



# Optimizing the safety and practice of ultrasound-guided regional anesthesia: the role of echogenic technology

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## Purpose of review

Significant improvements have been made in the quality of ultrasound imaging, and it is now much easier to see nerves. However, the key to safe ultrasound-guided regional anesthesia is to be able to direct the needle to the target. This relies on good needle visibility. We review the recent advances that have been made in this crucial area.

## Recent findings

Echogenic needles can improve shaft and tip visibility independent of experience level, compensate for suboptimal scanning technique, allow steeper insertion angles, reduce technical difficulty, and increase both confidence and satisfaction by anesthesiologists. An echogenic needle encourages holding the probe in one place on the patient, only advancing the needle when it can be seen, hence reducing the likelihood of quality-compromising behaviors. The poor visibility of nonechogenic needles when inserted at steeper angles commonly causes the observer to underestimate the insertion depth of the needle. Significant differences in echogenicity are found when comparing the currently available needles.

## Summary

Good echogenic needles should increase safety, efficacy, and simplicity, and hopefully further drive the adoption of ultrasound-guided techniques, to the benefit of our patients.

## Keywords

echogenic, equipment, needle, ultrasound, visibility

## INTRODUCTION

The ultimate success of ultrasound-guided regional anesthesia (UGRA) will be determined by its uptake by anesthesiologists and the number of patients receiving the benefits. For this to happen, UGRA ideally needs to be safe, efficacious, easily learned, and probably enjoyable. Echogenic needle technology plays an integral role in achieving all of these goals. The greatest impact has been with in-plane techniques and this review will focus primarily on these. However, we will also discuss emerging evidence that echogenic technology can assist with out-of-plane (OOP) techniques.

## EFFECT ON INSERTION ANGLE

The problems associated with poor needle visibility and the need for echogenic needles have been well documented [1–3]. Indeed, the classification of block complexity has been, at least in part, related to nerve depth and the requirement for a steep

needle insertion angle. Keeping a deep nerve in view, while trying to follow the vague movement of a poorly visible nonechogenic needle, is an advanced skill.

Good-quality imaging of the anatomy, nerves, and the needle is required for safer and accurate placement of local anesthetic. Improvements in ultrasound technology have made it easier to image the anatomy and where the needle should be placed, but visibility of standard block needles inserted at greater than 30° remains poor [2–4,5<sup>6</sup>,6<sup>7</sup>,7,8<sup>9</sup>]. The angle of incidence of the ultrasound to the needle

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## KEY POINTS

- Using echogenic needles encourages safer scanning and needling behaviors.
- Some echogenic needles are visible independent of in-plane insertion angle.
- Echogenic needle visibility may be independent of experience level.
- Echogenic needles may make ultrasound-guided regional anesthesia at steep angles easier to perform.
- For out-of-plane techniques, echogenic needles may become increasingly visible as insertion angle increases.

equals the angle of reflection from the needle surface. This means that as insertion angle increases, more of the ultrasound beam is reflected away from the transducer, and a poorer image of the needle is generated. Needle shafts are made more echogenic by a variety of surface technologies that reflect a greater percentage of the ultrasound beam striking the needle back to the ultrasound probe [4,5<sup>11</sup>,7,8<sup>9</sup>,10,11]. The more successful products have significantly altered the smooth surface of the metal needle making them visible even at steeper insertion angles. Luckily, with nonechogenic needles and insertion angles greater than 30° the tip of a needle is often more obvious than the shaft due to a large amount of diffraction that occurs around the irregular shape, sending echoes back to the probe [12].

The introduction of Enhanced Needle Visualization technology (Sonosite, Bothell, USA) and Needle Recognition software (GE Healthcare, Waukesha, USA) may help to overcome the poor visibility of nonechogenic needles. There are currently no published data, although at least one study is underway (<http://clinicaltrials.gov/ct2/show/NCT01583010>). Initial experience is promising and it is the authors' experience that the technology does improve visibility, albeit with limitations. As a result of the method used, there is an area that is not enhanced, which unfortunately for steeper and deeper blocks is a large area and often where the needle target is located.

