Ultrasound-Assisted Neuraxial Anesthesia – An Online Education Module

Bradley J. Mack, BSN, SRNA
Bryan College of Health Sciences

bradley.mack@bryanhealthcollege.edu
801-645-2355
Ultrasound Assisted Neuraxial Anesthesia – An Online Education Module

Introduction

The introduction of ultrasound (US) to medicine has changed the way that healthcare practitioners provide patient care in magnificent ways. Since the first work was published in 1942, its utility has increased dramatically with continually improving technology. Thus, it has become one of the most versatile tools of this generation for assessment, diagnosis, and interventional medicine.

Traditionally, neuraxial anesthesia is performed using tactile techniques to palpate common landmarks. This includes identifying Tuffier’s line by feeling the iliac crest and intersecting an imaginary line from the top of the crests to the midline of the back. This gives the anesthetist an estimate to where the L4 spinous process lies. One can palpate the interspinous space to determine the best site for needle puncture. Although equipment and supplies have improved significantly over the years, no significant changes to epidural placement technique have been implemented for over 80 years.

Implications of alternative techniques

The most challenging populations for the administration of neuraxial anesthesia include patients with scoliosis and other skeletal deformities, obesity, past back surgery, old age, and pregnancy. With increased BMI, the ability to palpate landmarks decreases; this creates an obstacle to palpation as obesity rates continue to rise in the United States. When landmarks are not palpable, and the patient has a limited ability to assume an optimal position for neuraxial anesthesia, such as in obesity or pregnancy, it can be especially difficult to perform neuraxial anesthesia.
Neuraxial anesthesia is already performed by “blind” techniques. Once the needle is through the skin, the exact relationship of the needle to surrounding landmarks is merely estimated according to the skill and experience of the provider. Scoliosis further challenges this “blind” technique by inhibiting the provider’s ability to accurately estimate needle projection in relation to target structures. The same is true for previous back surgery where hardware may impede needle progression.

In addition to the increased difficulty of performing neuraxial anesthesia in special populations, multiple studies have shown that even when landmarks are palpable, the incorrect level is identified in up to 73% of patients. Most of the time, the anesthesia provider misidentifies the interspace as being one level below its actual location (e.g. the anesthetist identifies a given level as L3/L4, but it is actually L2/L3). The conus medullaris ends at the L1/L2 intervertebral disc in most adults. One study demonstrated that 5% of intrathecal techniques were mistakenly performed at the L1/L2 interspace. This becomes especially concerning when one realizes that the conus medullaris extends to the body of L2 in 43% of women.

Because US imaging is successfully used for peripheral nerve blocks, central venous catheter placement, and other procedures, it is reasonable to suppose that it may be a solution to improve neuraxial anesthesia in challenging populations. Naturally, the next step is education and exposure for anesthesia providers to make ultrasound-assisted neuraxial anesthesia (USANA) available for the improvement of practice.

**Equipment**

**How does ultrasound work?**
To better understand the tools of USANA, a brief review of what US is and how it works will follow. Sound is the transmission of mechanical energy that crosses matter via waves of alternating compression and expansion (rarefaction). Simply put, ultrasonography works by the creation of sound waves that are transmitted through tissue followed by the interpretation of the returning waves into images.10

The US transducer is the primary component responsible for converting electric energy into mechanical energy and vice versa. In this way, the transducer both emits the acoustic pulse into tissues and receives returning echoes that it can convert back into electric signals. In modern US probes, piezoelectric materials are incorporated into the probe to facilitate the transduction of this energy. Piezoelectric materials change shape in the presence of electricity and with compression they can generate electric potentials. By applying a variable voltage to piezoelectric material, alternating changes of shape produce mechanical pressure waves or sound that is then transmitted into the tissue under examination.10

Although the word “probe” is a general term and “transducer” refers to the function of the device, the terms transducer and probe will be used interchangeably throughout the remainder of this module.

