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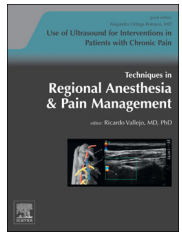

Basic considerations before injections and scanning techniques

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ABSTRACT

Portable and affordable high-resolution ultrasound (US) machines have accelerated the interest in the use of US guidance for interventional pain procedures. The advantages of ultrasonography over fluoroscopy are as follows: (1) no radiation exposure to both the patient (especially with repeated procedures) and the practitioner; (2) real-time visualization of soft tissues (nerves, muscles, tendons, and vessels); and (3) needle-tip advancement relevant to surrounding structures and local anesthetic spread. Even though the target structure is identified correctly, there is still the challenge of placing the needle tip in the optimum site. To encourage pain physicians to use US for interventional procedures, this article aims to review some basic aspects of scanning and imaging techniques.

The use of ultrasound (US) is the fastest growing area of regional anesthesia and pain medicine practice and research. In the field of interventional pain management (interventional axial, nonaxial, and musculoskeletal pain procedures), it is currently growing exponentially because of an improved and real-time high-resolution US imaging and because of its benefits such as the ability to visualize soft tissues, including muscle layers, nerves, and blood vessels, thus offering a "cross-sectional" view of anatomical structures, revealing anatomical variability; visualize real-time needle advancement; and reduce radiation exposure to both the patient and the practitioner.[1,2] In fact, "regional anesthesia always works, provided you put the right dose of the right drug in the right place."[3] US provides direct visual confirmation of needle-nerve contact and thus has many roles in pain management interventions, both peripheral and neuraxial.[4]

Regarding regional anesthesia, US provides significant advantages when performing brachial plexus block, including faster sensory block onset and greater block success.[5] Regarding lower extremity peripheral nerve blocks, US guidance provides improvements in the onset and success of sensory block, a decrease in local anesthetic requirements, and decreased time to perform them (level Ib evidence).[6]

US-assisted neuraxial techniques involve preprocedural scanning to determine midline, targeted interspace, or depth from skin to the epidural or subarachnoid spaces before performing the procedure using traditional methods. US is superior to physical examination, but inferior to radiologic imaging, for correctly identifying spinal interspace levels (IIa). US is highly accurate for predicting skin-to-epidural space depth in the cervical spine (adults) and the lumbar spine (adults and children) (Ib).[7]

The imaging tool of choice for the interventional pain community has been fluoroscopy. There can be reticence on the part of many who are comfortable with fluoroscopy and have not seen sufficient reasons to adopt US despite its potential advantages.[8] A major advantage of US over fluoroscopy or other radiographic imaging techniques is that US

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reduces radiation exposure to both the patient and the operator. Moreover, the US machine itself is more affordable and transferrable than a fluoroscopy, computed tomographic scan, or magnetic resonance imaging machine.[2] Thus, it can be used in an office setting without the need for special fluoroscopy suites.[9]

Minimizing the risk of vascular complications is critical during percutaneous injections for interventional pain management.[10,11] A major disadvantage of the US procedure for treating long-term pain is the inability to visualize intravascular injection and real-time spread of injectate in the epidural space.[1] Thereby, US enables the detection of blood vessels, whereas fluoroscopy does not. A needle positioned under traditional fluoroscopic guidance can puncture blood vessels.[12] US is an excellent tool in "visualizing" and, hence, "avoiding" vascular injury, whereas contrast fluoroscopy can only "detect" when the tip of the needle is intravascular (after the fact). Fluoroscopy may not detect that the needle has already traversed a vessel on its way to the target, whereas US can avoid this.[13] Detection of vascular penetration events with optical spectroscopy could be valuable in the context of US-guided procedures as optical reflectance spectroscopy could potentially allow for a reliable detection of intravascular needle-tip placement.[14]

The evidence base for US-guided interventional pain medicine[7] is quite limited, with most reports classified as feasibility studies; that is, cadavers or noncomparative patient models or both are used to explore the potential for US guidance to facilitate block procedures. In 2009, preliminary feasibility studies supported the use of US guidance for cervical selective nerve root block[12] and stellate ganglion block.[15]

In 2012, the American Society of Regional Anesthesia and Pain Medicine, the European Society of Regional Anaesthesia and Pain Therapy, and the Asian Australasian Federation of Pain Societies Joint Committee[16] published different levels of difficulty for the various pain procedures recognized. In July 2013, Bhatia and Brull[17] published a systematic review of chronic pain outcomes and concluded that evidence suggests that US guidance may match or improve performance- and safety-related outcomes compared with many anatomical landmark- and fluoroscopic-guided techniques; however, there are presently insufficient data to support improved efficacy for relieving chronic pain in both the short term and the long term (Table 1). US technology has a number of limitations.[17] Suboptimal resolution of US machines combined with small-sized targets (medial branches supplying lumbar facet joints) and, frequently, obesity further reduces image quality. Next, interventionalists familiar with fluoroscopy but new to US require additional training and skills: US images are different from those of fluoroscopy because US shows only those structures within the path of the beam, whereas fluoroscopy allows visualization of surrounding areas.[17] US does not illuminate contrast dye to confirm delivery of injectate and to exclude uptake by blood vessels. Unlike fluoroscopy, US does not always offer the option of visualizing multiple vertebrae in a single view. This makes correct level identification particularly difficult in patients with altered spinal anatomy due to pathology or surgery. Finally, certain spinal levels may be difficult to access with the US beam because of acoustic shadowing caused by the ilium.[17]

This article aims to review some basic aspects of scanning and imaging techniques so as to encourage pain physicians to use US for interventional procedures. Nevertheless, basic physics of US imaging has not been reviewed.

