

Ultrasound-guided lumbar central neuraxial block

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Key points

- Ultrasound-assisted neuraxial block is an advanced technique for use in patients with difficult spinal anatomy.
- The use of a pre-procedural scan improves the technical efficiency of central neuraxial block (CNB) by facilitating precise identification of underlying anatomical structures.
- The risk of traumatic or failed lumbar CNB may be reduced by the use of neuraxial ultrasound.
- Detailed knowledge of lumbar spinal anatomy and sonoanatomy is essential for interpretation of neuraxial ultrasound images.
- Practitioners should familiarize themselves with ultrasound-assisted neuraxial block in normal individuals before attempting it in patients with difficult anatomy.

The practice of central neuraxial block (CNB) has traditionally relied on the palpation of bony anatomical landmarks, namely the iliac crests and spinous processes, together with tactile feedback during needle insertion. However, these landmarks may be difficult to identify accurately—a problem exacerbated by altered patient anatomy, including obesity, age-related changes, and previous spinal surgery.

A 2008 guideline by the National Institute for Health and Care Excellence (NICE) recommended the routine use of neuraxial ultrasound for epidural catheterization, concluding that ultrasound might help achieve correct catheter placement.¹ This

ultrasound-assisted approach to CNB involves performing a pre-procedural scan which helps to identify relevant landmarks and thus guide subsequent needle insertion. Over the last decade, a large body of evidence has accumulated to support the benefit of this approach. Real-time ultrasound-guided CNB (where the needle is inserted under direct and continuous ultrasound visualization), on the other hand, remains an experimental and highly complex technique which will not be discussed further.

This article describes the relevant anatomy of the adult lumbar spine, the key ultrasonographic views, and a systematic approach to neuraxial ultrasound to facilitate the performance of CNB. An overview of the current evidence is also presented.

Gross anatomy of the lumbar spine

The lumbar spine comprises five vertebrae (L1–L5). Each vertebra has two functional parts: a vertebral body and a vertebral arch. Each vertebral arch is composed of a spinous process, pedicles, laminae, transverse processes, and superior and inferior articular processes. The lumbar spinous processes are broad (in the superior–inferior dimension), flat, oblong-shaped structures that project posteriorly from the union of the laminae. The superior and inferior articular processes extend posteriorly in a cranial and caudad direction, respectively, from the point at which the pedicles and laminae fuse. Long, slim transverse processes protrude laterally from the vertebral arch at the junction of the laminae and pedicles. The laminae slope from posterior to anterior in a caudad-to-cephalad direction. In contrast to the thoracic spine, the laminae and spinous processes of adjacent lumbar vertebrae do not overlap. This gives rise to distinct gaps—the interlaminar and interspinous spaces—through which the vertebral canal can be accessed. These spaces can be enlarged by forward flexion of the lumbar spine. The anterior wall of the vertebral canal is formed by the posterior longitudinal ligament and the posterior

surface of the vertebral bodies and intervertebral discs. The posterior wall of the vertebral canal comprises the laminae and the ligamentum flavum, which forms a thick, fibrous bridge over the interlaminar spaces (Fig. 1).

General preparation for scanning

The patient is placed in a sitting or lateral decubitus position for the block, with forward flexion at the lumbar spine. This eliminates lumbar lordosis, opens up the lumbar interspinous spaces, and generally improves the acoustic window. The use of a curved, low-frequency (2–5 MHz) probe is recommended to provide enhanced beam penetration, and wide field of view, both of which improve identification of anatomy.

Sonoanatomy of the spine and ultrasonographic views for neuraxial block

Bone is not penetrated by ultrasound and casts a dense acoustic shadow. The contours of the posterior bony surfaces of the lumbar vertebra thus have characteristic patterns of acoustic shadowing that are key to interpretation of the sonoanatomy of the lumbar spine. Visualization of the vertebral canal is only possible through the soft-tissue acoustic windows of the interlaminar and interspinous spaces.

There are five basic ultrasonographic views of the spine that can be systematically obtained:

- (i) parasagittal transverse process view,
- (ii) parasagittal articular process view,
- (iii) parasagittal oblique (interlaminar) view,
- (iv) transverse spinous process view,
- (v) transverse interlaminar (interspinous) view.

The parasagittal oblique (interlaminar) view (PSO view) and the transverse interlaminar/interspinous view (TI view) are the most important views in clinical practice since they provide a view of the neuraxial structures through acoustic windows. These structures include: ligamentum flavum, posterior dura, spinal canal, anterior dura, and posterior longitudinal ligament.

Parasagittal transverse process view

The ultrasound probe is placed over the lower lumbar spine in a parasagittal orientation, a few centimetres lateral to the midline.