As sound travels through matter, waves vary in amplitude and frequency. Amplitude refers to the height of the wave while frequency refers to the number of wave cycles included in a period of time. The hertz (Hz) is the unit used to measure acoustic frequency in cycles per second. One megahertz (MHz) is equal to 1,000,000 Hz. The term ultrasound is a relative term used to describe soundwaves with frequencies greater than the human limitations of hearing. The frequencies used in US are more than 500 times higher than what the human ear can detect.10
Hyperechoic is an adjective used to describe the appearance of structures on an US imaging screen. It is a relative term that reflects more echogenic or denser structures that reflect or echo more sound waves back to the transducer. Hyperechoic structures appear as brighter or whiter on the screen.¹⁰

Hypoechoic is the opposite of hyperechoic. This adjective is used to relatively describe materials that are less echogenic than surrounding structures. Less dense structures allow more sound waves to pass through them rather than producing a strong echo and they appear as darkening shades of gray to black on screen.¹⁰

**Selecting the right equipment**

Most US machines will be sufficient for performing pre-assessment scans. However, newer versions tend to offer cleaner images with better visibility. Likewise, a variety of manufacturers are listed throughout published research. The most appropriate choice in machines and transducers is wisely made by stakeholders to determine what option best fits the needs of patients and the resources of institutions. Because the majority of the referenced studies recommend a 2-5 MHz curved array transducer¹¹,¹² for US neuraxial examination, the remainder of this module will focus mostly on this probe.

**Advantages/Disadvantages of each probe**

Selecting the proper probe can potentially make the difference between an optimal image and the inability to identify landmarks. For most anesthesia procedures, including peripheral nerve blocks and vascular access procedures, a 6-13 MHz linear transducer is sufficient for adequate visualization.¹⁰ It produces a high-resolution image at depths of 0 to 3 cm. However, for neuraxial anesthesia, structures that need to be visualized at a depth of greater than 3 cm, the most commonly recommended transducer is a 2-5 MHz curved array probe (other curved array
probes referenced include 3-5 MHz, 2-5.5 MHz, and 3-6 MHz transducers). Although image clarity is sacrificed with a low frequency probe, such as the 2-5 MHz curved array transducer, visibility of deeper structures improves with better penetration compared to the linear probe.\textsuperscript{13}

In one study,\textsuperscript{15} residents scanned the lumbosacral regions using both the linear and curved array probes. They identified structures in three basic planes (transverse median, longitudinal median, and longitudinal paramedian oblique) with each probe. Supervising anesthesiologists then assessed the accuracy of identifying landmarks. The study determined that residents were able to accurately identify structures most often when the curved array probe was used. Further, they determined that the longitudinal paramedian oblique plane offered the best view when compared to other planes.

**Neuraxial Anatomy**

Essential anatomy of the lumbar region for USANA includes a general understanding of the shape of the lumbar vertebrae, the vertebral canal, and surrounding structures. After one has a solid understanding of the sonoanatomy of the lumbar vertebrae, transitioning to the thoracic vertebrae is easily accomplished.

A typical vertebra consists of a vertebral body, a vertebral arch, and 7 processes.\textsuperscript{16} The superior and inferior articular processes, transverse processes, and the spinous process are bony prominences of the vertebral arch that serve as places of attachment for the supporting muscles of the spine. For USANA they become important landmarks for identifying structures.

The sacrum is composed of five fused vertebrae. In the average person, the sacrum is identified with US in the longitudinal median view by comparing the stop-and-go pattern of the
bright white, or hyperechoic, spinous processes and dull interspaces to the continuous hyperechoic line representing the surface of the fused sacral vertebrae.\textsuperscript{4}

The ligamenta flava (LF) run longitudinally joining adjacent vertebrae by the individual laminae. In adults, the thickness of the LF ranges between 1.7 mm and 6.6 mm with an average thickness of about 3.5 mm at the L3/L4 intervertebral level.

Together with the concave surface of the vertebral arches, the LF form the alternating sections of the posterior wall of the vertebral canal.\textsuperscript{16} The epidural space is a potential space between the LF and the posterior aspect of the dura mater. Because the LF and posterior dura mater are frequently viewed as an indistinguishable hyperechoic structure under US, they are often referred to as a single unit called the posterior complex (PC).\textsuperscript{2,17,18} The average depth from the skin to the epidural space is about 4-6 cm (This remains true whether evaluating the thoracic or lumbar spine and in the TMV as well as the PSV).\textsuperscript{2,17,19,20}

The posterior longitudinal ligament is composed of strong, dense fibers and runs along the length of the posterior surfaces of the vertebral bodies and intervertebral discs. It forms the anterior border to the vertebral canal. Like the PC, the posterior longitudinal ligament and anterior dura mater also appear as a single hyperechoic structure on US and are collectively referred to as the anterior complex (AC).