Select the probe

Sound waves constitute a mechanical longitudinal wave and can be described in terms of particle displacement or pressure changes.[18] Some of the more important quantities that are described in US imaging consist of frequency, propagation speed, pulsed US, interaction of US with tissue, angle of incidence, and attenuation. Many of the objects and artifacts seen in US images are because of the physical properties of ultrasonic beams, such as reflection, refraction, and attenuation.[18]

Selecting the appropriate frequency of the emitted US wave is perhaps the most crucial of all adjustments. US probes are named after the geometric arrangement of their piezoelectric elements distinguishing 3 types of probes:

(1) *Linear probes*: The piezoelectric elements are arranged in parallel. They can be activated singly or in groups. The resulting image is square, with good resolution in the near field but narrow depth.
(2) *Sector probes*: The sound waves are emitted from a single point and diverge fanwise. This gives good resolution and depth, but structures in the vicinity of the probe are very poorly imaged.
(3) *Convex probes*: This is a kind of compromise between a linear and a sector probe. Both the near and the deep field show good resolution. Probe categories can be divided into high-frequency (8-12 MHz), medium-frequency (6-10 MHz), and low-frequency (2-5 MHz) ranges.

Resolution refers to the US machine's ability to distinguish one object from another. Probe selection is always a trade-off between axial resolution and depth of penetration: high-frequency transducer probes (8-12 MHz) afford high axial resolution of superficial structures but have low tissue penetration.[19] High-frequency transducers are best for depths of up to 3-4 cm; thereafter, a lower-frequency probe is often necessary.[20] The convex low-frequency transducer probes (4-7 MHz) allow for deeper tissue penetration (subgluteal region and neuroaxial structures) at the expense of less axial resolution. They produce scans that are fan shaped, so larger sections of deeper tissue can be scanned compared with the linear array transducer.

When performing a peripheral nerve block, choose the probe and settings with the highest possible frequency that would still afford adequate depth penetration for imaging of the target nerve.[19] Most US probes have a "central" (optimal) frequency as well as a range of frequencies on either side of this central frequency, known as the bandwidth. After choosing the appropriate probe, the operator may then fine-tune the frequency of the US wave emitted

Table 1 – Summary of the level of difficulty and evidence in support of ultrasound guidance as a useful alternative to traditional guidance techniques for interventional pain procedures.[16,17]

	Level of difficulty	Efficacy	Safety
Peripheral structures			
Greater occipital nerve	Level I (nuchal level)	*	
	Level II (C2 level)	*	
Suprascapular nerve	Level I	*	*
Cervical sympathetic trunk	Level II		*
Lateral femoral cutaneous nerve	Level II	*	
Pudendal nerve	Level II		*
Piriformis muscle	Level I		
Celiac plexus block	Level III		
Axial structures			
Caudal epidural	Level I		
Lumbar facet intraarticular	Level II	*	
Lumbar facet joint nerves	Level II	*	
Lumbar nerve root	Level III	*	
Sacroiliac joint	Level I		
Cervical nerve root	Level II		*
Cervical facet joint nerve supply	Level III		
Cervical facet intraarticular	Level II		
Musculoskeletal structures			
Joints injection and aspiration, bursa, ligaments, intramuscular, and peritendinous injections	Level I		
Fenestration and lavage	Level II		
Scoring criteria for the level of block difficulty			
Ease of visualization of target structure	1 = Easy	2 = Intermediate	3 = Difficult
Ease of visualization of identifying structures	1 = Easy	2 = Intermediate	3 = Difficult
Technical performance of block	1 = Easy	2 = Intermediate	3 = Difficult
Risk of complications from associated structures	1 = Low	2 = Intermediate	3 = High

Blank cells indicate that there is insufficient evidence to recommend ultrasound for improving outcome for the indicated category compared with traditional comparators.[17]
The level of difficulty is appraised based on 4 criteria (listed in the table). The summation of the scores from these 4 criteria results in the summary score: level I (basic) is 4-6, level II (intermediate) is 7-9, and level III (advanced) is 10-12.[16]

from the transducer by actively selecting only the upper, middle, or lower frequencies from each transducer's bandwidth.[20]

US imaging of the neuroaxial anatomy (eg, lumbar plexus block) is challenging because of its deep anatomical location and the "acoustic shadow" of the overlying bones. Innovations in equipments and signal processing have offered significant improvements in penetration and imaging resolution, equating the resolutions of linear and convex transducers. An example of this is the low-frequency (C5-1, 5-1 MHz) curved array transducer of Philips iU22 ultrasound system (Philips Healthcare, Andover, MA) equipped with PureWave crystal technology,[21] which seems to improve imaging of deep blocks.[22]

All US probes have a landmark that appears on the US machine screen as a dot or a trademark, so the structures near the landmark can be visualized on the screen near the dot or the trademark. It is mandatory to know how our probe is orientated. If we are not able to localize the landmark on the probe, the touch of a side of the US faceplate with a finger would let us know the probe orientation with respect to the screen.

Aseptic technique for US-guided interventions

Instructions for cleaning the US equipment are usually supplied by the manufactures (in the instructions manual). Most of them recommend cleaning the probe with free alcoholic solutions because it can damage the piezoelectric crystals.