The transverse processes appear as finger-like acoustic shadows, separated by the striated psoas major muscle, which lies deep to the transverse processes. The erector spinae muscle lies superficial (posterior) to the transverse processes (Fig. 2 top).

Parasagittal articular process view

Maintaining a strictly sagittal orientation, the ultrasound probe is now moved medially until the acoustic shadows of the transverse processes give way to a pattern of continuous hump-like shadows, formed by the overlapping superior and inferior articular processes. The articular process view is also distinguished from the transverse process view by the more superficial depth of the acoustic shadows (Fig. 2 bottom).

Parasagittal oblique (interlaminar) view (PSO view)

Starting from the parasagittal articular process view, the ultrasound probe is now slowly tilted to direct the beam in a lateral-to-medial direction until the humped pattern of the articular processes changes into a ‘sawtooth’ pattern of acoustic shadows. The ‘teeth’ correspond to the downsloping laminae and the gaps between represent the interlaminar spaces. The PSO view therefore gives us an acoustic window into the vertebral canal.

Structures that are penetrated by the ultrasound beam are (from posterior to anterior): ligamentum flavum, epidural space, dura (posterior), intrathecal space, dura (anterior), and posterior longitudinal ligament. The ligamentum flavum, epidural space, and posterior dura appear as a hyperechoic linear structure and are collectively referred to as the *posterior complex*; while the anterior dura, posterior longitudinal ligament, and posterior border of the vertebral body and discs constitute a deeper hyperechoic linear structure called the *anterior complex*. In practice, the individual elements of these complexes are usually not distinguishable (Fig. 3).

Transverse spinous process view

In order to obtain a transverse spinous process view, the ultrasound probe is placed in a horizontal orientation with the centre of the probe placed over the midline. If the ultrasound beam is placed over a spinous process, the tip of the spinous process appears as a superficial hyperechoic ‘cap’ surmounting a tall dense acoustic shadow. Lateral to the spinous process, the erector

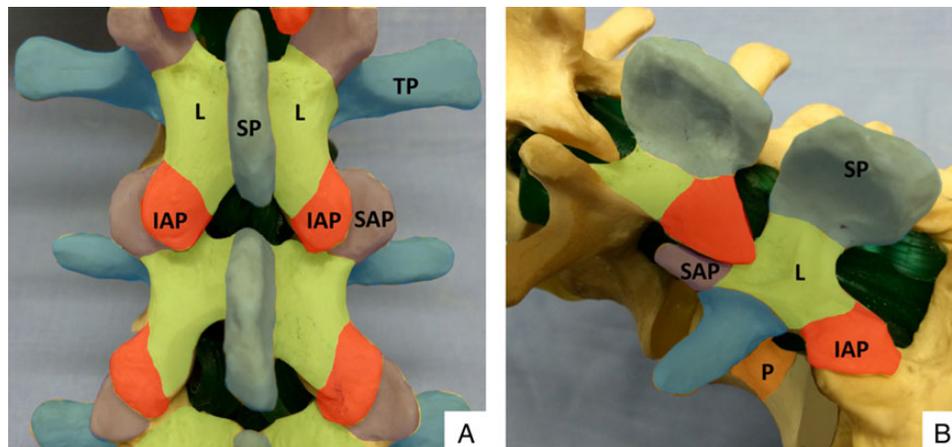


Fig 1 Bony anatomy of the lumbar spine, posterior view (A) and oblique view (B). SP, spinous process; IAP, inferior articular process; SAP, superior articular process; L, lamina; TP, transverse process; P, pedicle. (Image courtesy of www.usra.ca.)

