Review Article

Role of Ultrasound Guidance in Regional Anesthesia

Shalini Dhir, Sugantha Ganapathy, Achal Dhir
Department of Anesthesia and Perioperative Medicine, University of Western Ontario, London, Canada

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ABSTRACT

Imaging is playing an increased role in almost every field of medicine and anesthesiologists around the world are not far behind. The use of ultrasound image guidance for regional anesthesia is a relatively new and evolving concept, though it was first reported in 1978. Technological advances have led to the development of good, smaller, portable and less expensive ultrasound machines with better picture quality. The most important and unique advantage of ultrasound guided regional anesthesia is the ability of visualize the needle nerve interaction and spread of local anesthetic around the nerve. Ultrasound technology is particularly useful in situations where anatomy is altered; elicitation of neurostimulation is painful or not possible as well as for failed block rescue.
Performance of ultrasound guided nerve blocks in clinical practice is a skill and needs to be acquired by practice. Ultrasound imaging may transform the art of regional anesthesia into a science.

KEYWORDS: peripheral nerve block, regional anesthesia, ultrasound

INTRODUCTION

Continuous peripheral nerve blocks provide extended, site specific, post operative analgesia, few side effects, improved patient satisfaction and accelerated functional recovery after extremity surgery[1]. Prospective randomized trials have demonstrated time and again, the effectiveness of ambulatory continuous peripheral nerve blocks after painful orthopedic procedures[2,3]. The main concern with continuous blocks is placement of catheter close to the nerve so that local anesthetic drug is optimally distributed around nerves. Nerves are not blocked by the needle but by the local anesthetic[4] and unsuccessful blocks mean that the local anesthetic is not where it should be.

We have come a long way since 1884 when the first block was done under direct vision by Halsted. Since then, this goal has been achieved by various methods. Traditionally, blocks have depended on fascial clicks and / or elicitation of paresthesia with or without the use of nerve stimulators. Blind blocks are known to produce serious complications[5,6] and the motor response to nerve stimulation may be absent when the needle is on[7] or even in[8,9] the nerve. Also damage to nerve structures by direct puncture can happen[10]. Imaging is playing an increasing role in many fields of medicine including vascular access, cardiac evaluation, transesophageal echocardiography, obstetric and gynecological diagnosis and emergency medicine. Practitioners of regional anesthesia are not far behind.

HISTORY

In 1978, La Grange and colleagues[11] reported the use of a Doppler ultrasound device to aid identification of the subclavian artery and vein before brachial plexus block by the supraclavicular approach with a success rate of 98% with no complications. In 1994, referring to the need for more precision in regional anesthesia, Winnie repeated John Lundy's statement, "Sooner or later someone will make a sufficiently close examination of the anatomy involved, so that exact techniques will be developed"[12].

In the same year, Kapral *et al* published the first paper using direct ultrasonographic visualization for a regional block (supraclavicular brachial plexus block) including the direct observation of the spread of the local anesthetic[13]. Since then, in principle, ultrasonographic guidance for different regional anesthetic methods was possible but the quality of the views remained poor due to inadequate resolution with the ultrasound technology used at that time. Two ultrasound studies of the brachial plexus were reported in the radiology journals in 1998[14,15] using magnetic resonance imaging (MRI) and CT scans as a guide to background anatomy. They described the plexus of nerves as having hypoechoic appearance.

RATIONALE: WHY USE ULTRASOUND?

Imaging is playing a major role in all fields of medicine. During the past ten years the interest of anesthesiologists around the world for ultrasonography

Address correspondence to:
Dr. S. Dhir, St. Joseph's Health Care, 268 Grosvenor Street, London, Ontario, N6A4V2, Canada. E-mail: sdhir2@uwo.ca

Fig. 1: Ultrasound machine
1 = on / off button, 2 = function control buttons, 3 = gain buttons, 4 = zoom (2x), 5 = adjust image depth, 6 = review stored images, 7 = patient information, 8 = freeze image, 9 = save image, 10 = color Doppler

in regional anesthesia has continuously increased. It is being used for almost all of the peripheral nerve blocks in the western world. Ultrasound-assisted nerve block has been described for localization of the brachial plexus[16-18], femoral nerve[19], lumbar plexus[20] and sciatic nerve[21-23]. While ultrasound application for regional anesthesia is a relatively new and evolving concept, its use to accurately locate target lesion for tissue biopsy has been standard medical practice for many years. Ultrasound (US) guidance has also proven to facilitate the neural blockade[24] as well as improve block quality[25].