First, the operator should use a standard US gel as medium when performing the initial step of sliding the probe on the patient's skin to localize the target nerve. Once the target is located, all the gel between the probe and the patient's skin should be cleaned. An aseptic technique is now mandatory. The skin of the same location is now thoroughly cleaned and sterilized with an aseptic solution. The same standards that apply to regional peripheral nerve stimulator blocks and conventional pain management procedures should be applied to US-guided blocks.[23] This requires cleansing of the transducer with an aseptic solution. As iodine solution might affect the surface of the transducer, Bruyn and Schmidt[24] recommend the use of a 70% alcoholic solution or a chlorhexidine solution. A strict sterile technique should

be followed throughout the procedure, including the probe and the gel. The probe should be covered in a sterile manner: a sterile sheath, probe cover, or even sterile glove can be used. To avoid air trapping, generous amounts of US-transmission gel should be applied between the probe and the inside of the sheath cover. In our hospital, we either use a clear plastic adhesive dressing, such as Tegaderm (3M Health Care, St Paul, MN), with no need of gel between the probe and the adhesive, or a US probe drape pack (Vygon, Ecouen, France).

The probe faceplate must fully be in contact with the skin without any interfacing air. Between the outside of the probe cover and the patient's skin surface sterile US gel[25] should be applied or sterile dextrose 5% in water instead.[26] Asepsia should include the probe wire when a regional catheter is going to be placed. Sterile syringes and needles should be used at all times (Figure 1).

Maintain appropriate US ergonomics

First of all, the operator must be familiar with the anatomy and the orientation of the probe before starting to perform US-guided injections. The probe should be held in one hand and the needle in the other. It is difficult to divide these tasks between 2 individuals because of difficulties in coordinating movements of the probe and needle.[24] Poor ergonomics was identified by Sites et al[27] as a key error made by anesthesia residents performing US-guided nerve blocks. This was defined as an arching torso, nondominant hand holding the needle, or head turned 45° or more. Langford et al[28] demonstrated that the accuracy, but not speed, of US-guided regional anesthesia (UGRA) can be improved by aligning the monitor in the line of sight of the operator. Speer et al[29] demonstrated an improved ability of novices to guide a needle when the US probe and needle were orientated along the visual axis (Figure 2).

The sonographer should assume the most ergonomic positioning of his equipment and himself. Usually, the US machine is placed on the opposite side to where the block is to be performed. When possible, the operator should be seated, his arm should rest on the stretcher. The height of the patient's stretcher should be adjusted accordingly. All these things together help prevent operator fatigue and discomfort.[30] When holding the probe, it is often helpful to steady its position by gripping it lower down and placing the operator's fingers against the patient's skin (Table 2).[31]

Because of the complexity of this task and the potential for harm to the patient, it is recommended that initial skill acquisition should be achieved using a phantom,[32] and trainees should only progress to performing US-guided

PRACTICE TIPS:

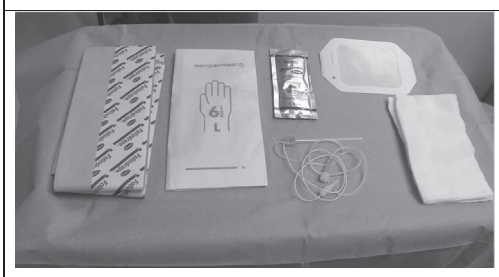
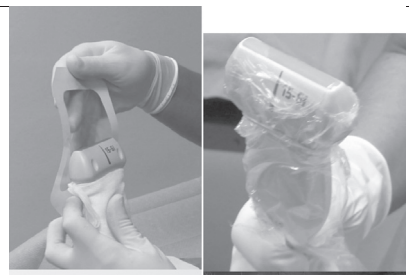
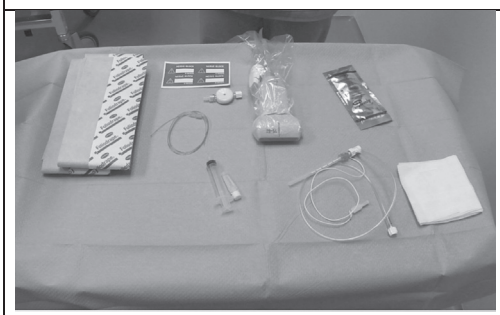
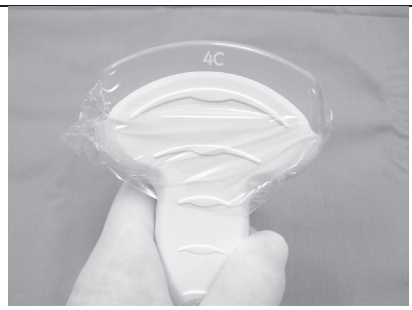
. Skin antiseptic solution, drape the site and cover the US probe with a sterile sheath. . Chlorhexidine scrub of the patient's skin surface.	. Probe cover: clear plastic adhesive dressing. . Wire cover if a catheter is going to be placed. . Generous amounts of sterile US transmission gel should be applied between the probe and the patient's skin surface.
	
	

Fig. 1 – Practice tips for an aseptic technique for ultrasound-guided interventions.

