Practical aspects of ultrasound-guided regional anaesthesia

Pavan Kumar BC Raju
Calum RK Grant

Learning objectives

After reading this article, you should understand the:
- basic principles and common terminologies used in ultrasound-guided regional anaesthesia
- importance of a working knowledge of the equipment used and adequate preparation
- key practical considerations for performing nerve blocks

Abstract

Ultrasound-guided regional anaesthesia is increasingly popular, offering the user a number of advantages over alternative methods of nerve localization (neurostimulation or paraesthesia). These include a more accurate understanding of individual patient anatomy, identification of needle tip position and the ability to assess local anaesthetic spread in relation to a target nerve. An understanding of the basic principles and commonly used terminologies of ultrasound scanning is a fundamental requirement when using this technology. The aim of this article is to outline these basic principles and explain the practical aspects of performing nerve blocks, using ultrasound, in order to achieve quick, safe and effective block performance with minimal procedural discomfort for the patient.

Keywords Anaesthesia; nerve blocks; regional; ultrasound

Royal College of Anaesthetists CPD Matrix: 2G02, 2G03, 2G04

Basic principles of ultrasound

Ultrasound is a form of mechanical sound energy that travels through a conducting medium as a longitudinal wave producing alternating compression and rarefaction. Medical ultrasound has a frequency range of 2–18 MHz, well above the 20 kHz upper limit of the human audible range, and travels through human body tissue at an average speed of 1540 m/second.

Piezoelectric effect

This describes the conversion of sound to electrical energy. The emitted ultrasound signal is produced by the application of an electrical charge to piezoelectric crystals within the transducer (or probe). After passing into the tissues, some of the ultrasound signal is reflected. The returning pressure wave distorts the transducer crystals again, this time creating an electrical charge (piezoelectric effect) that can then be processed and displayed on the monitor.[1]

B-mode ultrasound

Brightness (B or 2D) mode ultrasound (Figure 1) produces a grey-scale image of the tissue underlying the transducer. The transmitted ultrasound wave is reflected by the tissues, the extent of which is referred to as tissue echogenicity. Strong ultrasound reflection produces hyperechoic, white images (e.g. bone, pleura), weaker reflection results in an hypoechoic, darker, grey image (e.g. some peripheral nerves) and no reflection of the ultrasound signal produces an anechoic, dark image (i.e. lumen of blood vessels). The depth of each structure is determined by the time taken for the transmitted ultrasound to pass from the transducer through the tissues and return to the probe.

Colour Doppler

The Doppler effect[1] describes an apparent change in the returning ultrasound signal due to the relative motion between the sound source (the structure reflecting the ultrasound signal) and the receiver. If the source is moving towards the receiver, the perceived frequency is higher and displayed as red in colour and if the source is moving away from the receiver, the frequency is lower and displayed as blue in colour. This is useful in identifying vascular structures and distinguishing them from peripheral nerves, both of which may appear as round or oval hypoechoic structures.

Image resolution

Image resolution depends on the ability of the ultrasound machine to distinguish individual structures situated close together as being physically separate. Spatial resolution determines the degree of image clarity and is influenced by axial and lateral resolution. Axial resolution is the ability to distinguish two structures that lie along the longitudinal axis as separate and distinct, whereas lateral resolution distinguishes structures lying in close proximity side-by-side.[1] Higher ultrasound frequencies, in general, produce the best image resolution.

Compound imaging

Conventional ultrasound is prone to image artifacts. By adding spatial compounding technology, the final quality of the image displayed is enhanced and the artifacts are minimized. This process involves combining multiple overlapping image frames from different ultrasound beam angles to form a single real-time image on the display producing a final image that appears less grainy with improved resolution.[2]

Artifact

An artifact is any perceived distortion, error or addition caused by the instrument of observation.[3] It is important to identify common imaging artifacts which can result in degraded images or inaccurate anatomical representation.[4] There are several forms of artifacts and a complete list is out-with the scope of this

***Pavan Kumar BC Raju** MD FRCA is a Consultant Anaesthetist at Ninewells Hospital and Medical School, Dundee, Scotland, UK. Conflicts of interest: none declared.*

***Calum RK Grant** FRCA is a Consultant Anaesthetist at Ninewells Hospital and Medical School, Dundee, Scotland, UK. Conflicts of interest: none declared.*