### EFFECT ON NEEDLE INSERTION SITE

The ability to image needles inserted at a steep angle transforms the relationship between the ultrasound probe and the needle insertion site. With nonechogenic needles, the recommended needle insertion

site is often some distance from the probe. This generates a shallow approach angle so the needle would be visible once under the ultrasound probe. There are inherent problems with this technique. The needle has to be inserted a longer distance before it is expected to come into view so greater precision is required. It is more likely that ultrasound probe adjustments will be needed to find the needle. This has the potential effect of losing the image of the neural structures and starts a cycle of needle and probe movements. The initial passage of the needle is blind, which is against the principle of UGRA, and teaches movement of an unseen needle, a habit that Sites *et al.* [13] have shown is hard to break. Additionally, it is not clear at what depth the proceduralist should stop advancing the needle before they move the probe to find the needle. Increasing insertion depth makes the risk of an overshoot more likely. Moving the probe closer to the initial insertion site can reduce the problem but this risks losing the view of the nerve and encourages large probe movements. Altering the angulation can also be difficult once the needle has travelled through 3–4 cm of the tissue. The needle may need to be withdrawn and repositioned, potentially restarting the cycle of finding the needle. These repeated needle passes might also increase patient discomfort and the risk of complications.

Echogenic needles can be inserted as close to the probe as desired, making it easier to image in-plane. The needle only needs to pass a very short distance before it should be visible on the ultrasound screen. If it does not appear then small adjustments of the probe can be made to find the needle. This means the initial vision of the neural structures is not lost, and reinforces that only small movements of the probe are required. Once the needle is seen, it can easily be angled towards the target, as there is only a small amount of tissue fixing the needle.

### INCREASED NEEDLE TIP PRECISION

Increased needle tip precision has obvious safety implications for avoidance of damage to surrounding structures and the nerve itself. Since the resurgence of the debate regarding intraneural injections [14], there has also been increased attention on the precise location of the needle to the nerve at the time of injection [15]. Discussion over the effect of injection in the endoneurium, perineurium, epineurium, or paraneurium will mean little unless we have the ability to accurately identify and place the needle tip with millimeter accuracy. Current evidence suggests that imaging of nonechogenic needles during steeper needle insertions is difficult

and it is unlikely that this precise differentiation of position is possible. Echogenic needles should give the option of making a clinical choice regarding the desired location of injection.

### COMPENSATION FOR SUBOPTIMAL TECHNIQUE

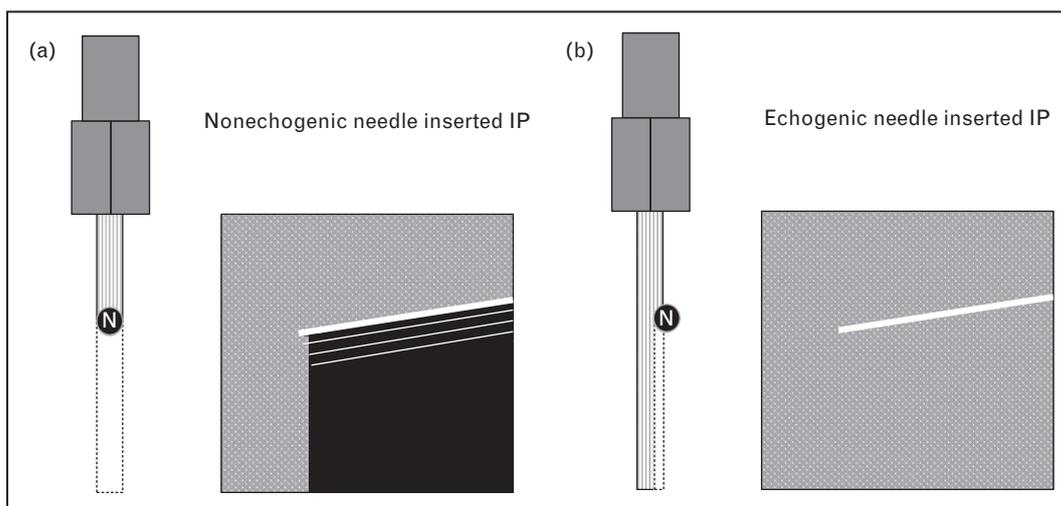
The reasons that echogenic needles improve UGRA techniques are more complex than simply the needle being brighter when inserted at steep angles. For in-plane techniques, a brighter needle does make visual recognition easier, but more importantly, needle/probe alignment can be less precise with a brighter needle. A nonechogenic needle will need to be more precisely aligned within the ultrasound beam to be imaged. This will also mean that it is more likely to reverberate and cast a shadow obscuring structures deep to the needle shaft, potentially obscuring important structures when redirecting the needle (Fig. 1). An echogenic needle can be a small distance from the midline of the beam and still be highly visible. This means less subtle movements are needed to maintain needle visibility, therefore simplifying the technique. The off-center positioning of the needle also allows some of the beam to pass the needle meaning that shadowing is less prominent and deeper structures are often still imaged. This could potentially increase block safety.