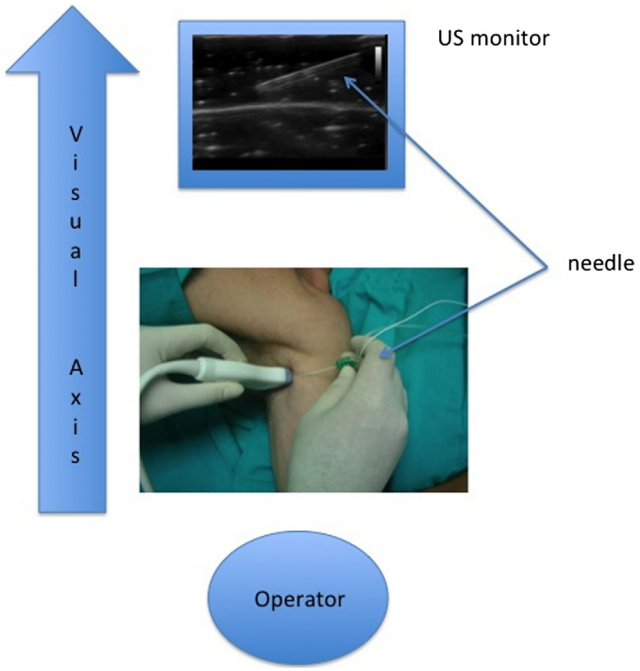


Fig. 2 – Orientation of monitor screen, operator, US probe, and needle. (Color version of figure is available online.)

nerve blocks in patients once they are competent at needle imaging and tracking. A US *phantom* is a simulation tool that mimics several properties of human tissue, including tactile texture and compressibility of human skin, in addition to the typical needle appearance and feel as it is passed under the guidance of US. Phantoms have been made from many different materials such as water balloons or water baths, gelatin or agar, or readily available materials like surgical gel pads. Others objects that can be used as a phantom include chicken, turkey, pork, sponges, and cheese. Practicing US-guided needle-tip visualization on a phantom simulator may also address some important patient safety concerns by improving needle-manipulation skills and further develop abilities with needle-tip visualization that will alleviate many of the stressors associated with practicing US-guided interventional pain medicine on patients.[33] Teaching methods that make use of cadavers or electronic models and US are not mandatory but desirable.[34]

By studying novices, Sites et al[35] successfully identified patterns of errors and quality-compromising events that when avoided should result in proficient procedures: (1) consistent needle imaging, (2) appreciation of the correct spread of local anesthesia, (3) appreciation of intramuscular needle-tip location and direct muscle stimulation, (4) reduction in unintentional probe movement (contributed to by fatigue and poor ergonomics), and (5) standardization of screen terminology for describing "sidedness" of the patient.[35]

A new US system with wireless, cable-free transducers—Siemens ACUSON Freestyle (Siemens AG, Munich, Germany) (Figure 3)—lets the practitioner work in a more ergonomic and aseptic way without cables and provides more freedom as it operates up to 3 m away.[36]

Systematic scan

Image acquisition relies on the machine capabilities and operator skill, interpretation of the resultant image requires training and experience, and performance of practical procedures needs good needle visibility and hand-eye coordination.

A good systematic scan includes a perfect management of the probe. We first place the transducer perpendicular to the target (short axis) and it should then be moved in a slow and controlled manner, using the 3 basic transducer movements (sliding, tilting, and rotating) described as "ART" by Marhofer and Chan[37] to optimize the view of the anatomical structures (Figure 4). Alignment (A) refers to the sliding movement of the transducer along the skin surface to trace the course of a nerve lengthwise. Rotation (R) refers to the clockwise and counterclockwise transducer movement that is most useful for imaging the long axis of a nerve or the block needle by aligning the target with the beam. Tilting (T) refers to the angling movement of the transducer on the skin surface that is useful for optimizing the angle of incidence (90°) and maximizing beam signal return to the transducer in most instances.

Optimization color Doppler

Doppler technology allows for the identification and quantification (velocity and direction) of blood flow. In essence, the Doppler principle states that if an US pulse is sent out and strikes moving red blood cells, the US that is reflected back to the probe will have a frequency that is different from the original emitted frequency.[19,38]

The Doppler technology is useful for distinguishing smaller nerves from vessels,[4] but the most important use for regional anesthesiologists is to confirm the absence of blood flow in anticipated trajectory of the needle to the target.[19] The sonographer should be aware that if a small blood vessel is not visible, it does not necessarily mean that the blood vessel does not exist. Failure to identify a small blood vessel may be the result of the limitation of the US resolution or the operator's limited experience.[13]

However, the assessment of blood flow has the potential for artifact generation[39] as the major concern is to falsely

Table 2 – Practice tips to maintain appropriate ultrasound ergonomics.

No arching torso.
Place the US machine on the opposite side to where the block is to be performed.
Do not turn head 45° or more.
Align the monitor in the line of sight of the operator.
Orientate the ultrasound probe and needle along the visual axis.
Take a seat and, when possible, rest your arm on the stretcher.
The height of the patient's stretcher should be adjusted accordingly.
Do not cross hands (probe and needle).
Novices should hold the needle with the dominant hand.
When holding the probe, steady its position by gripping it lower down and placing the operator's fingers against the patient's skin.

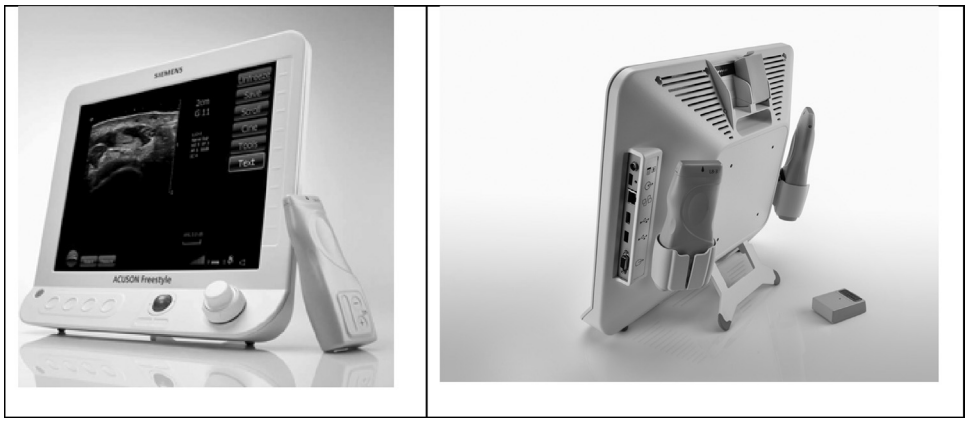


Fig. 3 – Siemens ACUSON Freestyle.

