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REVIEW ARTICLES

Needle-related ultrasound artifacts and their importance in anaesthetic practice

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Editor's key points

- Visualizing advancement of the needle is important in ultrasound-guided procedures.
- This paper is a review of needle-related artifacts and how can they be interpreted.
- Importantly, it provides knowledge regarding correct placement of the needle tip and safe practice.

Summary. Real-time ultrasound guidance for any intervention relies on visualization of needle advancement towards a target. Unfortunately, correct identification of the needle tip is not straightforward, as artifacts always distort the image. The ultrasonic appearance of the needle is often degraded by reverberation, comet tail, side-lobe, beam-width, or bayonet artifacts, which can easily confuse an unprepared operator. Furthermore, the typical needle image, that is, a dot or a straight line (out-of-plane and in-plane approaches, respectively), is also a result of artifacts that hide the real dimensions of the needle. Knowledge and correct interpretation of these artifacts is important for safe practice and is paramount to success when precise needle manipulation is mandatory, for example, when the target is small. In this review, authors discuss the most important needle-related artifacts and provide a physical explanation focusing on implications for everyday practice. Recent advances that allow increased needle visualization and reduction of artifacts are also discussed.

Keywords: artifacts; needles; ultrasonography, interventional; patient safety; vascular access devices

Ultrasound is now commonly used in anaesthetic practice as a guidance tool for invasive procedures. In most cases, the procedure involves a needle advancing towards a target; the procedure could be either a regional block needle insertion or a catheter insertion. Several studies showed that real-time visual control of needle manipulation increases the safety of the intervention, and consequently, recent guidelines highly recommend ultrasound guidance for a variety of applications.[1–6] The needle tip may cause complications, so its visualization throughout the procedure is crucial to avoid complications.

Exact identification of the needle tip is not straightforward partly because artifacts (i.e. any perceived distortion caused by the instrument of observation) always obscure the picture.[7] When the target is large, this is usually not a problem, but the correct interpretation of the image becomes increasingly more important when the target is smaller, in the case of regional anaesthetic blocks.

Some of the artifacts are virtually always present as they are based on the physical limits of ultrasound imaging, that is, common artifacts. Some other uncommon artifacts only occasionally distort the image, but when they do, it can be very confusing to an unprepared operator.

Physical background of needle imaging and common ultrasound artifacts

The needle shaft is a fine-bore metal tube; its transverse section is a circle and the longitudinal section consists of two walls (i.e. anterior and posterior needle walls) with a lumen in between. On the ultrasound image, however, the needle typically appears as a dot (out-of-plane technique) or *one* long line (in-plane technique), and is best identifiable when aligned parallel to the probe; visualization becomes poor at large insertion angles. The difference between the visual and the ultrasound appearance of the needle can be explained by three physical concepts: resolution, reflection, and acoustic shadowing.

Resolution

In an image, spatial resolution is defined as the ability to distinguish two objects very close together in space[8] (not to be confused with temporal resolution, which is related to the frame rate and is not applicable to still images). Spatial resolution can be further sub-categorized into axial resolution (along the axis of the ultrasound beam) and lateral resolution (perpendicular to the beam). There is a misconception that ultrasound resolution is insufficient to make a distinction between the two walls of the needle shaft, and it is not always true.

The axial resolution of the ultrasound theoretically equals half of the pulse length.[9] As the width of the ultrasound pulse, which is emitted by the transducer, is typically 1–3 wavelengths, the resolution is ~1 wavelength. This can be calculated by dividing ultrasound velocity (1540 m s^{-1} in soft tissues) by its frequency; it means that at 10 MHz the resolution limit in soft tissues is ~0.15 mm. As needle diameter is in the order of 1 mm (e.g. 0.9 and 1.6 mm for a 20 and a 16 G needle, respectively), the resolution of modern ultrasound machines is sufficient to see the structure of the needle, that is, to show both the anterior and posterior needle walls with a lumen in between. In fact, in contrast to metal needles, both walls of plastic catheters are usually identifiable (Fig. 1).