The spinous processes of lumbar vertebrae are broader and less slanted than are the thoracic vertebrae. Laminae have no overlap in the lumbar region which provides a better window to the epidural and subarachnoid spaces when compared with thoracic vertebrae.

**Sonoanatomy of Lumbar Spine**

Bony structures appear as bright, hyperechoic forms on US with visible shadowing because US beams are unable to pass.\textsuperscript{18} Ligaments and the dura mater are somewhat
hyperechoic, but they are not as bright as bone and US beams are able to pass through them. Fat, muscle, and fluid are characterized as relatively hypoechoic to varying degrees.

The sagittal or longitudinal median view (LMV) will clearly show exactly where the spinous processes and interspaces lie beneath the subcutaneous tissue. In some patients, this view may allow for minimal visualization of the posterior complex. The LMV shows relationship of spinous processes and interspaces beneath the skin. This view of the sacrum compares the stop-and-go pattern of the bright white, or hyperechoic spinous processes and the dull interspaces to the continuous hyperechoic line that is the median sacral crest. Spinous processes form a pattern of hyperechoic arches alternating with soft tissues gaps. The LMV may allow for minimal visualization of the PC.

In the longitudinal paramedian oblique view (LPV) the laminae are clearly visible as they stack one above the other. Most authors agree that the window to the epidural and subarachnoid spaces are visualized best from this perspective. The acoustic window is wider and allows for more consistent visibility of the PC. The laminae are clearly visible as they stack one above the other in the “sawtooth” or “horse heads” pattern. Transverse processes appear as relatively small hyperechoic arches with fingerlike shadow projections (“Trident” pattern) when the probe is slid 3-4 cm to the left or right from the midline.

The transverse median view (TMV) across spinous process will show laminae and the spinous process but there will be no visibility of the interspinous space, articular processes, or transverse processes. With the probe directly over a spinous process, the “circus tent” pattern may be seen where the hyperechoic bony process appears just below the skin and the laminae of the vertebral arch taper out creating the hypoechoic shadow and draping appearance of a tent.
At the interspace the TMV will show articular processes forming facet joints, transverse processes, and the posterior complex (PC). The laminae are not seen in this view. Some texts refer to this US image as the “flying bat” view where the ears of the bat are represented by the facet joints formed by the articular processes, the outward stretching wings are the transverse processes, and the face is featured by the posterior and anterior complexes.\textsuperscript{4} By definition, the PC will be located anterior to the transverse processes.

In almost all instances where studies have compared the TMV to the LPV, researchers found that image quality is superior in the LPV\textsuperscript{4,12,21} The acoustic window is wider and allows for more consistent visibility of the PC.

**Approach/Technique**

When positioning a patient for pre-puncture US, the patient’s position should be the same as the position for the placement of the epidural catheter or spinal anesthetic. It is important to perform the US in the same position as that when the actual procedure is performed to avoid changes in the relationship of markings on the skin and the underlying structures.\textsuperscript{22} Most often the procedure is carried out with the patient in the sitting position, with the spine curved and neck flexed, similar to the position used for epidural needle placement.\textsuperscript{23} Although some report using the lateral decubitus position.\textsuperscript{11}

Provider positioning should also be adjusted to maximize comfort. Sitting may afford the sonographer the most comfortable position and a more stable grasp for performing neuraxial US.\textsuperscript{22} The bed is raised to a comfortable height where the provider may sit behind the patient. When learning to perform US assessment of the lumbar spine for first time, the author recommends beginning with a traditional technique by identifying Tuffier’s line by palpation.\textsuperscript{2,18,3,20} This way, the provider can compare the predicted interspace by palpation to the
actual interspace identified under US. After palpation, position oneself by placing the elbow of
the scanning arm on the surface of the bed. Place the probe over the skin in the longitudinal
median plane and slide probe in a caudal direction until the continuous, horizontal, hyperechoic
line formed by the bony structure of the sacrum can be identified.\textsuperscript{24,25} While maintaining an
LMV, scan the vertebrae in a cephalad direction; count up to the desired interspace.\textsuperscript{23,26} Consider
marking each interspace as scanning proceeds to avoid losing count and having to start over.