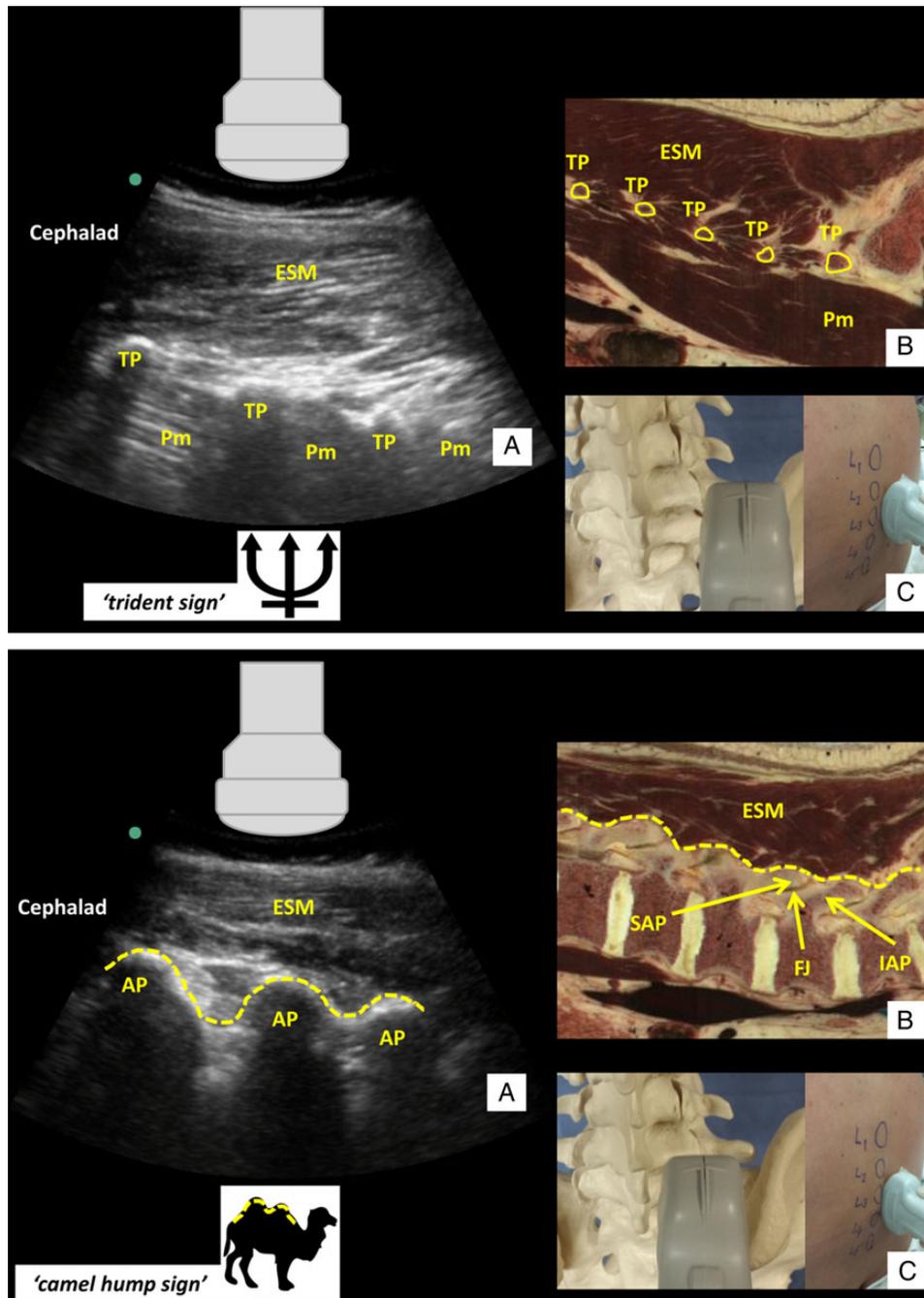


Fig 2 (Top) Parasagittal transverse process view of the lumbar spine (A) with corresponding anatomical section (B) (virtual slice extraction from visiblehuman.epfl.ch) and ultrasound probe orientation (C). ESM, erector spinae muscle; TP, transverse process; Pm, psoas muscle. The appearance of the finger-like acoustic shadows produced by the transverse processes is also called the 'trident sign'. (Bottom) Parasagittal articular process view of the lumbar spine (A) with corresponding anatomical section (B) and ultrasound probe orientation (C). ESM, erector spinae muscle; AP, articular process; SAP, superior articular process; FJ, facet joint; IAP, inferior articular process. Dotted lines in (A) and (B) highlight the contour of the articular processes, resembling a series of camel humps ('camel hump sign'). (Image courtesy of www.usra.ca.) [Anatomical section images courtesy Prof. R.D. Hersch, Ecole Polytechnique Fédérale de Lausanne (EPFL), site: <http://visiblehuman.epfl.ch>, with original 3D data from the Visible Human Project, US National Library of Medicine, Bethesda.]

spinae muscle can be visualized, with the lamina of the vertebral body casting its own dense acoustic shadow at the level of the anterior border of the erector spinae muscle (Fig. 4).

Transverse interlaminar/interspinous view (TI view)

Starting from the transverse spinous process view, the TI view is obtained by sliding the probe in a cephalad or caudad direction as

needed until the beam enters the acoustic window between the spinous processes. A slight cephalad tilt in the horizontal plane may have to be applied to compensate for the angulation of the spinous processes. The interspinous ligament appears as a hypoechoic midline stripe. The hypoechoic intrathecal space is bounded anteriorly and posteriorly by the parallel hyperechoic lines of the anterior and posterior complexes, respectively (Fig. 5).