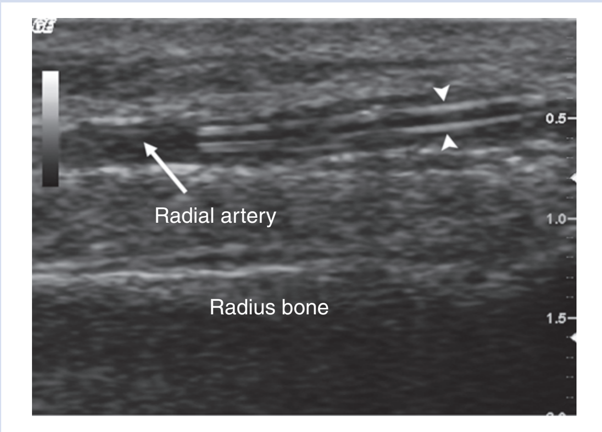

Fig 1 A 20 G arterial cannula in the radial artery (long-axis view). In contrast to needles, both the anterior and the posterior walls of the plastic cannula are clearly recognizable (arrowheads) and there is no image distortion below the catheter.

Reflection

The ultrasound beam is reflected back at tissue interfaces; this is crucial to ultrasound imaging, as to be able to show an object, the transducer must receive an echo from its surface and contents. Rough surfaces scatter the ultrasound to all directions and the exact orientation does not have a large impact on picture quality. In contrast, very smooth surfaces, for example, metal needles and cannulas, behave like a mirror and the reflected ultrasound travels in a straight line. This is called specular reflection and similarly to light, the angle of incidence equals the angle of reflection.[9 10] Furthermore, smooth surfaces are best seen when the angle of incidence is zero (i.e. the ultrasound beam is perpendicular to the surface), but visualization of traditional needles becomes poor at steep insertion angles (Fig. 2A and B).[11]

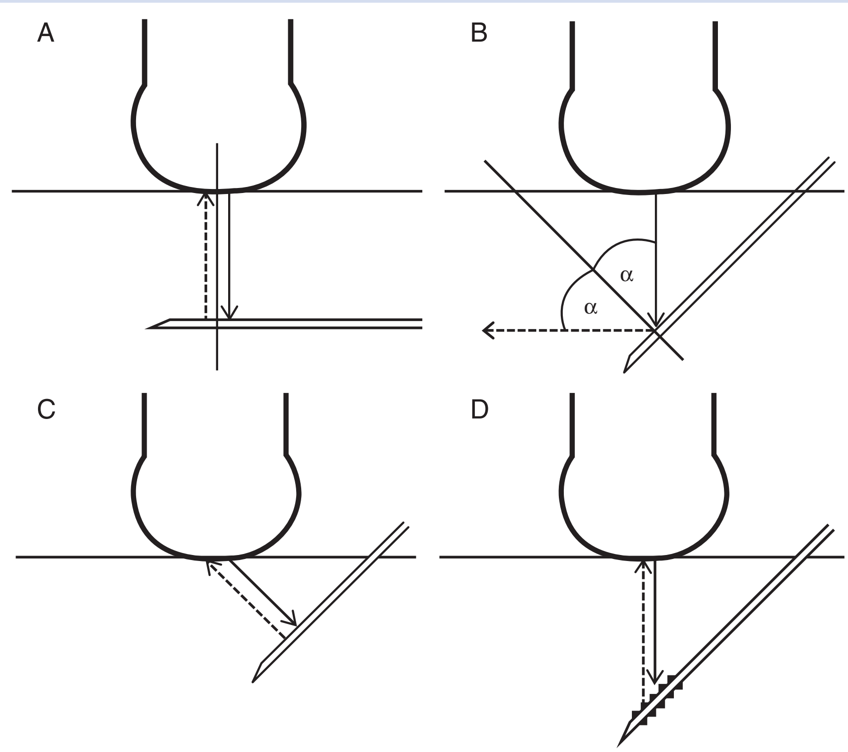

Fig 2 Specular reflection from the needle. The angle of incidence equals the angle of reflection. Visualization is best when the angle of incidence is zero (A) but becomes poor at steep insertions because the echoes are reflected away from the transducer (B). Beam steering (C) and echogenic needles (D) overcome this problem—see explanation later in text under ‘Advanced two-dimensional imaging’ (C) and ‘Echogenic needles’ (D).