Ultrasonography of the lumbar spine for neuraxial and lumbar plexus blocks

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Purpose of review

Ultrasonography of the spine has evolved into a well described technique that can be applied to facilitate neuraxial and lumbar plexus blockade.

Recent findings

There is increasing evidence for the clinical benefits of ultrasound imaging prior to administration of neuraxial blockade. Recent randomized controlled trials have shown that efficacy of epidural analgesia is improved, and the technical difficulty of spinal and epidural anaesthesia is reduced. Ultrasound imaging may also permit more accurate prediction of the depth to epidural and intrathecal spaces and more accurate identification of intervertebral levels. The use of ultrasound in lumbar plexus blockade has been described in the context of both preprocedural imaging and real-time needle guidance; however, its clinical benefit in this setting has not yet been clearly established.

Summary

Preprocedural ultrasound imaging of the spine may reduce the technical difficulty of neuraxial blockade and also improve clinical efficacy. Similar benefits are expected in the setting of lumbar plexus blockade although there is currently no evidence to confirm this. Real-time ultrasound-guided neuraxial and lumbar plexus blockade are challenging techniques that need further validation.

Keywords

epidural anaesthesia, lumbar plexus block, psoas compartment block, spinal anaesthesia, ultrasound

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Introduction

Ultrasonography of the spine is not a new tool in anaesthesiology practice. However, it has been relatively underutilized due mainly to the perceived difficulty of ultrasound imaging and efficacy of the conventional surface landmark-guided regional anaesthesia techniques of the spine. Incorporating the use of a stepwise scanning approach to central neuraxial and lumbar plexus ultrasound imaging may serve to facilitate successful block performance in patients with both normal and abnormal spinal anatomy, and in the process, add to patient safety and comfort. A systematic approach to ultrasound imaging of the spine has been well described in two recent review articles [1•,2••], and will therefore not be further elaborated upon. Instead, this review article will summarize the growing body of evidence for clinical application of ultrasound to the techniques of both neuraxial (spinal and epidural anaesthesia) and lumbar plexus blockade.

Ultrasonography of the spine may be used to assist the practitioner with neuraxial and lumbar plexus blockade in one of two ways. Most commonly, the anatomy of the spine is delineated by a preprocedural ultrasound scan. This provides information on the interspace level; the location of the spinous processes, midline, and transverse processes; the optimal needle puncture point; the optimal angle for needle insertion; the estimated depth to the structures of interest (e.g. epidural space, psoas muscle, lumbar plexus). Once equipped with the additional information, the block procedure is performed in a manner similar to conventional surface landmark-guided techniques. The term 'ultrasound-guided' in this review is intended to indicate the technique of preprocedural scanning. 'Real-time ultrasound-guided' neuraxial and lumbar plexus blockade, on the contrary, refers to needle insertion under direct ultrasonographic visualization. In the context of neuraxial blockade, this has been described in only five small studies, four of which were case reports or series [3–7]. Similarly, real-time ultrasound-guided lumbar plexus blockade is described in only four articles, all of which were case reports or series. Therefore, whereas this is an interesting area of development, in our opinion, these are still experimental and highly challenging techniques that cannot be recommended for routine use at this time.

Ultrasound may improve the clinical efficacy and reduce the technical difficulty of neuraxial blockade

There is evidence from three randomized controlled trials (RCTs) [8,9,10••] that ultrasound guidance improves both the success and quality of epidural analgesia compared to conventional landmark-guided neuraxial techniques. All three investigations involved obstetric patients receiving either epidural or combined spinal–epidural anaesthesia/analgesia. Two of the studies were performed by a single operator and published by Grau *et al.* [8,9] between the years 2001 and 2004. In the largest of the studies ($n=300$) [9], a significantly lower rate of incomplete analgesia (2 vs. 8%) and significantly lower postblock pain scores as well as higher patient satisfaction scores in the ultrasound-guided patient group were reported. More recently, Vallejo *et al.* [10••] studied 370 parturients undergoing labour epidurals performed by a cohort of 15 first-year anaesthesiology residents. One group of patients underwent preprocedural ultrasound imaging of the lumbar spine by a single operator with 6 months previous experience in the technique, whereas the other group of patients did not have preprocedural ultrasound scanning performed. The information obtained from the preprocedure ultrasound scan (depth to the epidural space and location of landmarks) was communicated to a resident who performed the epidural under the supervision of another blinded staff anaesthesiologist. The rate of inadequate analgesia (i.e. requiring replacement of the epidural) once again proved to be significantly lower in the group of patients that had preprocedural ultrasound scanning performed (1.6 vs. 5.5%).