Transitional vertebrae are identified in about 5-12\% of people.\textsuperscript{23} Lumbarization of the
first sacral vertebra or sacralization of the fifth lumbar vertebra may occur to varying degrees.\textsuperscript{27}
This can make it difficult to accurately number vertebrae correctly. To overcome identification
errors related to sacralization of a lumbar vertebra or lumbarization of a sacral vertebra, the
provider may scan up to the presumed T12 vertebra to check for the articulation with the twelfth
rib.\textsuperscript{23,28,14} Or one could assume the counting-down method by starting the scan with the
identification of T12 and then counting in a caudal direction. It should be noted that a small
number of the population will present with an extra pair of “lumbar” ribs which could lead to
misidentification. The only absolute way to identify the correct vertebrae is to obtain imaging of
the entire spine.

Once the L3/L4 and L4/L5 intervertebral spaces are identified, the provider may decide
on which interspace to choose for the procedure based on which space offers the best/clearest
view of the targeted structures.\textsuperscript{24,29,30} After selecting the most visible space, slide the probe
laterally and identify the “saw-tooth” or “horse heads” pattern that is created by the laminae of
the vertebrae.\textsuperscript{23} This will be noted approximately 1 to 2 cm from the midline.\textsuperscript{18} The probe can
then be angled slightly toward the midline where the acoustic, interlaminar window will come
into view.\textsuperscript{28,31} The PC and AC will become visible here.
To save additional time after obtaining sufficient practice, the provider may skip scanning in the LMV and begin immediately by placing the probe in the LPV at the level of the sacrum before passing the probe cephalad and counting the interspaces.\textsuperscript{23,28,17,32} This method reduces the steps to obtaining the desired view. The belief of the author is that it is important to recognize the various patterns of different views before reducing steps to identify structures in order to familiarize oneself with the specific sonoanatomy of the spine.

Because this is an US-assisted technique and not performed in real time, marking the skin is required to ensure enhanced needle placement.\textsuperscript{24} With the US probe in the paramedian sagittal plane, center it over the interlaminar window to visualize the epidural space.\textsuperscript{33,22} With the probe in position, mark the skin with a transverse line that crosses the midline of the back to indicate the horizontal axis of the estimated needle entry point.\textsuperscript{17,34}

The probe can then be rotated 90 degrees to obtain a transverse median view of the vertebrae.\textsuperscript{24,18,26} If the probe is directly over a spinous process, the “circus tent” pattern may be seen where the hyperechoic bony process appears just below the skin and the lamina of the vertebral arch tapers out creating the hypoechoic shadow and draping appearance of a tent.\textsuperscript{4}

Adjust the position of the probe by sliding caudad or cephalad until the appropriate interspace is identified. Tilt the probe slightly cephalad until the “flying bat” pattern is visualized and centered on the US screen.\textsuperscript{4} Another line can now be drawn from the center point of the probe that extends cephalad and caudad to indicate the skin overlying the midline of the epidural space.\textsuperscript{32,35} Extend the mark until it intersects the previously drawn transverse line.\textsuperscript{18} The intersecting point indicates the estimated needle entry site.\textsuperscript{24,29}

Take note of the probe angle as this will translate to the estimated angle of the needle trajectory.\textsuperscript{24,17} Note that there will be some degree of tissue compression where the probe is
placed over the skin. Depending on the thickness of the subcutaneous tissue and the pressure being applied to the probe, the estimated depth to the epidural space (DES) will likely be increased by a centimeter, or more, deeper than the measured value on the US machine. It is especially important to estimate how much the tissue compresses in the obese population.

Identify the PC, then use this view to estimate the DES. One may get a general idea of the DES by counting the number of centimeters on the screen. For a more accurate measurement and to minimize the discrepancy between US-measured DES and the actual clinical measurement, it is important to consider depth variability by noting the relationship of subcutaneous tissue to the compression of structures. To perform this step with the least amount of tissue compression possible, gradually release pressure while maintaining visualization of the required structures. A relatively accurate measurement can then be taken by “freezing” the screen then, using the built-in electronic calipers of the US machine, obtaining a cm-value as the DES is measured from the skin to the inner aspect of the LF.