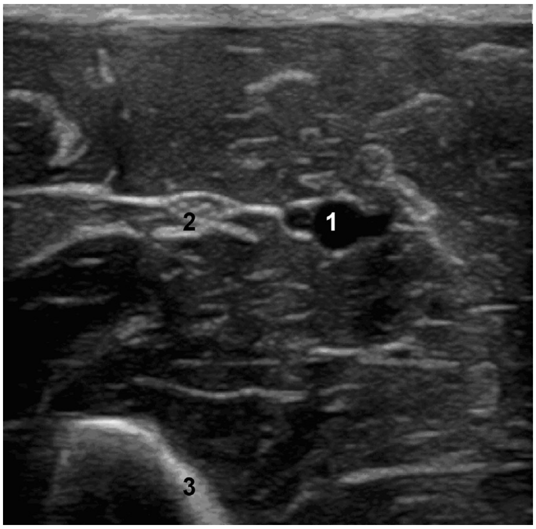


Figure 1 Transverse ultrasound image at mid-forearm level demonstrating the dark, anechoic ulnar artery (1), hyperechoic or 'honeycomb' appearance of the ulnar nerve (2) and bright, hyperechoic bony outline of the ulna (3).

article. Acoustic enhancement artifacts (i.e. deep to a vessel), acoustic shadow artifacts (i.e. deep to a bony outline), reverberation artifacts (e.g. pleura, block needle), air artifact from air bubbles in the local anaesthetic injectate and dropout artifacts (i.e. lack of conductive gel) are those most frequently encountered (Figure 2) in daily practice.[4]

Gain

As ultrasound penetrates the tissue layers, it loses energy (attenuation) and the signal amplitude decreases. This impacts on the final image produced because the reflecting signal from these attenuated signals will be of low intensity. Gain is the process of increasing the amplitude (intensity) of the returning signal and in turn the brightness of the image. The drawback is an increase in signal background noise that can reduce image quality; however, most modern machines are capable of controlling the gain at specified depth intervals, limiting this interference. This property is termed time gain compensation (TGC).[5]

Practical aspects of ultrasound-guided regional anaesthesia (UGRA)

Preparation for UGRA

Verbal consent from the patient is necessary after taking a relevant anaesthetic history and examination, identifying any potential contraindications to the nerve block. All patients should have intravenous access and standard monitoring established, based on current Association of Anaesthetists of Great Britain & Ireland (AAGBI) guidance.[6] Emergency drugs should be readily available and appropriate skilled assistance sought. In co-operative adult patients, ultrasound-guided peripheral nerve blocks are ideally performed awake or under light sedation. Performing nerve blocks under general anaesthesia is largely confined to paediatric practice.

Ultrasound machine

Ideally ultrasound machines used for peripheral nerve block should have automatic B-mode image optimizing ability (thereby allowing the user to produce the best possible sono-image), a multi-transducer port to facilitate simple, quick transducer change, compound imaging, colour Doppler and still image/video recording abilities for teaching and research purposes.

Transducer selection

There are a range of commercially available hand-held transducers (Figure 3) for ultrasound-guided regional anaesthesia (UGRA) which vary in ultrasound frequency and physical shape (or 'footprint'). The majority of peripheral nerve blocks can be performed with a high-frequency transverse linear probe which will provide optimum resolution of relatively superficial structures such as the brachial plexus, femoral and popliteal nerves. Probes that have a smaller footprint are useful in children and for accessing specific anatomical areas in adults where a standard probe is too bulky (i.e. the neck or ankle). Curvilinear probes

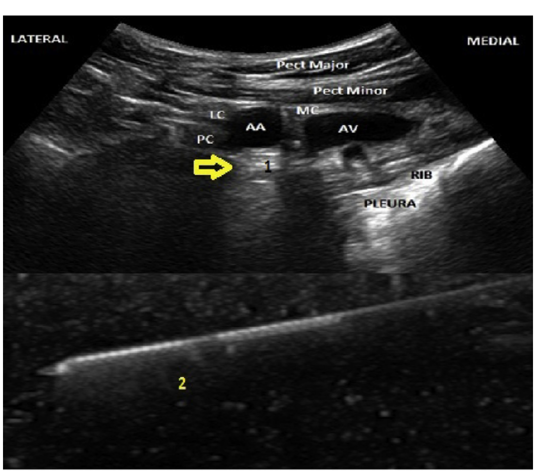


Figure 2 Acoustic enhancement artifact (1, arrow) seen deep to the axillary artery in the infraclavicular fossa which can be mistaken for a nerve (cord) and reverberation artifact (2) seen along the needle shaft producing a multilayered appearance to the image. Note echogenic reflectors enhancing needle visualization in the lower image.

