Practical aspects of ultrasound-guided regional anaesthesia

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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; blocks; needles; nerve; 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—15 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 (e.g. 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 article. Acoustic enhancement artifacts (i.e. deep to a vessel),

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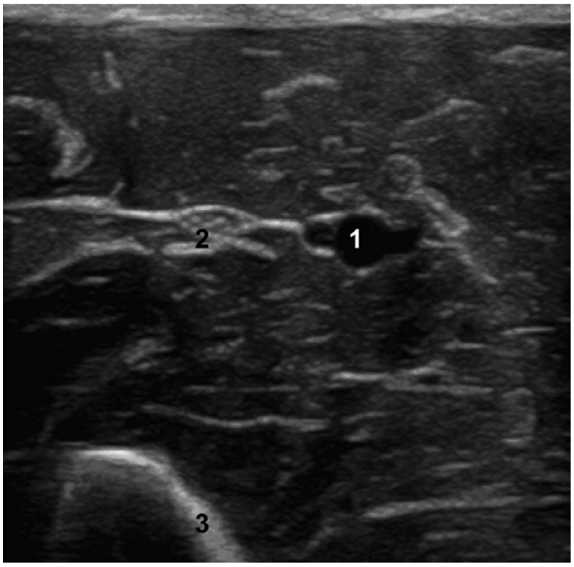

Figure 1 Transverse ultrasound image at mid-forearm level demonstrating the dark, anechoic ulnar artery (1), hyperechoic or 'honeycomb' appearance of the ulnar nerve (2) and bright, hyperechoic bony outline of the ulna (3).

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]

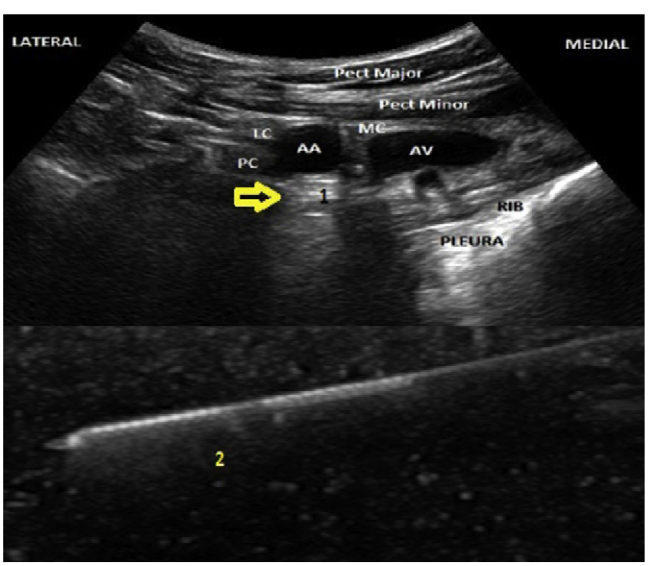

Figure 2 Acoustic enhancement artefact (1, arrow) seen deep to the axillary artery in the infraclavicular fossa which can be mistaken for a nerve (cord) and reverberation artefact (2) seen along the needle shaft producing a multilayered appearance to the image. Note echogenic reflectors enhancing needle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

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 the minimum standard of monitoring established, based on the Association of Anaesthetists of Great Britain and Ireland (AAGBI) guidance.[6] Emergency drugs should be readily available and appropriate skilled assistance sought. In cooperative 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 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 emit a divergent ultrasound beam and are usually of a lower frequency, providing

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- to mid-frequency curve-linear and high-frequency linear probes.