Ultrasonography allows one to visualize the neural structures, its surrounding, structures at risk such as pleura and vessels as well as spread of the delivered local anesthetic in proximity to the nerves. US also allows one to estimate the tip of catheter location using color Doppler and see the spread of anesthetic in real time. One is able to reduce the dose of local anesthetic required because the drug is delivered precisely near the target. This technology is particularly useful to rescue blocks when a block has failed using neuro-stimulation or paresthesia as neither of the latter two techniques can be used in a partially blocked nerve. It is also useful in situations where neuro-stimulation induced motor twitches can be very painful for the patients following trauma and fractures. This technique is particularly useful in obese patients or patients with altered anatomy. This is the only technique that sheds light on anatomical variations between individuals.

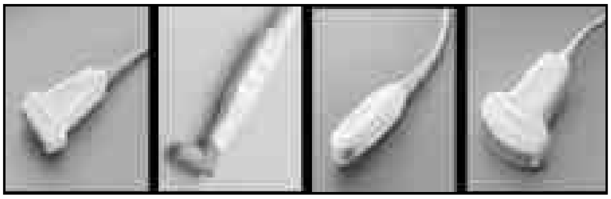

Fig. 2a: Different types of transducers

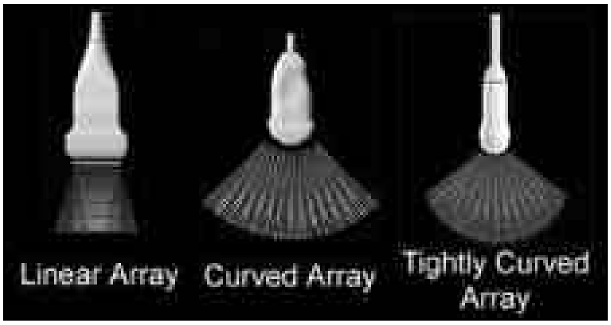

Fig. 2b: Different probes with array

Table 1: Various tissues and their ultrasonic image.

Artery	Hypoechoic, pulsatile, non compressible
Vein	Hypoechoic, non pulsatile, compressible
Bone	Hyperechoic rim, anechoic underneath
Tendon	Hyperechoic
Muscle	Hypoechoic with striations
Nerve	Hypoechoic with rim, bunch of grapes, hyperechoic

Major barriers to the implementation of ultrasound in regional anesthesia into daily clinical practice are the expense of the equipment and the need for specialized training.

EQUIPMENT

There are several categories of ultrasound machines available in the market. The more expensive ones can provide cleaner images of nerves with compound imaging (equivalent to digital subtraction imaging). There are portable ones as small as a laptop that can be used as “point of care” devices and taken to the bedside of the patient to facilitate block. The latter tend to provide images good enough for the performance of various regional blocks. Good portable ultrasound units have been developed in recent years (Fig. 1) and they are significantly less expensive than larger systems found in the radiology suites.

The equipment consists of a processor with a screen to display the images and a variety of transducers that act as a generator as well as receiver of ultrasonic sound waves (Fig. 2a and 2b). The transducers have an array of piezoelectric crystals that vibrate when electricity is applied to them and generate ultrasonic waves. The frequency of sound waves generated by these transducers is in the megahertz zone (human hearing range is up to 20 kilohertz). These waves are reflected back by