Figure 3 A selection of ultrasound scanning probes commonly used in regional anaesthesia. From (L) to (R) high-frequency linear probe with small footprint, low-mid frequency curve-linear and high-frequency linear probes.

emit a divergent ultrasound beam and are usually of a lower frequency, providing superior tissue penetration and a wider depth of field for imaging deeper structures such as the sciatic nerve.

Conducting medium

Sterile aqueous gel should be used generously between the transducer and the area of contact as a conducting medium; in addition this will also prevent any air trapping. It is important to avoid drop out shadows produced by improper contact between the skin and the transducer because of insufficient gel or incorrect positioning of the transducer.

Needle selection

Single-shot techniques are usually performed with 22G short-bevelled regional block needles. Larger 18G needles, often with a Tuohy tip or short-bevel, are required for introducing a peri-neural catheter. Both types of needle are available with the option to combine with neurostimulation. The length of the needle will be determined by the depth of the neural structures and the choice of needle approach: in or out of plane with respect to the ultrasound beam. Generally, a longer needle is required when performing in-plane procedures.

When a needle is inserted in-plane, relatively parallel to the ultrasound probe, it appears as a bright echogenic line that is obvious along its length to the needle tip. At steep angles of needle insertion, during in-plane procedures, it can be difficult to visualize the needle shaft or tip due to increasing refraction and decreasing reflection of the ultrasound signal. A recent advance in needle technology has led to the development of a number of commercially available echogenic needle designs. These needles are either laser etched or manufactured with a series of small reflectors situated at the tip of the needle (Figure 4) that enhance ultrasound reflection (and minimize refraction), improving needle tip visualization, even at relatively steep angles of insertion.[7]

Local anaesthetic

The choice of local anaesthetic depends on the intended purpose of the nerve block and the desired duration of anaesthesia or analgesia. The use of ultrasound guidance almost certainly leads to more accurate local anaesthetic deposition when compared to other methods of nerve localization and, in general, significantly lower volumes and total doses of local anaesthetic can be used. There are obvious advantages in the reduced potential for dose related side effects, in particular local anaesthetic toxicity but also a lower incidence of block specific complications, for example phrenic nerve block when performing interscalene block.[8]

Patient positioning

As a general rule the operator, nerve block site and ultrasound machine should be positioned in a straight line (in that order) to allow the operator to be able to monitor the patient, needle, probe position and ultrasound image. It is important that block needle insertion is not impeded by the position of the patient and/or the ultrasound probe. Ensuring that both patient and operator are in a comfortable position is likely to improve the chances of a successful procedure.

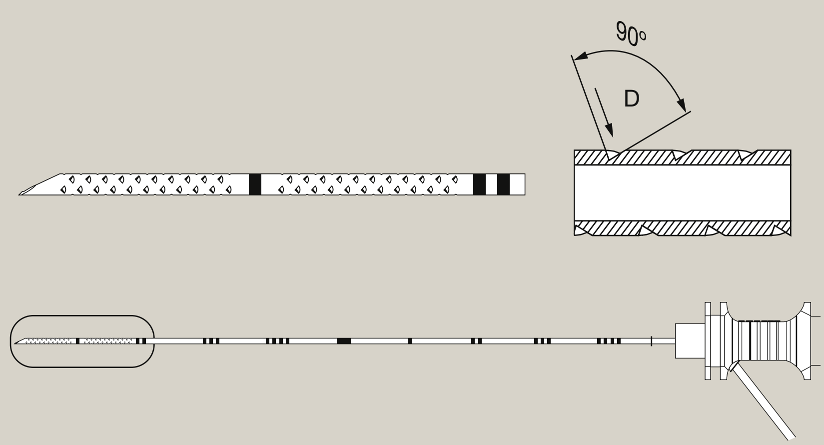
Performing an ultrasound-guided nerve block

Prior to performing the block, a final check or 'stop before you block' should be carried out to confirm correct patient details, position and site for nerve block, this should ensure that incorrect site nerve block is avoided.[9]

Sterile field

A sterile field should be maintained throughout the procedure. Skin should be sterilized with an antiseptic solution. Full aseptic precautions should be taken when performing a peri-neural catheter insertion. Transducer sterility can be achieved by using either a sterile sheath or more economical adhesive

A schematic representation of an echogenic regional block needle highlighting reflectors 2 cm from the needle tip



The reflectors increase ultrasound reflection at steeper angles of needle insertion. (Reproduced with kind permission, Dr G Hocking).