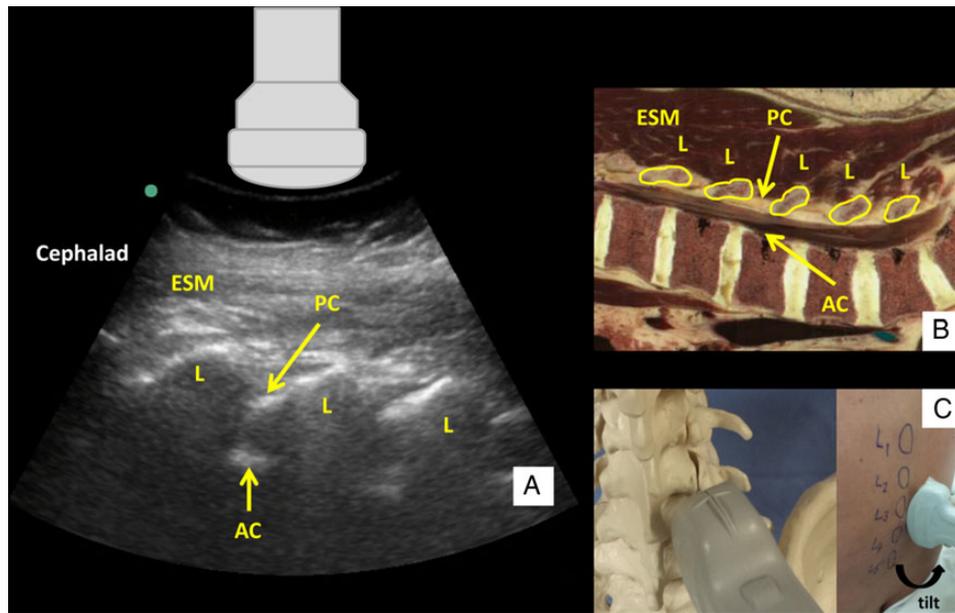


Fig 3 Parasagittal oblique view of the lumbar spine (A) with corresponding anatomical section (B) and ultrasound probe orientation (C). ESM, erector spinae muscle; L, lamina; PC, posterior complex; AC, anterior complex. (Image courtesy of www.usra.ca.) [Anatomical section image courtesy of Prof. R.D. Hersch, Ecole Polytechnique Fédérale de Lausanne (EPFL), site: <http://visiblehuman.epfl.ch>, with original 3D data from the Visible Human Project, US National Library of Medicine, Bethesda.]

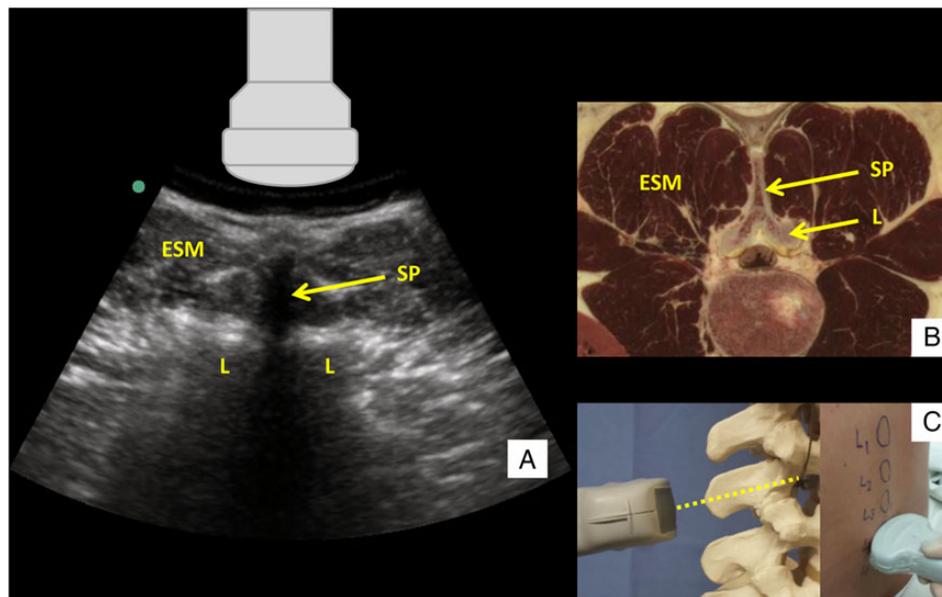


Fig 4 Transverse spinous process view of the lumbar spine (A) with corresponding anatomical section (B) and ultrasound probe orientation (C). ESM, erector spinae muscle; L, lamina; SP, spinous process. Dotted line in (C) represents the direction of the ultrasound beam. (Image courtesy of www.usra.ca.) [Anatomical section image courtesy of Prof. R.D. Hersch, Ecole Polytechnique Fédérale de Lausanne (EPFL), site: <http://visiblehuman.epfl.ch>, with original 3D data from the Visible Human Project, US National Library of Medicine, Bethesda.]