It is the authors' experience that a major hurdle in UGRA is correction of rotational errors between the probe and needle. With a shallow needle insertion the ultrasound pattern of the shaft is relatively easily recognized, and gentle rotation of the probe about the visible part of the needle can bring the

entire needle into full view. Once both the shaft and the tip of the needle can be seen, the needle should stay in plane with further advancement of the needle. With nonechogenic needles and steeper insertions, correction of rotational errors is difficult. If only the tip of the needle is seen the plane of the needle cannot be determined. A rotational error will only be recognized by the needle disappearing out of view when advanced. All of the echogenic needles on the market have echogenic shafts, which makes determination of rotational errors with steep needle insertions the same as for shallow blocks. This is probably the most important factor that simplifies the technique with echogenic needles. This simplification of the technique is supported by several studies demonstrating that subjective needle visibility is not affected by experience level when using an echogenic needle [4,16].

### EFFECT ON EDUCATION AND LEARNING

Sites *et al.* [13] found one of the most common errors in UGRA was failure to visualize the needle before advancement. This behavior is difficult to correct when even the optimal view of the needle is poor and needle tip location may only be determined by needle-induced tissue movement. Poor visibility therefore encourages the unsafe technique of moving an unseen needle to locate it. Echogenic needles minimize visibility problems by making it easier to see both the needle shaft and tip allowing more accurate placement [4,5<sup>11</sup>,7,8<sup>12</sup>]. Knowing that an echogenic needle should be plainly visible makes a 'stop/start' approach to both needle and probe movements much easier to perform and easier to



**FIGURE 1.** Simplified diagram explaining why there is often less shadowing using an IP echogenic needle. Since it is still visible even when not exactly aligned in the center of the beam, some of the beam can still pass the needle and be reflected to the probe. IP, in-plane.

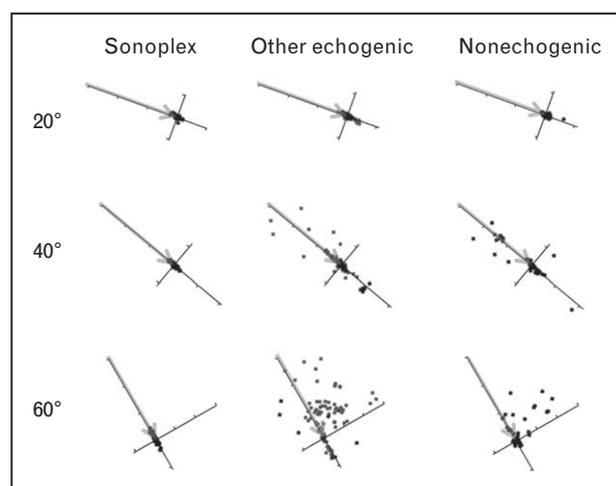
teach. When the needle is not clearly visible, the operator should stop advancing the needle and start subtly moving the probe to improve the needle view. When the needle tip and shaft are visible the operator should stop any probe movements and can continue to advance the needle.