The aforementioned approach is recommended most frequently because the view of the PC is most visible from the LPV. However, if the TMV provides images that are sufficient to identify structures, one could reduce steps by simply identifying the desired interspace from the TMV only and then draw transverse and longitudinal indicator lines from the middle of the probe. The longitudinal line will coincide with the midline and can be marked from the center point on the cephalad side of the probe. Likewise, the transverse line will coincide with the most direct interspace plane. The line should be drawn from the center points of the lateral sides of the probe.

**Special Populations**
The application of USANA is especially useful when regional anesthesia may be challenging in special populations. Generally, the process for performing USANA is the same in special populations as it is in the average patient via lumbar interspaces.

**Scoliosis**

Scoliosis is defined by not only a lateral curvature of the spine, but also with the rotation of the vertebrae around the longitudinal axis.\(^4\) Approximately 2% of the general population has some degree of scoliosis and it is twice as likely to be found in women than in men.

Begin by marking out the locations of several spinous processes to visualize the lateral curvature of the spine.\(^36\) Using the previously described technique for scanning the lumbar vertebrae, similar patterns will be recognized. US will allow the scanner to determine any degree of lateral curvature of the spine. With the probe held perpendicular to the skin, slide it either to the left or the right 1 to 2 cm to evaluate longitudinal rotation.\(^4\) If a significant degree of rotation is observed, the probe should be placed on the convex side of the rotation.\(^36\) Depending on the degree of longitudinal rotation, the scanner may observe the LPV while holding the probe in longitudinal paramedian plane, perpendicular to the skin.

**Previous back surgery**

In the presence of previous back surgery, there are a few things to consider. First, spinous processes may be poorly palpable because of scar tissue or they may be absent altogether. Knowing the procedures and at what levels they were performed may help determine the accessibility of intrathecal space or epidural space. Many procedures result in extreme modification of the epidural space. In one study, patients who had previous back surgery were evaluated for epidural fibrosis using epiduroscopy.\(^37\) Of the 78 patients, 95.7% had some degree of epidural fibrosis and 83% of the 78 were given classifications as “severe” epidural fibrosis. If
the PC can be visualized under US then spinal anesthesia should not be ruled out. However, because of the drastic changes in the epidural space, the increased risk of failed epidural catheter placement or spread of medication should be discussed with the patient beforehand.

**Obesity**

Even though some studies focused on obese patients and others focused on patients with a BMI < 35, the technique for performing the ultrasound assessment is the same. Obesity presents a few challenges to neuraxial anesthesia. It makes positioning difficult for some patients. The ability to palpate bony prominences and estimate the needle insertion site accurately is impaired; compared to patients with BMI < 35, accuracy of interspace identification is impaired by obesity (p = 0.001). Lastly, the DES can vary considerably among patients; often at depths greater than 6 cm. This increased DES impedes confident needle advancement.

**Thoracic epidural catheters**

Just as with the lumbar spine, the thoracic spine is approached using the palpation method by most anesthetists. The provider estimates the level of T7 by identifying the intersection of the apices of the scapulae with the midline of the back. From this intersection, one can then count spinous processes until the desired level is reached.

In comparison to the lumbar region, the laminae of the thoracic vertebrae are broader and even overlap. The spinous processes form an interspace with steep, narrow angulations toward the epidural and subarachnoid spaces. The combination of these anatomical features offers only a small window for US beams to reach the PC. The more superior segments of the LF are thinner than that found in the lumbar regions where the fibers are denser and stronger.

One study expressed that image quality of the thoracic spine decreases as researchers scanned higher thoracic spaces. In the PSO plane, conclusive images were acquired in 97.5% of
lower thoracic scans, 86.0% of midthoracic scans, and 63.3% of upper thoracic scans. This difference is attributed to the steepening angle of the superior interspace levels and the limited interspatial acoustic window. Another challenge is the loss of skin-to-probe contact in the TM plane when steepening the angle on the upper spine because there is less subcutaneous tissue to pad the view.

Begin by identifying the 12th rib and then scanning in the longitudinal midline plane. As the probe is moved in a cephalad direction, count the interspaces and mark spinous processes to avoid losing count.

**Pediatrics**

The biggest difference between USANA for children and adults is that structures are much easier to see in a child. Although the 2-5 MHz curved array probe is recommended for neuraxial US scanning in adults, the proximity of neuraxial structures to the skin warrants the use of a typical 12-15 MHz linear probe.