Systematic approach to ultrasound-guided neuraxial block by a midline approach

1. Patient position and equipment
 - Place patient in the position in which neuraxial block will be performed: sitting or lateral, with forward flexion of the lumbar spine.

- Attempt to identify midline and lumbar spine by palpation of standard anatomical landmarks.
 - Use a low-frequency (2–5 MHz), curved-array probe.
2. Parasagittal transverse process view
 - Place probe in a sagittal orientation ~3–4 cm lateral from midline on lumbar spine, slightly cephalad to the sacrum

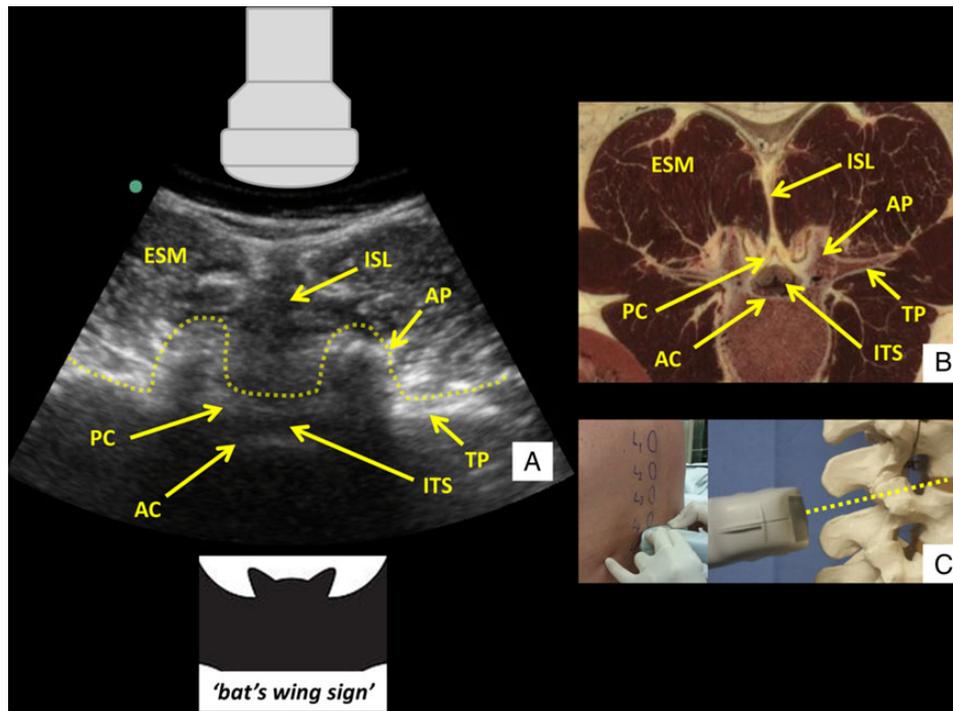


Fig 5 Transverse interlaminar view of the lumbar spine (A) with corresponding anatomical section (B) and ultrasound probe orientation (C). ES, erector spinae muscle; PC, posterior complex; AC, anterior complex; ITS, intrathecal space; ISL, interspinous ligament; AP, articular process; TP, transverse process. Dotted line in (A) outlines the contour of the ultrasonographic structures giving rise to the 'bat's wing sign'. Dotted line in (C) represents the direction of the ultrasound beam. (Image courtesy of www.usra.ca.) [Anatomical section image courtesy of Prof. R.D. Hersch, Ecole Polytechnique Fédérale de Lausanne (EPFL), site: <http://visiblehuman.epfl.ch>, with original 3D data from the Visible Human Project, US National Library of Medicine, Bethesda.]

to identify the finger-like acoustic shadows of the transverse processes.

Key ultrasonographic structures: erector spinae muscle, psoas muscle, transverse processes

3. Parasagittal articular process view
 - Slide probe medially while maintaining a strictly parasagittal orientation.
 - Observe the transition from the discontinuous pattern of the transverse process view to the continuous, hyperechoic line formed by the articular processes.

Key ultrasonographic structures: erector spinae muscle, articular processes

4. Parasagittal oblique (interlaminar) view (PSO view)
 - From the parasagittal articular process view, tilt the probe obliquely to direct the ultrasound beam more medially into the vertebral canal.
 - Observe the transition from the rounded 'humps' of the articular processes to the sawtooth-like acoustic shadows of the laminae, with the hyperechoic posterior and anterior complexes visible in between.