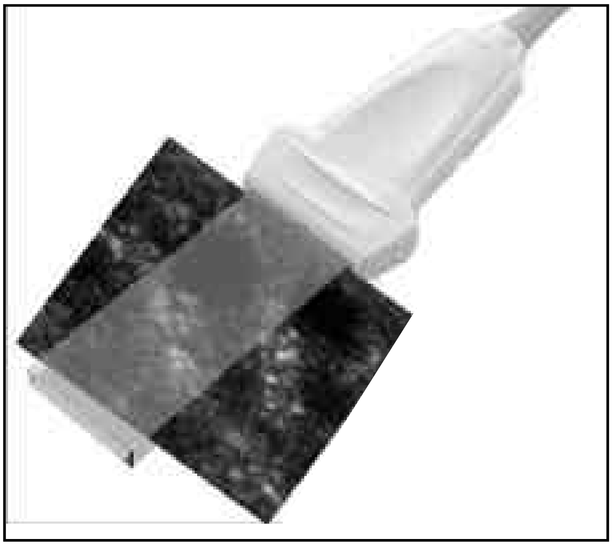

Fig. 3: Linear array probe with parallel sound beam 10-5 MHz, 38 mm linear. Useful for upper & lower limb

the tissues and are received by the transducer which again converts them to electric signals. These returned signals are reconstructed as a bitmap image on the screen by the processor. The reflectivity of the tissues varies. Bone does not allow the sound waves to pass through and thus appears as a hypoechoic (dark) shadow under a hyperechoic rim (Table 1). The connective tissue inside the nerve reflects ultrasound waves in an anisotopic manner. Angle and intensity of the reflection depends on the angle of the ultrasound wave relative to the long axis of the nerve. Therefore, the true echogenicity of a nerve is only seen if the sound wave is oriented perpendicularly to the nerve axis.

Blood vessels often look as hypoechoic pulsatile structures. While veins are compressible, arteries are usually non-compressible (with a gentle pressure). One may be able to distinguish arteries from veins using the color Doppler that delineates flow through the vessel and direction of flow in relation to the probe. These vessels and nerves can also be viewed in the longitudinal view. While it is easy to identify vessels in the longitudinal view due to the pulsations, nerves are more difficult to discern as they look like a bunch of strands, similar to the surrounding muscles.

There are linear transducers that emit parallel sound beam (Fig. 3) and curved array probes that emit diverging beam (Fig. 4). Lower the frequency of the probe, greater the penetration and higher the frequency, lower the penetration. Many high-end machines will allow one to adjust the frequency on the console to optimize image quality. Normally they come in frequencies labeled as a range (2 - 5 MHz or 7-12 MHz). Often the depth adjustment, penetration, *etc.* on the console will allow the use of the appropriate range of a probe to improve image quality.

Fig. 4: View with curved array probe with divergent beam 5-2 MHz, 60 mm curved. Useful for gluteal area

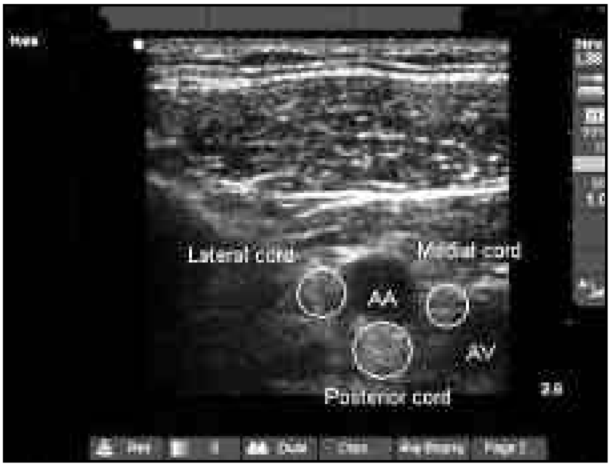

Fig. 5: Nerves as seen on ultrasound in infraclavicular area
AA= axillary artery; AV = axillary vein

Ultrasound-guided nerve blocks can be performed with most modern ultrasound systems. They should be equipped with software to visualize both superficial tissues and musculoskeletal structures. High-resolution ultrasound (HRUS) systems come with software that allows optimized visualization of tissue contrast. Color and pulsed-wave Doppler imaging helps to identify vessels in proximity to nerves. If the equipment includes a high-capacity hard disk the images can be stored for future reference. Short film sequences can then be stored and transferred to a disc via a CD or DVD burner. Files can be stored in RAW-data, JPG, BMP or MPG formats. Visualizing nerves by sound waves requires the use of high frequencies to offer high-resolution images. However, high frequency means lower penetration depth and this is good for superficial structures. For deeper structures such as the sciatic nerve, we need lower frequency probes (2 - 5 MHz) for greater penetration. Most nerve block applications require frequencies in the range of 10 to 14 MHz. Broad-band transducers covering a bandwidth of 5 to 12 MHz or 8 to 14 MHz offer excellent resolution of superficial structures in the