conclude that a structure is not a blood vessel when no flow is seen. Doppler technology allows for the assessment of both velocity and directionality of blood flow, but the complicating factor is that for accurate analysis, blood flow should be parallel to the US beam.[38] In most cases, the regional anesthesiologist images blood vessels on short axis, so, the blood flow is completely perpendicular to the US beam. Thus, the appearance of blood flow would be dependent of the angle of incidence (between the US beam and the blood flow). If no flow is seen, rotate the probe handle slightly cephalad to change the angle of incidence less than 90°.[39] But the appearance of blood flow will also be dependent on the scale set to evaluate velocities and the color gain settings. Low scales and higher color gain will tend to increase the sensitivity to detect flow.

Power Doppler is a newer US technology that is up to 5 times more sensitive in detecting blood flow than color Doppler and can therefore detect vessels that are difficult or impossible to see using standard color Doppler.[40] Unlike color Doppler, power Doppler is almost angle independent, thus reducing the incidence of false negatives. However, there are 2 disadvantages: it gives rise to more motion artifact with subtle movements such as respiration and it cannot resolve the direction of flow. Rather than displaying blue or red color, only a single color (usually orange) is used in a range of hues to indicate flow.[20]

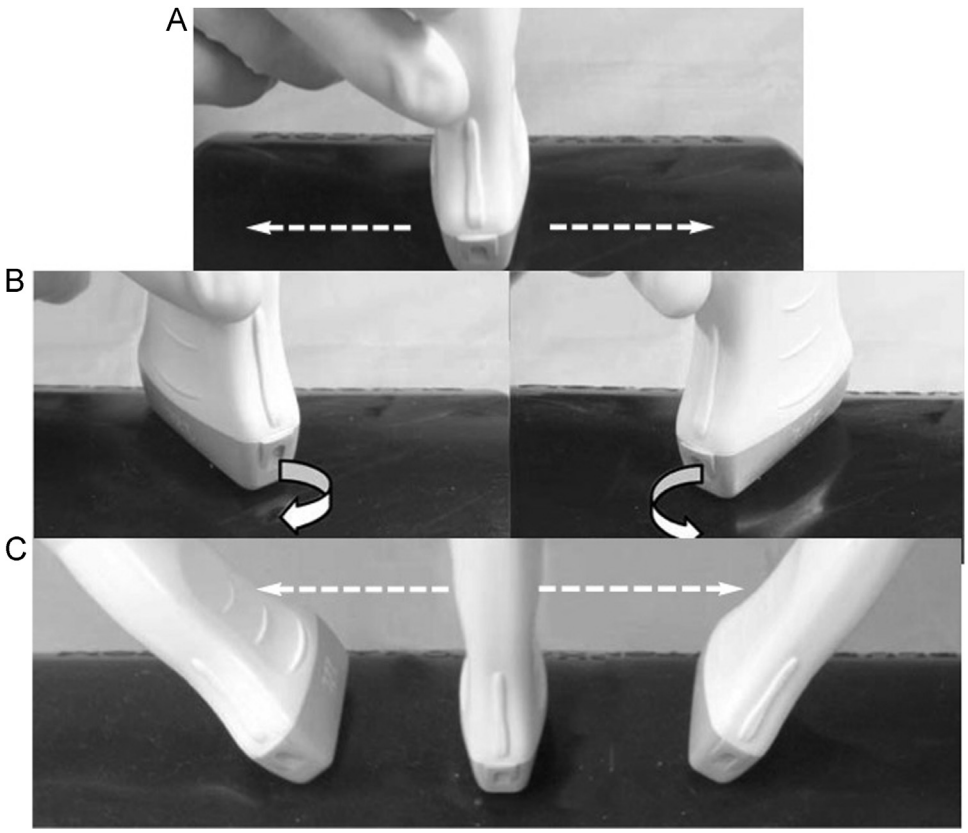


Fig. 4 – Transducer movements of sliding (A), rotating (B), and tilting (C).

Check the target

Realization of a successful regional anesthetic necessitates manual skills and theoretical knowledge.[34] Knowledge of anatomy, probe positioning, and the ability to coordinate probe and needle are necessary when injecting patients with sonographic guidance.[24,41] Anatomical artifacts are tissue structures—either normal or aberrant—that may resemble the target nerve and thus mislead the operator into pursuing the wrong target. These errors in interpretation are often referred to as "pitfall errors."[39] The common solutions to all pitfall errors are as follows: (1) trace the target nerve along its expected anatomical course and (2) use a peripheral nerve stimulator as an adjunct to confirm the target's identity.[39]

There are some limitations of the physics that will cause difficultly in carrying out US-guided blocks. Image resolution and quality vary inversely with depth of penetration. It cannot see through bones or air, so anatomical structures deep in the bones (eg, neuroaxial structures and intercostal nerves) are often shadowed by the bone, and imaging accessibility will be highly restricted. It is also challenging to image smaller nerves (<1 cm) in deep locations, but visualization of small superficial nerves (eg, occipital and ilioinguinal and iliohypogastric nerves) is possible.[37] Only what is within a narrow beam can be seen (we cannot see the big picture or around corners); structures and local anesthetic spread can only be displayed as a 2-dimensional (2D) image.[42] If one cannot visualize the spread of the injectate in the epidural space under ultrasonography or rule out intravascular injection (contrary to the commonly used fluoroscopy in pain medicine practice), then it is a "partially blind technique" until we have better US technology.[43]