Key ultrasonographic structures: laminae, posterior complex, intrathecal space, anterior complex

5. Identify and mark appropriate intervertebral spaces, using the PSO view
 - In the PSO view, slide the probe caudad until the sacrum is identified as a long horizontal hyperechoic line. This is an important and easily recognizable ultrasonographic landmark. The gap between the hyperechoic line of the sacrum and the 'sawtooth' of the adjacent L5 lamina represents the L5–S1 interspace. Starting at this point, each interspace is

centred on the ultrasound screen and a corresponding skin mark made at the midpoint of the long edge of the probe to indicate its location.

6. Transverse interlaminar/interspinous view (TI view)
 - Turn the probe 90° into a transverse orientation and slide cephalad or caudad to obtain the TI view into a chosen lumbar interspace.
 - The anterior complex is the most important ultrasonographic landmark; the posterior complex is often only faintly visible.
 - Cephalad tilt of the probe and beam may improve the quality of the view, especially where spaces are narrow.

Key ultrasonographic structures: anterior complex, posterior complex, midline interspinous ligament, articular processes, transverse processes

7. Identify and mark needle insertion for a midline approach, using the TI view
 - Centre the neuraxial midline on the screen.
 - Make skin marks at the: (i) midpoint of the probe's long edge (corresponding to the neuraxial midline); (ii) midpoint of the probe's short edge (corresponding to the interspinous/interlaminar space). The intersection of these two marks gives the needle insertion point for a midline approach.
 - Estimate needle insertion depth by measuring the distance from skin to the deep aspect of the posterior complex.
 - If a satisfactory TI view (i.e. one in which the posterior complex is visible) cannot be obtained, the location of the interlaminar space may be instead determined from the PSO view, which usually offers a larger and better window into

the vertebral canal. This is the same skin marking used to indicate the identity of the intervertebral levels (see point 5). The intersection of this mark with the skin mark of the neuraxial midline obtained in the TI view is a suitable alternative needle insertion point for a midline approach.

8. Needle insertion

- Insert the needle at the marked site in the midline (Fig. 6).²
- Maintain the same cephalad angle with respect to the horizontal plane that was applied to the probe to obtain the optimal TI view.
- Needle insertion and re-direction should be guided by tactile feedback (contact with bone, 'feel' of the ligamentum flavum, loss of resistance, etc.) in a similar manner to the conventional landmark-based technique of neuraxial block.
- Ensure that needle redirections are not inappropriately large, and that there is no deflection from its intended trajectory, particularly when using smaller-gauge spinal needles.

Alternative skin marking and needle insertion for a paramedian approach

In patients with narrowed interspinous spaces, a paramedian needle approach may be required for successful entry into the epidural/intrathecal space. The use of ultrasound to facilitate a paramedian (paraspinal) approach has recently been described,³ and this technique may also be used where a satisfactory TI view cannot be obtained.

Here the transverse spinous process view is used to identify the neuraxial midline and the spinous processes bordering the targeted intervertebral space. The spinous process shadow is centred in the middle of the ultrasound screen, and skin marks are made at: (i) the midpoint of the long edge of the probe (corresponding to the neuraxial midline); (ii) the midpoint of the short edge (corresponding to the spinous process in the transverse plane). This is repeated for at least two adjacent spinous processes. The initial needle insertion point is marked 1 cm lateral to the midline and 1 cm superior to the line indicating the lower spinous process. The needle is inserted with a slight medial and cephalad angulation (5°–10°) alongside the spinous process (Fig. 7).⁴ Tactile feedback (e.g. contact with the bony lamina) will indicate the need for incremental needle redirection, usually in a cephalad direction. Once again this is done in a similar



Fig 6 Needle insertion for a midline needle approach at the intersection point between the skin markings of the neuraxial midline and the interspinous/interlaminar space. This image is extracted from an instructional video available online at <http://youtu.be/vgtdMn8RnI>.²

manner to the conventional landmark-based technique of neuraxial block, and is based on a sound understanding of vertebral anatomy.