Other quality-compromising behaviors such as 'failure to recognize an intramuscular location of the needle tip before injection' and 'poor choice of needle-insertion site and angle with respect to the probe' should also be virtually eradicated with echogenic needles. Needle tip location should be clearer and insertion angle no longer reduces visibility [9<sup>■</sup>].

In addition, a known textured pattern clearly distinguishes the needle from possible other linear reflections associated with tissue planes. This improves identification of both needle tip and shaft by both experienced and inexperienced operators [4,16]. Indeed it has been shown that needle identification is independent of experience level when using a truly echogenic needle. This leads to increased confidence by anesthesiologists, which is likely to drive uptake of the technique [4,5<sup>■</sup>,16].

#### ECHOGENIC NEEDLE RESEARCH: WHAT DO WE KNOW SO FAR?

During the past 2 years there has been a steady stream of research to support the theoretical advantages of the new echogenic needles. Edgcombe and Hocking [4] showed that when needles were inserted steeply into fresh cadavers it was easier to identify the tip of an echogenic needle at any insertion angle greater than 20°. Hebard *et al.* [5<sup>■</sup>] subsequently assessed the two-dimensional error that occurred when needles were inserted at 20°, 40°, and 60° into fresh cadavers (Fig. 2). There was a systematic error in recognizing the tips of the less echogenic needles. At 40°, the path of the needle was generally identified but the location of the tip on this path was not. At 60°, even the path of the needle was often incorrectly identified. Importantly, needle tips were most often identified as being in the quadrant superficial to the needle tip. Therefore the needle tip was actually deeper and further advanced than the anesthesiologist thought. This systematic error of thinking has significant safety implications in UGRA as commonly the structures that should be avoided are deeper or further than the planned location for needle placement. In addition, even at 60° insertion angle, every Sonoplex needle tip was accurately identified and located within a mean error of 1.3 mm. This was not the case with the other echogenic needles in which mean error ranged 8–11 mm and up to 25% of needle tips could not be located. Bouic *et al.* [8<sup>■</sup>] demonstrated in phantoms (Blue Phantom, Seattle, USA) that an echogenic needle



**FIGURE 2.** Two-dimensional error data for tip location of echogenic and nonechogenic needles in a human cadaveric tissue study [5<sup>■</sup>]. In each graph, the needle has been inserted from the top left corner, at the angle demonstrated, with the actual tip position located at the cross-point of the axes. Axes marked at 10 mm intervals. Data points represent observers' assessments of needle tip position. Graphs modified from original publication to better demonstrate needle insertion angle. Reproduced with permission.

was significantly more efficient for the procedure with better visibility, physician comfort, and time to needle visualization when compared to the non-echogenic needle for angles greater than 30°.

Most research has been performed in phantoms or cadavers. However, we have previously demonstrated the variability in echogenic needle visibility, and that assessment of any needle in an environment less challenging than cadavers is prone to make needles look more echogenic than they may appear in daily clinical practice [6<sup>■</sup>]. Nothing is truly comparable to studies in live patients. Hebard and Hocking [9<sup>■</sup>] therefore studied needle visibility during real-time in-plane femoral and sciatic nerve blocks. Videos were recorded and reviewed. Subjective and objective needle visibility were both essentially independent of needle insertion angle with the echogenic needle.

We know that the background echo-texture of surrounding tissue can vary between patients and this influences needle visibility [6<sup>■</sup>]. Taking this into account, the effect of insertion angle on needle visibility has recently been repeated using a 3-injection technique for axillary blocks (Capdevila *et al.*, unpublished data). This method allows needle visibility to be assessed at three insertion angles in the same patient on the same occasion.