When performing a regional block, choose the probe[19] and focus the US beam on the structure of interest. The focal zone of the US beam indicated on most screen displays represents the narrowest part of the beam and should be positioned at the exact level of the target nerve.[19] Nerves or targeting structure must be imaged in short axis (transverse) or long axis (longitudinal). US-guided blocks are generally performed with short-axis views of nerves for several reasons: identification of peripheral nerves (>1 cm) is relatively easy, there is good resolution of the fascial barriers that surround nerves, dynamic assessment and verification of circumferential distribution of local anesthetic with injection is possible, and, finally, if the transducer moves slightly, the image is still workable (an oblique view of the nerve).[4]

There are 2 approaches to guidance: direct and indirect.[24] The indirect method uses skin markings, for which the US is used to locate the area to be injected, the skin is marked and the depth of field is measured. Injection is done using the markings for guidance, and there is no direct visualization. The second method is the direct one, in which US is used to locate the target and guide the needle. The needle guidance and injection are then done using direct real-time sonographic visualization to ensure accurate placement.[24]

Regarding the direct approach, there are 2 techniques: the out-of-plane (OOP) and the in-plane (IP) techniques (Figures 5 and 6).

The OOP technique involves inserting the needle so that it crosses the plane of imaging near the target. The target is typically centered within the field of view and the depth noted. If the needle tip is not visualized, the end point for injection is not so clear and may require more dependence on small-volume test injections for visualization of adequate local anesthetic distribution. The OOP technique can be made similar to the IP technique with sliding and tilting of the transducer so as to follow the needle tip. Tsui and Dillane[44] described a "walk-down" technique to aid OOP needle-tip visualization. It consists of inserting the needle at a distance from the transducer equivalent to the depth of the target, such that the tip will eventually intersect the US beam and target at a trajectory angle of approximately 45°. However, the initial insertion angle should be shallow so as to facilitate detection of the needle tip. The needle is then incrementally angled, with the tip visualized at progressively greater depths until the target is reached. Potential disadvantages of this technique include the need for multiple needle passes and a long needle track to reach deeper targets, both of which may increase patient discomfort. Chin et al[31] recommend inserting the needle close to the transducer (within 1 cm), irrespective of target depth, and at a steeper (approximately 75°) angle to the skin. The operator should appreciate the limitations of the OOP technique; primarily, the inability to confirm the real-time exact location of the needle tip.[39]

In the IP approach, the needle is inserted along its long axis, parallel to the ultrasonic beam to visualize the entire shaft and tip, parallel to the US beam. The imaged needle path should be maximized by placing the target on the side of the imaging field of view, away from the approaching needle. The needle should appear on the side of the US image where it is localized anatomically, for example, if it is introduced from the right side of the probe it should appear on the right side of the screen. Most right-handed sonographers would have the US probe in their left hand (nondominant) and the needle in their right hand. Therefore, they would prefer an approach where the needle comes from the right side.[24] So, the needle is inserted from the posterolateral side of the probe, and the needle in advanced in a medial and anterior direction. Entering the skin with the needle close to the transducer disturbs the surface contact and forces steep angles to the target. The transducer can be manipulated as necessary to bring the needle into the plane of imaging. If the needle tip is not clearly identified within the plane of imaging, do not advance the needle.[4] Chin and Chan[45] consider neurostimulation to be a useful tool in conjunction with US, especially for confirming nerve identity.

This IP approach is considered to be a safer approach because it continuously monitors needle-tip progression. However, recent studies demonstrated that the IP approach induced a false sense of security because continuous visualization of the needle tip is complex and not always traced by US.[35,46,47]

If the needle tip becomes poorly visible at any time, it should not be advanced further. Needle advancement or local anesthetic injection without adequate needle-tip visualization, or both, may result in unintentional vascular, neural, or visceral injury.[31] The first step to troubleshooting a "disappearing" needle is to visually inspect the needle and transducer position and exclude gross misalignment. The