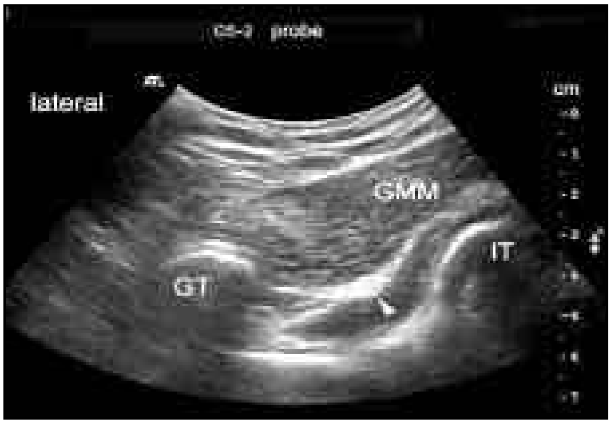

Fig. 6: Hyperechoic (bright) structures
Δ Sciatic nerve, GT: Greater Trochanter, IT: Ischial Tuberosity

Fig. 8: Nerves as seen on longitudinal view with ultrasound

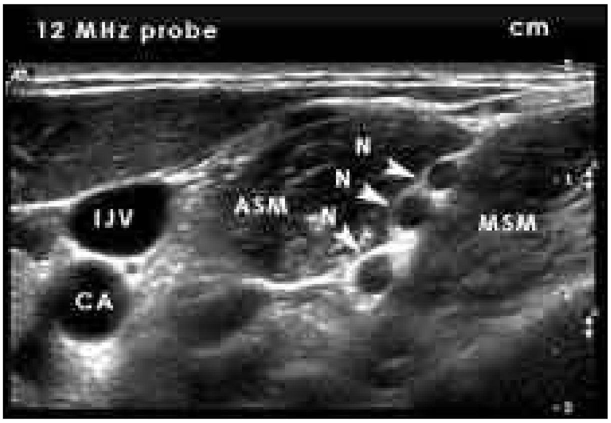

Fig. 7: Nerves as seen on Ultrasound scan of Interscalene area
N = nerve, hypoechoic structures surrounded by hyperechoic rim, IJV = Internal Jugular vein, CA = Carotid artery, ASM = Anterior scalene muscle, MSM = Middle scalene muscle

upper extremity, and good penetration depth in the lower extremity.

Image quality is of great importance when using ultrasound. Probe characteristics, such as frequency, screen display characteristics determine ultrasound image quality. The frequencies usually used in brachial plexus blocks range from 7-12 MHz.

NEEDLE VISIBILITY

Ultrasound visibility of needles depends upon the insertion angle and the gauge. Large bore needles for *e.g.*, 18 G are more readily visualized and easier to manipulate under ultrasound because their larger cross-sectional area makes them easier to locate. Larger needles are also less flexible and less likely to bend out of the plane of imaging. At steeper angles, there is back scatter from the needle that is received by the transducer[26] and this results in reduced needle tip visibility. Echogenic needles also can provide improved visibility[27] but there are no dedicated echogenic block needles at this time[28]. Occasionally, the tip of the needle is etched to make it more echogenic (Terumo Corporation). Often moving ("jiggling") or rotating the needle will make the tip more visible.

APPEARANCE OF NERVES UNDER ULTRASOUND

Peripheral nerves may have a hypoechoic (dark structures like vessels: Fig. 5 and 7) or hyperechoic (bright structures: Fig. 6) sonographic appearance[29,30] depending on the size of the nerve, the sonographic frequency, and the angle of the ultrasound beam. We perform most blocks on transverse scans, where the nerves appear as multiple round or oval hypoechoic structures encircled by a relatively hyperechoic horizon (Fig. 7). These hyperechoic structures are the fascicles of the nerves while the hypoechoic background reflects the connective tissue between neuronal structures. In a longitudinal view, each nerve appears as a relatively hyperechoic band characterized by multiple discontinuous stripes (Fig. 8). As the fascicles are the main sonographic feature of peripheral nerves, their appearance has been described as a 'fascicular pattern' as opposed to the 'fibrillar pattern' of tendons, characterized by multiple hyperechoic continuous lines. The number of fascicles observed on HRUS does not reflect the true number of fascicles within the nerve, as the smallest fascicles cannot be visualized by ultrasound. The fascicular pattern seems to be typical of large peripheral (*e.g.* median, ulnar and radial) nerves and is not seen with smaller (*e.g.* recurrent laryngeal and vagal) nerves.