Ultrasound for lumbar spinal and epidural anaesthesia: current evidence

Accurate identification of specific intervertebral levels

There is consistent evidence to suggest that neuraxial ultrasound can be used to identify vertebral levels more accurately than palpation of surface anatomical landmarks. A recent systematic review highlighted the poor correlation between vertebral levels determined by ultrasound and palpation, with rates of agreement varying from 14% to 64%.⁵ In the majority of cases, the levels determined by palpation were higher, and often by more than one interspace, than when determined using ultrasound. Other studies have used additional imaging techniques such as plain radiographs, computed tomography,⁶ and magnetic resonance imaging to further verify the accuracy of vertebral level identification. Once again, ultrasound proved both more accurate and more precise than palpation, since any discrepancy was only one space above or below the true level, when compared with two or three levels with palpation. Ultrasound correctly identified the vertebral level 68–76% of the time; underscoring the fact that it is not infallible. However, these were older studies and operator experience may be a factor, as shown by a more recent study indicating that accuracy rates of >90% can be achieved with adequate repetition.⁶

Measurement of depth to the intrathecal or epidural space

There is excellent correlation between ultrasound-measured depth and actual needle insertion depth using either transverse, sagittal, or PSO views.⁵ The difference between the actual and measured distance in most studies was small, ~5 mm. Ultrasound measurement tends to underestimate actual needle insertion depth, probably due to compression of tissues by the ultrasound probe. Other sources of error include the accuracy of the placement of the electronic calipers, minor inaccuracies inherent in the technology, and differences in beam and needle trajectory.

Improvement in clinical efficacy of neuraxial block

Data from randomized, controlled trials (RCTs) suggest an improvement in the clinical efficacy of obstetric epidural analgesia when using ultrasound compared with surface-landmark guided techniques.^{5,7} Significantly, lower rates of incomplete analgesia (2% vs 8%) and post-block pain scores were reported in the largest of these studies involving 300 obstetric patients.⁸ In this instance, the pre-procedural scan, block, and outcome assessment were carried out by a single, experienced operator.

Vallejo and colleagues⁹ studied 370 labour epidurals performed by a cohort of first-year anaesthesia trainees, with or without guidance from a pre-procedural ultrasound scan performed by a single experienced operator. The failure rate (defined by the need for epidural replacement secondary to inadequate analgesia) in the ultrasound-assisted patient group was significantly lower (1.6% vs 5.5%, $P < 0.02$).

Shaikh and colleagues⁷ published a systematic review and meta-analysis comparing ultrasound-guided and non-ultrasound-guided neuraxial techniques. This encompassed