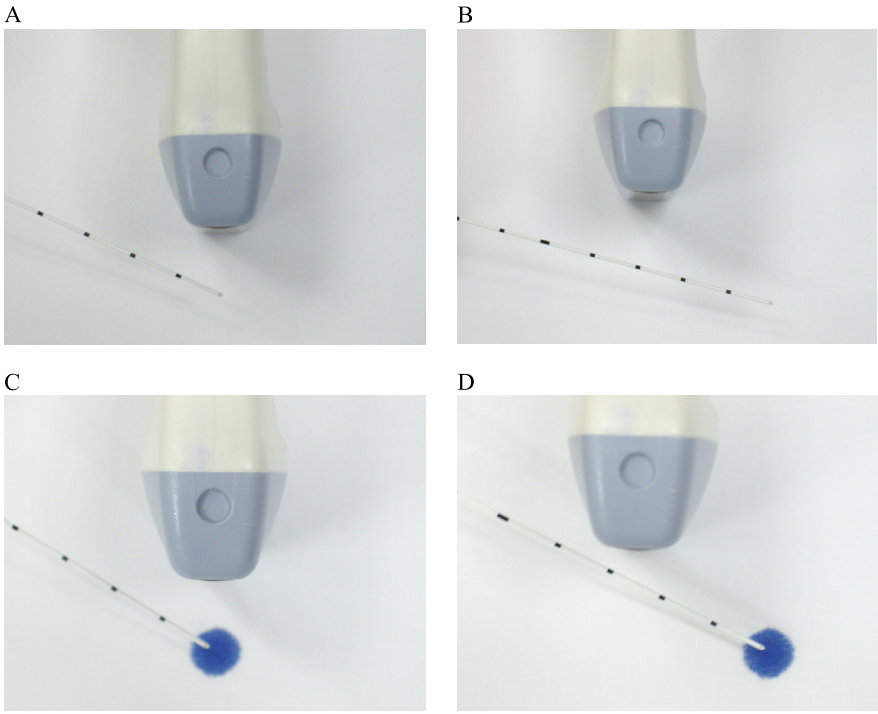


Fig. 5 – The out-of-plane (OOP) technique. (A) Correct position of the tip in the OOP technique. (B) Incorrect position of the tip. (C) Confirmation of the needle tip by injecting a small-volume test injection. (D) If the needle tip is not visualized, the end point for the injection cannot be observed. (Color version of figure is available online.)

transducer should then be moved in a slow and controlled manner, using the 3 basic movements (sliding, tilting, and rotating), until the needle shaft and tip have been brought back into view. Chin et al[31] do not recommend moving the transducer and needle at the same time when trying to align them as this makes the task more difficult and increases the risk of unintentional needle trauma.

Therefore, the IP approach requires modifications of the standard practice of regional anesthesia and pain management (neurostimulation-skilled and prescription-skilled physicians), including different sites of puncture, needle direction, and sensations, during needle progression. Conversely, the OOP approach allows pain physicians to maintain their usual clinical approaches.

Optimal needle visibility or "echogenicity" is important for precise US guidance.[23] Schafhalter-Zoppoth et al[48] identified and quantified a number of needle- and US-specific factors that alter needle visibility. Based on their study, the largest needle size reasonably possible, inserted using a medium-sized guide wire located in its shaft, provided the best US visibility. In addition to optimal echogenicity, the needle tip should be sharp enough for easy skin insertion while still blunt enough for the perception of subtle differences in resistance of anatomical structures as they are encountered. Simultaneous nerve stimulation capability can, in cases of difficult visibility (as with low-frequency curved probes), prove beneficial as well.[48]

Besides the gauge, the insertion angle of the needle is the main factor that determines needle visibility.[4,48] Needle-tip visibility is inherently reduced at steep angles.[4] To have a clear picture of the needle, it is preferable to introduce it 1-2 in away from the probe to avoid a steep introductory angle. The role of an acoustic background is substantial: the needle tip is best visualized within dark (anechoic) vessels or local anesthetic. A dark background, which can be created by low receiver gain, can improve needle-tip visibility.[4] Commercial modifications (coating or dimpling) improve echogenicity of regional block needles.

Some of the 2D US units and machines with 3D capabilities permit combining images in different planes (in "real time") on the same US screen. This allows the practitioner to observe both anatomical structures and the needle in 2 or more planes simultaneously. A biplane transducer is used for 2D US and 3D US probes to produce multiplane images. Both biplane and multiplane imaging techniques may have great potential for improving needle visualization and US-guided interventional procedures, but as the technology is still relatively new, its utility is yet to be established.[49]

Follow the tip

The needle has to be handled between the index finger and the thumb (as one would hold a pencil).[35] The bevel-up position provides improved visualization of the needle tip because the US beam is maximally reflected in this position.[49]

The most commonly performed error by the novice is advancement of the needle when the tip is not visualized.[35] As part of a qualitative analysis, Sites et al[35] identified 5 patterns of behavior: (1) recognizing misdistribution of the local anesthesia, (2) recognizing intramuscular location of the needle tip before injection, (3) prevention of operator fatigue, (4) correct correlation