Figure 4

transparent dressings such as Tegaderm™, taking care to avoid air trapping between the transducer and its cover.

Scanning the area and orientation

Ensure a generous amount of sterile gel is applied between the transducer and the skin. Once contact is developed, it is important to optimize transducer frequency, depth, focus and gain. Most currently available machines will have a single button required to optimize the quality of the image. It is important for the user to orientate themself with the probe and identify which side will be lateral (or superior) and which medial (or inferior) when it is placed on the subject. Most probes have a marker on one side that corresponds to one side of the ultrasound screen; alternatively a finger placed on the probe will produce an artifact on the screen allowing user orientation.

Controlling transducer movements

Ultrasound scanning is a dynamic process and achieving the best image and appreciation of sonoanatomy requires appropriate adjustment of the ultrasound probe. Pressure, alignment, rotation and tilt (PART) are the basic manoeuvres that define the control of a transducer. Alignment describes longitudinal probe movements and can be used to visualize nerves along their length. Rotation is the clockwise/anti-clockwise movement of the probe and tilt the change in angle of the probe relative to the skin; both adjustments help to improve nerve localization in transverse section. Once an appreciation of the underlying anatomy is acquired, the needle is inserted and guided next to the nerve. Continuous visualization of the needle and its tip is extremely important for safe and successful nerve block. When visibility of the needle or needle tip is decreased, the needle should be held stationary and the transducer manipulated using one or a combination of the ART manoeuvres, as previously described. Developing the hand—eye coordination to maintain visualization of both needle tip and nerve throughout these procedures requires significant concentration, skill and practice.

Nerve localization techniques

With practice, it is possible to identify almost any peripheral nerve in the body although, as a general rule, larger, superficial nerves are most easily identified. Peripheral nerves usually have a round, hypoechoic appearance in proximal anatomical locations (such as the brachial plexus above the clavicle) and a honeycomb appearance more distally due to the increasing connective tissue component of the nerve fascicles. Nerves may form part of a neurovascular bundle that includes arteries and veins or they may lie in relation to a fascial plane. Arteries are pulsatile, non-compressible hypoechoic structures whereas veins are non-pulsatile and easily compressible. Both types of vessel can be further distinguished from nerves by applying colour flow doppler.

When performing the nerve block, if local anaesthetic is placed around and especially underneath nerves it can significantly improve nerve visualization. The use of combined neurostimulation may also be helpful if there is uncertainty over the ultrasound appearance of peripheral nerves or if the nerve lies at a deeper location where the image resolution may not be as clear. The clinician can seek an appropriate motor response to confirm that the structure in question is the correct nerve. Stimulating thresholds below 0.5 mA are suggestive of intraneural needle tip placement and should prompt repositioning of the block needle prior to local anaesthetic injection.

Needle insertion techniques

Commonly, two types of approaches are used for inserting the needle in relation to the transducer (Figure 5).

Out-of-plane approach: the needle is inserted perpendicular to the transducer and is visualized as a hyperechoic dot as it crosses the ultrasound beam. Accurate identification of tip position is challenging using this approach as it can be difficult to differentiate between the shaft and the tip of the needle, as both appear similar under ultrasound. One potential advantage is the shorter needle-to-nerve distance which may limit patient discomfort.

In-plane approach: the needle is inserted parallel to the transducer and ultrasound beam. The aim is to visualize both the needle shaft and tip throughout the procedure. This approach is particularly appropriate for superficial nerve blocks such as brachial plexus or femoral blocks, as the angle of insertion of the needle relative to the probe remains relatively superficial, improving needle visualization and facilitating accurate needle tip identification.