**Ultrasound assistance vs real-time guidance**

For real-time US-guided neuraxial anesthesia, one of the greatest hinderances is the challenge of performing the technique without an assistant. A second set of hands may be needed to either hold the US probe or to obtain confirmation by LOR for epidural catheter placement. Several solutions to this barrier have been explored including a fairly new spring-loaded syringe that applies a constant pressure until it releases its contents when LOR is achieved (EpisureTM AutoDetectTM syringe). The changes that are required for successful the real-time US technique are described in the following paragraphs.
Once the patient has been examined and the site has been steriley prepped and draped, the transducer is draped with a sterile sleeve. Because there are limited data on the safety of US gel being introduced onto neuraxial structures, either the needle entry site should be cleansed of all US gel, or saline may be used as a substitute (though less effective) coupling agent. As a result of limited needle visualization and a decreased ability to simultaneously maneuver the probe or needle while maintaining the perfect image, the TMV is a much less feasible option compared to the PSV. In the PSV, the needle is inserted caudad to the transducer and in plane with the US beam. Similar to other US-guided regional techniques, the needle tip should remain in view throughout the procedure. However, maintaining visualization may be difficult because of the needle’s relatively steep angle of projection. After the needle is advanced and engaged in the LF, the LOR technique may then be applied.

Methods

The methods used for this education module include the completion of a topic search from several databases including Academic Search Premier, CINAHL and PubMed. A search of the following terms was included: Pre-insertion, pre-procedural, neuraxial anesthesia, epidural, spinal, ultrasonography, ultrasound guided, real-time, ultrasound assisted, scoliosis, obesity, geriatric, parturient/pregnant, hardware/fusion. Once an adequate collection of literature was compiled, findings were analyzed and comparisons were summarized to generate generalizations that can be implemented into current practice and technique. The primary objective was to identify known techniques for performing USANA and to determine how to learn accurate neuraxial anatomy as a provider might see under ultrasound.

Conclusion
USANA is a solution to traditionally “blind” anesthesia techniques. Although a significant learning curve is to be expected when first learning to identify sonoanatomy and estimate the DES and needle projection angle, this technique may become an essential tool for the skilled provider. More importantly, USANA permits special populations to receive neuraxial anesthesia where they may not have been considered candidates otherwise. Pattern recognition is key for consistently successful USANA. Even when the PC is not easily visualized by US, recognizing the surrounding structures can allow the trained eye to still estimate the depth to the epidural space accurately. Most importantly, USANA permits special populations to receive neuraxial anesthesia where they otherwise may not have been considered candidates.

Additional Resources

https://www.youtube.com/watch?v=JgBbsPV5QDc

Competency Test

Learning objectives

1. Identify common sonoanatomy structures of the lumbar spine.
2. Describe the recommended technique for pre-puncture ultrasound assessment of the lumbar spine.
3. Recognize the populations for which the suggested pre-puncture ultrasound assessment is most beneficial for neuraxial anesthesia.

Competency test questions

1) True or False: In the majority of patients, palpating Tuffier’s line is a reliable method for correctly identifying spinal interspaces.
   a. True
   b. False

2) Where does the spinal cord end in most adult people?
   a. T12/L1 interspace
   b. L1 vertebral body
   c. L1/L2 interspace
   d. L3 vertebral body

3) One megahertz (MHz) is equal to ____ hertz (Hz).
   a. 10
   b. 1,000
   c. 100,000
   d. 1,000,000

4) Which of the following describe the term “hyperechoic”?
   a. More echogenic
   b. More reflective
   c. Appears brighter/whiter on screen
   d. All of the above

5) Which of the following terms is described as frequencies greater than the human limitations of hearing?
   a. Hertz
   b. Piezoelectric
   c. Ultrasound
   d. Amplitude

6) What is the most commonly recommended transducer for performing ultrasound-assisted neuraxial anesthesia (USANA) in adults?
   a. 2-5 MHz curved array transducer
   b. 6-13 MHz curved array transducer
c. 2-5 MHz linear transducer
d. 6-13 MHz linear transducer

7) What is the average thickness of the ligamentum flavum in the lumbar region of an adult?
   a. 1-2 mm
   b. 3.5 mm
   c. 6.5 mm
   d. 10 mm