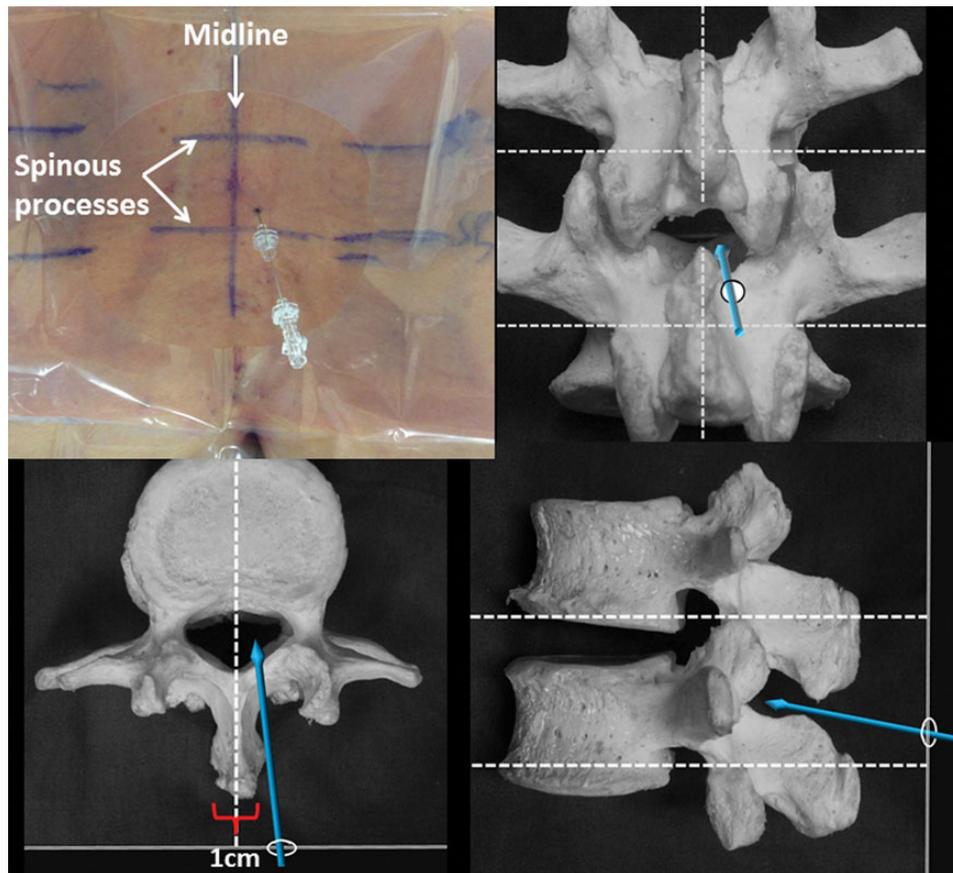


Fig 7 Needle insertion for a paraspinous (paramedian) needle approach using surface markings of the neuraxial midline and the spinous processes. The needle is inserted 1 cm lateral to the midline and 1 cm superior to the line of the lower spinous process. This image is extracted from an instructional video available online at <http://youtu.be/-IE6xMUXMuQ>.⁴

epidural, spinal, and lumbar puncture procedures, and included both adult and paediatric populations, and both pre-procedural and real-time ultrasound scans. A 79% reduction in the overall procedure failure rate was observed when ultrasound guidance was used. A significant (49%) reduction in procedural failure has also been confirmed in a more recent meta-analysis by Perlas and colleagues.⁵ They identified six additional studies published between 2012 and 2014 and evaluated efficacy data from a total of 14 RCTs involving 1768 patients, including those with obscured surface anatomical landmarks secondary to obesity, scoliosis, or previous spinal surgery: eight RCTs studied obstetric epidural anaesthesia, three studied spinal anaesthesia in orthopaedic patients, and three evaluated diagnostic lumbar puncture within the emergency department setting.

Improvement in technical performance of neuraxial block

Both meta-analyses show that neuraxial ultrasound can improve the technical performance of CNB. This is clinically relevant as multiple needle passes cause tissue trauma and may increase the risk of complications. Shaikh and colleagues⁷ found a significant reduction in both skin punctures and needle redirection attempts with the use of ultrasound, while Perlas and colleagues⁵ noted a reduction in overall needle passes (mean difference 0.75).

CNB may be especially challenging in instances where anatomical landmarks are abnormal or poorly palpable, and here ultrasound is of particular benefit. In their study of 120 orthopaedic patients with obesity ($BMI > 35 \text{ kg m}^{-2}$), lumbar scoliosis, or previous lumbar spinal surgery, randomized to receive spinal anaesthesia by the conventional landmark-guided technique or by an ultrasound-assisted approach, Chin and colleagues¹⁰ reported that pre-procedural ultrasound significantly increased first-attempt success rates, and reduced both the median number of needle insertions and additional needle passes. Subgroup analyses in obese patients with $BMI > 35 \text{ kg m}^{-2}$ or poorly palpable landmarks demonstrated that the ultrasound-guided approach reduced the number of needle insertion attempts and needle passes by $> 50\%$. In their meta-analysis, Shaikh and colleagues⁷ similarly found that the use of ultrasound produced a more marked decrease in needle redirections in the subgroup of patients with predicted technical difficulty compared with those without (mean difference 3.65 vs 0.99 passes).

Acquiring competency in ultrasound-assisted CNB

As with any advanced skillset, ultrasound-assisted CNB requires study and practice if competence is to be attained. Learning studies are limited to date but suggest that case experience of at least 30–40 procedures may be required for competency.^{6,11}

Recommended learning strategies include the following:

- familiarization with the gross anatomy and sonoanatomy of the spine,
- repetitive scanning on human volunteers and patients,
- the use of spine phantom models for scanning and needle insertion,¹²
- hands-on instruction at expert-led workshops,
- self-directed learning using reference articles,¹³
- online interactive scanning models (e.g. <http://www.usra.ca/vspine.php>) and instructional videos.^{2,4}

Summary

The current evidence supports the use of neuraxial ultrasound as a useful adjunct to conventional CNB techniques: it can be used to accurately identify lumbar intervertebral levels and allows precise measurement of depth to the epidural space. Neuraxial ultrasound may also improve the efficacy and safety of CNB by facilitating more accurate needle placement and decreasing the number of needle redirections and skin punctures.

Ultrasound-assisted CNB is not designed to replace the conventional surface landmark-guided technique, which is simple and effective in the majority of patients. Rather, it is an advanced tool to be used when technical difficulty is anticipated or when increased precision is desired. Having said that, the acquisition and maintenance of competency in neuraxial ultrasound requires practice. We therefore recommend that anaesthetists should incorporate neuraxial ultrasound into their clinical practice whenever possible until they attain the desired level of comfort with the ultrasound-assisted approach to CNB.

Declaration of interest

None declared.

MCQs

The associated MCQs (to support CME/CPD activity) can be accessed at <https://access.oxfordjournals.org> by subscribers to BJA Education.

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