In the two RCTs mentioned above and performed by Grau *et al.* [8,9], patients receiving the ultrasound-guided technique required half the number of needle passes for successful neuraxial blockade compared to those patients in the group receiving the conventional neuraxial technique (caveat: all procedures were performed by a single experienced operator). In addition, Vallejo *et al.* [10••] were also able to demonstrate a similar benefit for preprocedural ultrasound imaging in labour epidurals that were performed by junior trainees (median number of insertion attempts 1 vs. 2, ultrasound-guided vs. control groups, respectively).

Ultrasound imaging may prove to be particularly helpful in patients with poorly palpable (e.g. obese patients) or abnormal anatomical landmarks (e.g. scoliosis). This is supported by numerous case reports of successful ultrasound-guided neuraxial blockade in patients with marked obesity [11,12], previous spinal surgery and/or spinal instrumentation [13–17], and in those patients with spinal deformity [18•,19,20•]. There are two RCTs that specifically studied patients in whom performing neuraxial blockade was known or anticipated to be difficult. Grau *et al.* [8] provided labour epidural analgesia to 72 parturients with either spinal deformity, obesity (BMI >33 kg/m^2), or a history of previous difficulty with placement of neuraxial anaesthesia/analgesia. Successful epidural placement was achieved with significantly fewer needle passes (mean 1.5 vs. 2.6) and attempts at fewer spinal interspaces (1.3 vs. 1.6, $P<0.05$) in the ultrasound-guided group compared to the control group. Most recently, Chin *et al.* [21••] studied 120 patients undergoing spinal anaesthesia for total joint replacement surgery. These patients had poorly palpable surface landmarks and a BMI greater than 35 kg/m^2, significant spinal deformity, or previous spinal surgery/instrumentation that resulted in anatomical distortion or absence of surface landmarks. A distinguishing feature of this study compared to the earlier described RCTs is that there were multiple experienced operators involved, each of whom performed both anatomical landmark identification (by either palpation alone or palpation along with ultrasound) and placement of the spinal anaesthetic. The results from the study revealed a two-fold difference between the ultrasound-guided group and the control group (palpation alone) in the median number of procedure needle passes required for successful spinal anaesthesia (6 vs. 13) and the first-attempt success rate (62 vs. 32%).

Ultrasound imaging of the spine has therefore been shown to improve the ease and efficiency of performing a neuraxial block by either the novice or experienced practitioner alike, particularly in those patients in whom neuraxial blockade is anticipated to be difficult. However, it has yet to be determined if the same benefits will be seen when less experienced clinicians perform both the ultrasound scan as well as the neuraxial block procedure.

Key points

- Preprocedural ultrasound imaging reduces technical difficulty of neuraxial blockade, especially in patients with indistinct or altered surface landmarks.
- Preprocedural ultrasound imaging may also improve the clinical efficacy of obstetric epidural analgesia, although the mechanism is unclear.
- Ultrasound can provide useful anatomical information to guide the performance of lumbar plexus block; however, the clinical benefits of doing so have not been formally established.

Estimation of needle insertion depth and identification of intervertebral levels for neuraxial blockade

The correlation between ultrasound-measured depth and actual needle insertion depth has been evaluated in 10 studies in obstetric patients [8,10••,22–29], and two studies in nonobstetric patients [30,31]. Correlation was excellent in all studies (Pearson's correlation coefficients of 0.80–0.99), regardless of whether ultrasound depth measurements were made in the sagittal, parasagittal oblique, or transverse views. Out of six studies that analysed the difference between measured and actual depths, the ultrasound-measured depth tended to underestimate actual needle depth in four trials [23,25,28,31] and overestimate it in the other two trials [22,27] with 95% confidence limits for the difference ranging between 5 and 15 mm. This discrepancy in depth may be explained by the differing trajectories of the ultrasound beam and block needle as well as by any tissue compression created by the ultrasound probe during scanning or by the Tuohy needle during insertion.

Specific lumbar spinous processes and intervertebral levels have been shown to be identified more accurately by ultrasonography than by clinical estimation using palpation of the intercristal line [32]. The two methods have been observed to agree in only 36–55% of cases studied [33–35]. When a discrepancy exists, the clinically determined level is usually lower than that determined on ultrasound [34,35].

It must be noted that ultrasound, when compared against other imaging modalities such as MRI [36], plain radiographs [32], and computed tomography (CT) [37•] of the lumbar spine, accurately identified a spinous process or intervertebral space only 68–76% of the time. These results can be partly explained by technological limitations in the two older studies [32,36], and possibly by the level of operator experience and expertise. Halpern *et al.* [37•] performed a pilot investigation looking at the learning curve associated with ultrasonographic identification of spinous processes. In this study, two anaesthesiologists with no previous experience in ultrasound imaging of the spine performed a systematic ultrasound scan of the lumbar spine in 74 patients. They identified a designated spinous process, and the accuracy of this identification was verified by a radiologist on CT scan of the lumbar spine. Whereas the overall accuracy rate of the two novices studied was only 68%, cumulative sum (cusum) analysis showed that both anaesthesiologists were able to achieve accuracy rates of 90% or greater with increasing experience.

