioning the patient, and time performing the procedure. The familiarity of the procedure to both the anesthesiologist and surgical staff plays a role in timing as well. In the Dartmouth-Hitchcock study, the procedures were performed by Acute Pain service physicians, who are more likely to be knowledgeable about fluoroscopically guided techniques.

In comparison to fluoroscopy, ultrasound-guided neuraxial block provides similar pain relief with additional advantages in reducing the risk of intravascular injection by real-time vascular imaging and shorter procedure time [53, 54]. For neuraxial intervention, it is essential to visualize bony structures as a landmark in order to perform the procedure safely, and obesity may present challenges to ultrasound-guided visualization. Although there are emerging interests and promising outcomes in ultrasound utilization, future randomized controlled studies are needed to clarify the efficacy and complications of ultrasound-guided neuraxial blocks [55].

Ultrasound in Obstetric Neuraxial Anesthesia

Spinal and epidural anesthesia play an important role in the care of obstetric patients, as they offer labor analgesia with minimal side effects for both the mother and fetus. Typically, the traditional method of neuraxial anesthesia in obstetric patients relies on landmark palpation and traditional loss of resistance techniques. Correctly identifying anatomy in these patients can be particularly challenging given physical restrictions of pregnancy, anatomical changes to the spinal structures secondary to hormones, and overall weight gain and edema secondary to pregnancy [56]. Obstetric patients tend to have softer interspinous ligaments and narrowing of the intrathecal space [30]. For these reasons, obstetric patients undergoing landmark based neuraxial anesthesia have a higher rate of needle re-entry and redirection during these procedures [57]. Similar to non-obstetric patients, there have been studies to demonstrate that the use of a preprocedural scan can help determine midline and depth of needle insertion, and result in reduced rates of needle re-entry [58–60]. For example, a group of 110 women undergoing vaginal delivery was randomized to ultrasound versus traditional landmark based techniques for a combined spinal-epidural technique; the women in the ultrasound group had a higher rate of first attempt success (67 vs. 40%, $p = 0.04$), and had fewer puncture attempts and redirection attempts [61]. These improved end-points are reflected in higher patient satisfaction scores and reduced incidence of headaches with preprocedural scanning as compared to traditional landmark-based methods [62]. While all these benefits should increase the use of preprocedural scanning among practicing obstetric anesthesiologists, the success rate of the landmark based technique limits the utility of ultrasound in obstetric patients.

There are several areas within obstetric neuraxial procedures in which the use of ultrasound might be useful. One of these areas is in the education of new anesthetists. Vallejo et al. demonstrated that first year anesthesia residents, with and without ultrasound education, had a higher number of successful catheter placement attempts and reduced rates of catheter replacements in obstetric patients when utilizing a preprocedural scan [63]. Similarly, Grau et al. demonstrated an improvement in the learning curve of residents using ultrasound to place epidurals in pregnant women [64]. As mentioned previously, difficult spinal anatomy is another area where ultrasound might be useful. Grau et al. conducted another study of 72 parturients who were predicted to have difficult epidural placement, either because of obesity (BMI > 33), spinal deformity, or previously difficult epidural placement. They found that there were fewer needle passes and better patient satisfaction and pain scores in the ultrasound group [35]. Creany et al. noted a similar finding in 20 parturients with difficult to palpate spinous processes undergoing traditional palpation-based techniques vs. preprocedural scanning and found that there were significantly fewer needle passes in those with preprocedural scanning. Spinal deformities and prior surgical manipulation can also pose a difficult scenario for neuraxial anesthesia in pregnant women [65]. Costello et al. demonstrated the successful use of ultrasound for spinal anesthesia in a pregnant woman with Harrington rods [66]. The use of preprocedural ultrasound may also be useful in obese pregnant women. Ellinas et al. demonstrated a 35% first attempt success rate by traditional palpation methods in parturients with a BMI > 35 [67]. Sahin et al. performed subarachnoid blocks for cesarean section in 50 parturients with a BMI > 30. Patients were split into an ultrasound group and a traditional landmark based group prior to the procedure, and first attempt success rate under ultrasound guidance was 92% compared to 44% in the traditional landmark based method ($p < 0.001$) [60]. Additionally, the time to achieve the spinal block was shorter in the ultrasound group.

Overall, the use of ultrasound offers promising improvements in traditional practices for neuraxial anesthesia in obstetric patients. Ultrasound can be a costly addition to any obstetric unit, but promise of decreased complications may offset these costs.

Conclusions

The use of neuraxial ultrasound has consistently demonstrated its value in accurately identifying vertebral levels compared to simple palpation of surface landmarks. As a radiation-free imaging tool, ultrasound-guided needle insertion is extremely beneficial in patients with anatomical challenges such as obesity, spinal pathologies (scoliosis), implanted hardware, or during pregnancy [7]. A systematic review with both clinical trials and an meta-analysis by Perlas demonstrated that with preprocedural ultrasound as an adjunct to lumbar spinal and epidural anesthesia substantially improved both the precision and efficacy of the blockade [68•]. There continues to be demonstrated value in ultrasound use although its safety profile beyond obstetric cases requires further evaluation [69]. In summary, ultrasound mapping provides valuable anatomical information that is not obtainable by landmark based physical examination. The primary focus on ultrasound integration into standard practice throughout neuraxial anesthesia should be focused on providing cost effectiveness as well was needle-tracking methods to better improve the efficacy and safety of the procedure [70]. Even though neuraxial anesthesia modalities are the most commonly performed regional anesthesia technique, ultrasound is very much underutilized as compared to the other techniques such as peripheral nerve blocks. The new frontier of ultrasound in neuraxial anesthesia will require the evaluation of real-time ultrasound-guided needle insertion in conjunction with newer technologies and more controlled studies on the its clinical application and practical impacts [71].

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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