Translating enhanced needle visibility into evidence of increased safety is not easy. Despite the impression of increased safety, no published

studies are available to show reduced complication rates. Indeed, it may be difficult to recruit sufficient numbers to prove echogenic needles are safer due to the already high success rate and safety of modern regional anesthesia.

The ease of procedure is an important factor that has not been studied. Nagpaul *et al.* [16] showed that when both experienced and inexperienced anesthesiologists targeted deep structures, using the Sonoplex needle (Pajunk, Geisingen, Germany), it significantly reduced the time to target. Although speed should not be a priority, it could be considered a surrogate measure of the ease of the procedure, and is likely to be reflected in anesthesiologist satisfaction. Similarly, a recent study demonstrated that ultrasound-guided subclavian central venous access was a safe procedure compared to a landmark-based technique [17]. However, proceduralists rated the task as technically difficult, which was likely to limit uptake into their clinical practice. A technique might be proven to be reliable and safe but if it is difficult and time-consuming, then it is likely that other alternative methods will be used in a busy clinical practice. A subsequent study showed that echogenic technology significantly improved cannula visibility, decreased access time, and observer-rated technical complexity (7/10 to 4/10) of ultrasound-guided subclavian central venous access [18]. It is likely that the combination of proven safety and ease of procedure will encourage uptake of the technique. It would be reasonable to assume that similar improvements could be found for infraclavicular block as the location of entry, the needle, and the angle of insertion are very similar.

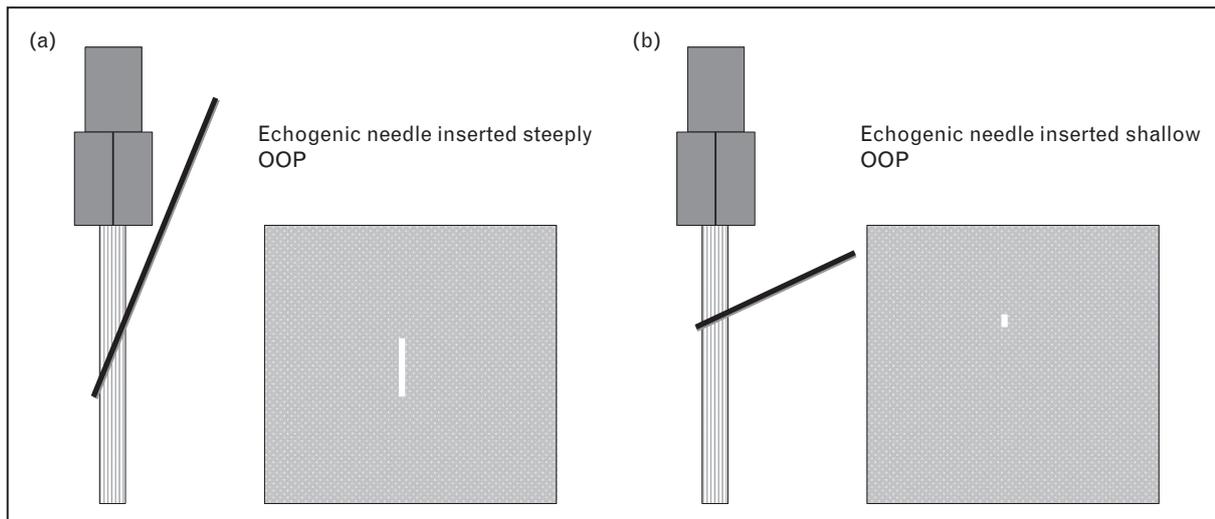
**LIMITATIONS AND FUTURE DIRECTIONS?**

The current range of echogenic needles do not solve all problems associated with needle visibility and UGRA. None of the current needles work as well with low-frequency probes as their long wavelengths are relatively large compared with the needle surface technology, thus limiting the reflection or scatter from the needle surface. Fortunately the bevel of the needle is large enough to reflect sufficient quantity of the beam to image the tip.