Poor ultrasound image quality in obese and elderly patient populations

In obese patients, structures are often less distinct due to both attenuation and a phase aberration effect resulting from the uneven speed of sound as it passes through irregularly shaped adipose tissue layers [38]. Nevertheless, there is evidence from case reports and observational studies [13,21••,23] that ultrasonography of the spine in obese patients is both feasible and helpful when performing neuraxial blockade, since at a minimum the spinous processes (indicating the midline) and interspinous gaps can usually be identified [12]. Advances in ultrasound imaging technology, for example compound imaging and tissue harmonic imaging, may also partly compensate for the deterioration in image quality.

The challenges and solutions to ultrasound scanning in elderly patients have not been systematically studied, but the main issues relate to narrowing of the interspinous spaces and interlaminar spaces due to age-related degenerative changes [39]. Prominent spinous processes in a thinner elderly patient may further complicate the ultrasound exam by hindering adequate skin-probe contact, thus contributing to poor visualization of neuraxial structures. In such patients, obtaining a transverse ultrasound view of the vertebral canal may be physically difficult or impossible; and the parasagittal oblique ultrasound view may be a better alternative. Contact may also be improved by using an ultrasound probe with a smaller footprint.

The learning curve for ultrasonography of the spine

Two small studies to date have attempted to examine the learning curve of anaesthesiologists with no prior experience in ultrasound imaging of the lumbar spine. The study by Halpern *et al.* [37•], used cusum analysis to determine the learning curve associated with using ultrasound to accurately identify a given spinous process (subsequently confirmed by CT). The authors studied two anaesthesiologists who received prior training in ultrasonography of the spine on five patients each. Competency (defined as $\geq$90% accuracy in identifying a given spinous process) was achieved by one anaesthesiologist after examining a further 22 patients, whereas 36 patients were required by the other anaesthesiologist.

In the second study, Margarido *et al.* [40•] recruited 18 anaesthesiologists, none of whom had any experience in ultrasound imaging of the spine, and provided them with comprehensive training that included reading material, an educational video, a 45-min lecture, and a 30-min hands-on workshop. The anaesthesiologists were assessed 7–14 days later on their ability to perform three ultrasound-related tasks in a human volunteer with normal anatomy and to identify lumbar intervertebral spaces, mark an optimal insertion point, and measure the depth to the epidural space. Accuracy was determined by comparing their performance with that of three other anaesthesiologists with expertise in ultrasound imaging of the lumbar spine. Cusum analysis was again used to determine if competence was achieved by the study anaesthesiologists. Only five anaesthesiologists (27%) achieved competence in identifying the intervertebral spaces, whereas none demonstrated competence at either of the other two tasks. The authors concluded that a training session and 20 supervised trials were insufficient for achieving competency in ultrasound imaging of the lumbar spine. However, these results must be interpreted with caution as only 11 (61%) anaesthesiologists managed to complete the stipulated number of 20 trials. The criteria for accuracy may also have been overly strict. The authors noted that most of the errors did not stem from an inability to recognize relevant anatomy, but rather from imprecision in skin marking and depth measurement that could have been avoided with greater meticulousness on the part of the operator.

These two studies suggest that experience of at least 40 or more cases may be required to attain competency in ultrasound imaging of the lumbar spine. This needs to be confirmed by larger and more robust studies. Additional research is also needed to determine the learning curve associated with the actual performance of a successful ultrasound-guided neuraxial block, as well as the optimal training strategies for developing competency in this task.

Ultrasound-guided neuraxial block in the paediatric population

The application of ultrasound imaging to neuraxial block in the paediatric population was recently reviewed by Tsui and Suresh [41••]. However, no new clinical studies investigating paediatric ultrasound-guided neuraxial blockade have been published in the past 3 years. The application of ultrasound imaging for neuraxial blockade is easier in the paediatric population than in adults because of the shallower depth to structures of interest, thus permitting the use of higher-frequency ultrasound probes with higher imaging resolution, and the larger acoustic windows offered by the relative lack of vertebral ossification. As a result, the dura mater and the ligamentum flavum can usually be clearly visualized, and the depth to the epidural space accurately measured [42–44]. The conus medullaris may also be imaged in neonates and infants [44]. Finally, ultrasound can aid in confirmation of epidural catheter placement by visualization of distension of the epidural space on injection [43–45], and in certain patients by direct visualization of the catheter itself [43]. Therefore, whereas it is conceivable that ultrasound-guided neuraxial blockade could offer clinical benefits similar to that seen in adults, further studies are required to confirm its utility.