Localization of needle tip: accurate identification of needle tip position has the potential to increase block success rates while limiting potential complications such as intraneural injection, intravascular injection and associated damage to surrounding structures (e.g. pleura, blood vessels). However, localizing the needle tip can be challenging. ART manoeuvres are helpful here, as are delicate to and fro movements of the needle which can displace the tissue indicating needle tip position. More commonly, very small aliquots of saline or local anaesthetic (0.5—1 ml) can be injected and observed for spread on the screen, a technique known as hydro-location.

Local anaesthetic injection

One of the most significant advantages of ultrasound-guided regional anaesthesia is the ability to identify the real-time spread

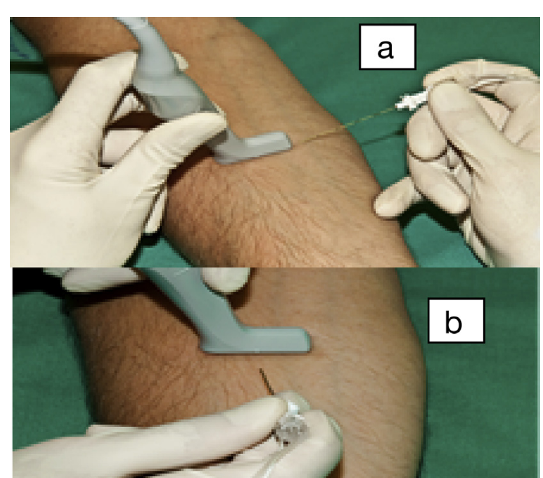


Figure 5 (**a**) Out-of-plane technique demonstrating needle alignment relatively perpendicular to ultrasound probe. (**b**) In-plane technique demonstrating needle alignment parallel to ultrasound probe.

of local anaesthetic around peripheral nerves to ensure effective nerve blockade. It may be necessary to re-position the block needle during the procedure in order to achieve the desired end-point. The ability to observe local anaesthetic spread offers additional safety benefits when compared to conventional neurostimulation or paraesthesia techniques. Intraneural and intravascular injection are both readily identified under ultrasound and, as previously mentioned, effective nerve block can be achieved with surprisingly small volumes of local anaesthetic. In addition to visualization of local anaesthetic spread, aspiration for blood should be performed prior to each aliquot of local anaesthetic injected to exclude intravascular needle placement and high injection pressures should alert the operator or assistant to the possibility of intraneural injection. As with all nerve block procedures, careful continuous monitoring of the patient should be maintained with vigilance at all times. ◆

REFERENCES

1 Chan VWS. Ultrasound imaging for regional anaesthesia. A practical guide. 3rd edn. Toronto: Toronto Printing Company Inc, 2010.

2 Entrekin R, Jackson P, Jago JR, Porter BA. Real time spatial compound imaging in breast ultrasound: technology and early clinical experience. *Medicamundi* 1999; **43:** 35–43.

3 Webster_s Online Dictionary. Available at: http://www.websters-online-dictionary.org/definition/artifact.

4 Sites BD, Brull R, Chan VWS, et al. Artifacts and pitfall errors associated with ultrasound-guided regional anesthesia. Part II: a pictorial approach to understanding and avoidance. *Reg Anesth Pain Med* 2007; **32:** 419–33.

5 Sites BD, Brull R, Chan VWS, et al. Artifacts and pitfall errors associated with ultrasound-guided regional anesthesia. Part I: understanding the basic principles of ultrasound physics and machine operations. *Reg Anesth Pain Med* 2007; **32:** 412–8.

6 Checketts MR, Alladi R, Ferguson K, et al. Recommendations for standards of monitoring during anaesthesia and recovery 2015 : association of Anaesthetists of Great Britain and Ireland. *Anaesthesia* 2016; **71:** 85–93.

7 Hebard S, Hocking G. Echogenic technology can improve needle visibility during ultrasound-guided regional anaesthesia. *Reg Anesth Pain Med* 2011; **36:** 185–9.

8 Riazi S, Carmichael N, Awad I, Holtby RM, McCartney CJ. Effect of local anaesthetic volume (20 vs 5 ml) on the efficacy and respiratory consequences of ultrasound-guided interscalene brachial plexus block. *Br J Anaesth* 2008; **101:** 549–56.

9 Stop Before You Block safety campaign. https://www.ra-uk.org/index.php/stop-before-you-block (accessed 27 September 2018).