Highly echogenic tissues also pose a challenge to echogenic needles, as the bright tissue decreases the contrast of the echogenic needle. A simple analogy is that light from a torch, shining on a wall, is easily seen at night but difficult to see during daytime. Echogenic needles have improved real time ultrasound-guided epidurals and paravertebral blocks, but the success is limited compared with block in hypoechoic areas like the infraclavicular nerve block. Due to the range of technologies used, the echogenic needles currently available are not equally echogenic. Evidence to date suggests the Pajunk Sonoplex needle (Pajunk, Geisingen, Germany) is currently the most echogenic needle available [4,5,6,7,8,19].

**EFFECT ON OUT-OF-PLANE TECHNIQUES**

Out-of-plane techniques have received much less research than in-plane techniques, but there are now two studies suggesting that echogenic needles are helpful. Guo *et al.* [7] found the Pajunk Sonoplex needle significantly more visible OOP than less echogenic needles when viewed at 30°, 45°, 60°,



**FIGURE 3.** Simplified illustration of why an OOP needle may become increasingly visible with increasing insertion angle. More of the echogenic shaft lies within the ultrasound beam such that it appears as a line, which is then easier to direct to the target. OOP, out of plane. (Beam thickness not drawn to scale to better demonstrate the phenomenon.)

and 75° angle of insertion. In contrast to in-plane techniques, the trend was for the needle to become more visible with increasing insertion angles. We hypothesize that this is due to the echogenic needle having a longer passage through the beam width with steep insertion angles. The needle is then represented as a line rather than a dot, which would normally be expected with an OOP approach (Fig. 3). The line is larger than the dot of the tip making it easier to see. More importantly it shows the direction the needle is advancing, which makes it easier to reach the target and avoid potential hazards. Stefanidis *et al.* [20] investigated the use of echogenic introducer needles vs. nonechogenic needles during real-time ultrasound-guided IJV cannulation. They demonstrated improved cannula visibility, decreased access time, and a reduction in subjective technical difficulty, all of which may increase adoption of the technique into clinical practice.

### ECHOGENIC CATHETERS?

Some catheters have recently been marketed as being echogenic. Many rely on the fact that there is a metal stylet or electrical wire (stimulating catheter) to increase echogenicity, rather than having a specific echogenic surface structure. There are currently no studies demonstrating benefit from any echogenic catheter. However, it is important to remember it is not usually the catheter that causes injury. The catheter is not guided from the skin but introduced a short distance from a prepositioned needle tip. Whereas it may be easier to image an echogenic catheter to determine actual tip position, there are other ways to do this. One simple technique involves positioning the needle where the catheter tip should be located, and then only threading the catheter until it just protrudes from the needle. Catheters tend to come packaged as a coil, which means they often curve once inside the patient due to the memory effect, particularly if they are being inserted into closed space. This makes it likely that even an echogenic catheter will be hard to image in its entirety and limit the further benefit over an echogenic introducer needle.

### CONCLUSION

Echogenic needles improve shaft and tip visibility independent of experience level, compensate for suboptimal scanning technique, allow steeper insertion angles, reduce technical difficulty, and increase both confidence and satisfaction by anesthesiologists. An echogenic needle encourages holding the

probe in one place on the patient, only advancing the needle when it can be seen reducing the likelihood of quality-compromising behaviors. All of these factors should increase safety, efficacy, and hopefully further drive the adoption of UGRA techniques, to the benefit of our patients. However, not all supposedly echogenic needles perform to the same standard, and individuals should assess which works best in their own practice.

### Acknowledgements

*C.H.M. designed and developed the Pajunk Sonoplex needle and has a financial interest in it. G.H. has received equipment support from Sonosite for multiple ultrasound workshops but has no financial interests. Funding: None.*

### Conflicts of interest

*G.H. has no conflicts to declare. C.H.M. was responsible for the design and development of the Pajunk Sonoplex needle and has a financial interest in it. We have therefore avoided referring to specific echogenic needles by name except where there is good supporting evidence from other institutions.*

### REFERENCES AND RECOMMENDED READING

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

- of special interest
- of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 000–000).

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