Most peripheral nerves can be visualized over their entire course. However, even ultrasound has its limitations. Deeper and more central nerves that can be overshadowed by bony structures are not visible clearly. The potential for ultrasound is limited in more central nerve blocks (*e.g.*, epidural) as the bone shadow interferes with the ability to see the deep epidural space. Till date, there are not many studies that have reported good success with ultrasound localization of epidural space.

EDUCATION

Good hand-eye coordination is required for tracking the needle on ultrasound, and the necessary skill of aligning the block needle with the ultrasound beam can be acquired through hands-on practice[31]. Insertion of needle in plane with the probe compared to off plane or perpendicular to the probe results in different images and requires practice.

There are many centers in the world which carry on workshops (most of which are hands-on) to learn ultrasound techniques for regional blocks. Five scientific study groups have significant parts in the implementation of ultrasonography for regional anesthesia and pain medicine in clinical practice. Dr. Thomas Grau and his colleagues from Germany, Dr. Vincent Chan, Dr. S. Ganapathy and their colleagues from Canada, Dr. Schafhalter-Zoppoth and Dr. Grey, from San Francisco, Dr. Michele Curatolo and Dr. Urs Eichenberger, from Switzerland and Dr. Manfred Greher and Dr. Stephan Kapral group in Vienna are some of them.

The most important and unique advantage of ultrasonographic-guided regional anesthesia is the ability to directly observe spread of local anesthetic solution. Traditional approaches to discriminatory nerve blockade have focused on the position of the block needle relative to the nerve. It has been assumed that precise placement of the block needle close to the nerve will ensure adequate blockade. However, that may not be the case as blockade is variable even when good motor endpoints using nerve stimulators are obtained. Ultrasound provides an explanation for this observation. Ultrasound allows the direct visualization of the spread of local anesthetic. If local anesthetic spreads to cover the entire nerve, blockade is assured. Despite close proximity of the needle to the nerve, if local anesthetic spread is incomplete, blockade may not occur or will be significantly delayed. It is important, for efficacy and safety reasons, for anesthesiologists to become familiar with this concept. It is clear that it is not simply the proximity of the tip of the needle to the nerve, but the actual spread of local anesthetic solution that is responsible for conduction blockade of the nerve! Ultrasonography is the only tool with which we are able to observe the spread of local anesthetic in an easy and non-invasive way.

The ability to visualize the interaction between nerves and local anesthetic spread may be the key to a consistently successful block.

The advantage of ultrasound in avoiding pneumothorax is apparent as one is able to see the needle and its path, observe needle nerve interaction, identify pleura and the lung[32] and can place drug precisely without any harm to the pleura. Greher and colleagues[33] have added to our knowledge of anatomy in relation to nerve blocks by using ultrasound to identify the brachial plexus in the infraclavicular region. It is of interest to note that their study indicates that anatomical landmarks are not ideal in all sizes of patients and may decrease the margin of safety by allowing close approach of needle to the pleura and vessels. They recommend that ultrasound guidance be used when performing this block.

FUTURE

Ultrasound imaging may transform the art of regional anesthesiology into a science[34]. In the present day of advanced technology, it appears that ultrasound can be a useful aid as a real time guide of needle and/or catheter position relative to the nerve or blood vessel and can be used to define spread of the local anesthetic[35]. It also allows anesthetists to reposition the needle if needed. Performance of ultrasound guided nerve blocks in clinical practice is a skill and needs to be acquired by practice.

Because it took a long time for us to evolve from Moore’s dictum **“No paresthesias - No anesthesia”**[36], so also it will take some time to convince the regional anesthetic community of the usefulness of ultrasonography in regional anesthesia.

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