8) What is the average depth from the skin to the epidural space in adults?
   a. 3 cm
   b. 4 cm
   c. 6 cm
   d. 8 cm

9) In the midline approach, from superficial to deep, what structures are punctured to access the intrathecal space?
   a. Interspinous ligament, posterior longitudinal ligament, ligamentum flavum, anterior longitudinal ligament.
   b. Supraspinous ligament, interspinous ligament, ligamentum flavum, posterior dura mater.
   c. Posterior longitudinal ligament, supraspinous ligament, ligamentum flavum, posterior dura mater.
   d. Supraspinous ligament, Interspinous ligament, ligamentum flavum, anterior dura mater.

10) Which one of the following is NOT an advantage of using the 2-5 MHz curved array transducer?
   a. Providers are more likely to identify structures accurately.
   b. Visibility of deeper structures improves.
   c. Penetration is greater.
   d. It produces a higher-resolution image at depths of 0 to 3 cm.

11) The posterior complex is composed of the ____________.
   a. posterior dura mater and ligamentum flavum
   b. superior articular processes and inferior articular processes
   c. posterior longitudinal ligament and the vertebral body
   d. lamina and ligamentum flavum

12) What is the correct order of structures from “hyperechoic” to “hypoechoic”.
   a. Adipose tissue, bone, dura mater, fluid.
   b. Bone, fluid, dura mater, adipose tissue.
   c. Fluid, adipose tissue, dura mater, bone.
   d. Bone, dura mater, adipose tissue, fluid.

13) In most cases, which view of the lumbar spine offers the clearest view of the epidural and intrathecal spaces?
a. Transverse median view (TMV)
b. Longitudinal median view (LMV)
c. Longitudinal paramedian oblique view (LPV)
d. None of the above

14) Which commonly seen pattern is recognized in the transverse median view (TMV)?
   a. “Circus tent”
   b. “Horse heads”
   c. “Trident”
   d. “Flying bat”

15) In which view can the pattern of “horse heads” be identified?
   a. Longitudinal paramedian oblique view (LPV)
   b. Longitudinal median view (LMV)
   c. Transverse median view (TMV)
   d. Transverse paramedian view (TPV)

16) All of the following steps are used to estimate the depth to the epidural space (DES) EXCEPT:
   a. Reduce the pressure applied to the site as much as possible.
   b. Center the probe over the interlaminar window.
   c. Compress the tissues as much as possible.
   d. Freeze the screen and measure the distance from the skin to the PC.

17) How is the angle of approach measured in the TMV?
   a. Freeze the screen and use built-in calipers to measure the angle.
   b. Estimate the angle of the probe and then mimic the observed angle upon needle insertion.
   c. Use a protractor to measure the angle of the US probe prior to needle insertion.
   d. None of the above.

18) True or False: Using the counting-up-from-the-sacrum method will allow the correct interspace to be identified in 100% of patients.
   a. True
   b. False

19) All of the following are TRUE regarding thoracic vertebrae when compared to lumbar vertebrae EXCEPT:
   a. Spinous processes form narrow, steep angulations toward the epidural space.
   b. The interspatial acoustic windows between vertebrae are large and open.
   c. Laminae are broader and may even overlap.
   d. The ligamenta flava are thinner.

20) True or False: When a patient presents with scoliosis, the only challenge the anesthesia provider needs to consider is the lateral curvature of the spine.
   a. True
b. False

21) True or False: Structures visualized with US are more difficult to identify in children?
   a. True
   b. False

22) True or False: For real-time US-guided neuraxial anesthesia, the longitudinal paramedian oblique plane is recommended for obtaining the best visualization of needle advancement.
   a. True
   b. False

23) True or False: USANA is the recommended method for performing neuraxial anesthesia in ALL patient populations.
   a. True
   b. False

24) For which of the following special populations could USANA be most beneficial?
   a. Scoliotic
   b. Obese
   c. Parturient
   d. All of the above

25) What is the condition of transitional vertebrae called when the L5 vertebra fuses with the S1 vertebra?
   a. Lumbarization of the S1 vertebra.
   b. Lumbarization of the L5 vertebra.
   c. Sacralization of the S1 vertebra.
   d. Sacralization of the L5 vertebra.
References