Ultrasound-guided lumbar plexus blockade

There are currently only eight published studies on ultrasound-guided lumbar plexus block (as of April 2011). Seven of these are in the adult population and include two medium-sized case series [46,47••], one series of five patients [48,49], two case reports [50•,51], and two feasibility studies in cadavers and volunteers [52,53]. There are currently no RCTs investigating this topic and only one paediatric study [49].

Sonoanatomy relevant to the lumbar plexus block has been well described in the literature [48,53]. The area is imaged by scanning lateral to the lumbar spine in either a longitudinal parasagittal or transverse plane. The transverse processes, psoas major muscle, and surrounding structures of interest (lower pole of the kidney, peritoneum, aorta and inferior vena cava) are usually readily identified. In a study of 32 paediatric patients, Kirchmair *et al.* [49] were able to visualize the lumbar plexus in the majority of patients. They attributed their success to the shallower depth of the anatomical structures and reduced fibrosis within the psoas major muscle. Visualization of the lumbar plexus in adults has been described [48,51], but this does not appear to be consistently possible. Karmakar *et al.* [48] described real-time ultrasound-guided lumbar plexus blockade in five patients, but were unable to visualize the lumbar plexus in two out of five adult patients. In addition, it was noted that the lumbar plexus was difficult to distinguish from intramuscular tendon fibres that have a similar hyperechoic linear appearance.

Ultrasound-guided lumbar plexus block: preprocedure vs. real-time imaging

Four out of the six clinical studies of ultrasound-guided lumbar plexus block describe a real-time ultrasound-guided technique [46,48,49,51]. The optimal technique is unclear, with four different approaches having been described: a transverse view of the plexus with the needle inserted out-of-plane to the ultrasound beam [49], a transverse view of the plexus with the needle inserted in-plane and in a lateral-to-medial direction [46,51], a transverse view of the plexus with the needle inserted in-plane and in a medial-to-lateral direction (study conducted in cadavers only) [52], and a longitudinal view of the plexus with the needle inserted in-plane [48]. In all of the cases described above, final needle tip position was confirmed by an appropriate quadriceps motor response to neurostimulation and not by ultrasound visualization of needle-to-nerve contact. In the largest of these four studies, Doi *et al.* [46] reported only partial block in five out of 67 patients studied (7%) and bilateral sensory block in two patients (3%). This particular study was published as a letter to the editor without explanation of methods or results, therefore making it difficult to draw conclusions from the limited information presented. Thus, our opinion, which is shared by others [54], is that real-time ultrasound-guided lumbar plexus is an extremely challenging and advanced technique that needs to be further refined and validated with additional studies.

Surface anatomical landmark-guided techniques do not reliably predict the location and depth of the transverse processes and lumbar plexus. Preprocedural ultrasound imaging may therefore be of benefit in delineating the important anatomy relevant to the lumbar plexus and can potentially reduce many of the complications associated with current landmark-guided techniques. In particular, ultrasound imaging allows the location and depth of the desired transverse process to be ascertained and the depth to the approximate location of the lumbar plexus (at the junction between the posterior one-third and anterior two-thirds of the psoas major) to be estimated.

Ilfeld *et al.* [47••] recently reported an observational study of 53 patients in whom preprocedural imaging was used to locate and measure depth to the transverse process prior to performing continuous lumbar plexus block. They were unable to identify the transverse processes in three obese patients, who subsequently required needle insertion depths of 9–12 cm for successful block. Imaging failure in these patients could have possibly been avoided if the investigators had used a curved-array transducer instead of a linear-array transducer with a maximum scanning depth of 6 cm. However, they were able to accurately predict depth to the transverse process to within 1 cm of actual needle insertion depth (median difference 0.5 cm) in all remaining patients. In addition, the authors found that the conventional surface landmark techniques [55] resulted in an insertion point that was too lateral to the tip of the transverse process in 50% of patients. These results clearly point to the clinical benefit of ultrasound imaging of the lumbar paravertebral area prior to lumbar plexus blockade, even in patients with normal anatomy. Ultrasound imaging is potentially even more useful when performing lumbar plexus blockade in patients with abnormal or distorted spinal anatomy as was illustrated in the case report by Factor and Perlas [50•].

Conclusion

Recent studies have confirmed that preprocedural ultrasound imaging of the spine reduces the technical difficulty of neuraxial blockade and may also improve the clinical efficacy of epidural analgesia. Although the evidence supporting the utility of ultrasound imaging in lumbar plexus blockade is much more limited, the preliminary studies suggest that the additional anatomical information should facilitate block performance and increase safety. At this time, however, there are insufficient data to support the widespread use of real-time ultrasound-guided techniques in either neuraxial or lumbar plexus blockade.

Acknowledgements

Conflicts of interest

None declared.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

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- •• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 597–598).

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