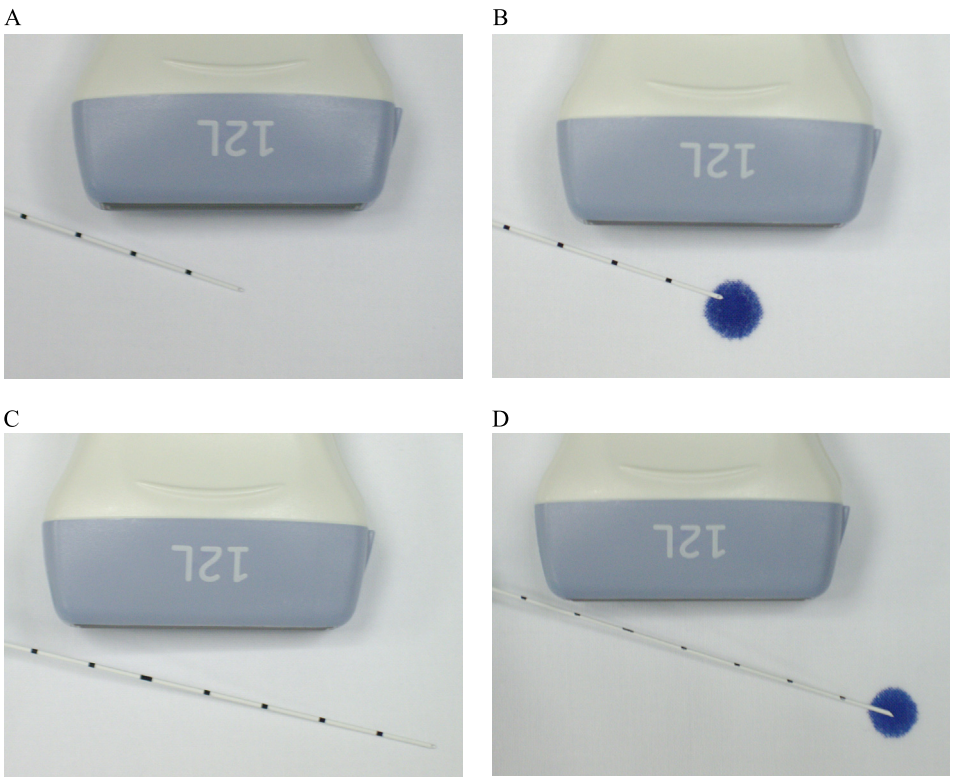


Fig. 6 – The in-plane (IP) technique. (A) The needle is inserted parallel to the US beam. (B) A small-volume test injection is injected to confirm correct localization of the tip. (C) The needle is inserted parallel to the US beam, but the tip is not visualized on the screen. (D) A small-volume test injection is injected, and it does not confirm correct localization of the tip. (Color version of figure is available online.)

of sidedness of the patient with the sidedness of the US image, and (5) successful choice of needle insertion site and angle with respect to the probe, allowing accurate needle visualization.

Little and rapid movements of the needle can help us to identify the tip location. Another technique is hydrolocalization (Hloc). Bloc et al[50] developed the Hloc technique during the OOP approach so as to increase the accuracy of needle-tip position detection. The Hloc technique consists of repetitive injections of a small volume of fluid given before any progression of the needle tip toward the targeted nervous structures.[50]

Another technique to visualize the needle tip is to inject small amounts of air (0.3-0.5 mL) into the tissue through a needle, which can be used to identify the location of the tip.[51] Although bubbles are easy to identify sonographically and can serve as a useful marker of the needle tip, bubbles also can disperse in the tissue and cause acoustic shadowing distally, becoming problematic. Therefore, all air bubbles are removed from the local anesthetic solution before injection.

One of the most important advantages of US imaging is the ability to reposition the needle after initial injection of local anesthetic. Test injections to visualize local anesthetic distribution should have a small volume (1-2 mL). If the local anesthetic distribution is not seen on the monitoring screen immediately stop, aspirate, and move the transducer or needle (do not continue to inject because inadvertent intravascular injection is one of the possibilities). If the local anesthetic distribution does not adequately surround the nerves, the block needle can be repositioned, and the process of test injections can be continued.[4]

Technical improvements in regional block needles involve modification of the echogenicity of the needle and tip. The "holy grail" of UGRA is the development of a needle that can be seen at all depths and at all angles. Coating (texturing) the needle, improving bevel design, and dimpling of the needle have all been shown to increase its reflectivity and improve visibility.[52] Other improvements involve US machines specifications, such as SonoMBe Advanced Needle Visualization[53] option (SonoSite, Inc, Bothell, WA) that make the needle especially visible during steep-angled procedures.

Electromagnetic tracking is a method permitting a needle spatial acquisition in real time. It can facilitate needle-beam alignment for IP approaches and indicates where the needle crosses the beam during OOP US-guided procedures. More detailed anatomical information and better spatial orientation can be provided by 3D US imaging than by 2D imaging; hence, it can provide help for catheter and local anesthetic spread information. Additionally, 4D US imaging enhances the visualization of a particular anatomy and offers real-time assessment of local anesthetic spread during UGRA.[54]

Monitor the pattern of injectate spread

Another important advantage of US imaging is the ability to monitor the pattern of injectate spread with real-time

visualization. As the needle tip is sometimes difficult to visualize (eg, deep target structures and small nerves), we have to first inject some amounts of solution (saline solution) to check the target and then inject the local anesthetic and decide if its distribution is correct and optimal. Some blocks are made on fascial planes and the needle tip is directed under the prevertebral fascia, superficial to the longus colli (for stellate ganglion block), in the "transversus abdominis plane" (ilioinguinal and iliohypogastric nerves), and into the internal intercostal muscle (intercostal block). As Doppler technology allows for the identification and quantification (velocity and direction) of flow, it is useful for monitoring the injection in real time. After injection, the local anesthetic distribution can be assessed by sliding the transducer along the nerve path with the nerve viewed in short axis.[4] We can also assess for symptomatic relief of symptoms and pain.

Conclusions

The American Society of Regional Anesthesia and Pain Medicine, the European Society of Regional Anaesthesia and Pain Therapy, and the Asian Australasian Federation of Pain Societies Joint Committee[16] identified the following tasks as helpful in performing an US-guided pain block. These tasks are not necessarily sequential and may not be appropriate for all block scenarios.

(1) Maintain an aseptic technique, including transducer sterility, throughout the procedure.
(2) Perform a systematic scan that allows for the confirmation of normal anatomy and recognition of structural pathologies and anatomical variations.
(3) Visualize key landmark structures, including nerves, blood vessels, pleura, muscles, tendons, fascia, and bone. Use the Doppler functions to identify vascular structures.
(4) Identify the target on short-axis imaging (preferred) or long-axis imaging (if applicable).
(5) Plan for a safe needle approach that avoids unnecessary tissue trauma or injury to other surrounding structures.
(6) Follow the tip of the needle under real-time visualization as it advances toward the target.
(7) Consider injecting an initial small volume of a test solution. If the solution is not visualized during injection, presume that the needle tip is either intravascular or out of the imaging plane.
(8) Monitor the spread of the injectate under real-time visualization and make necessary needle adjustments if an undesired pattern of injectate spread is visualized. The visualization of the injectate should be monitored throughout the injection to avoid intravascular injection and to limit spread to nontargeted adjacent structures.
(9) When performing musculoskeletal procedures, avoid intratendinous corticosteroid injections and needle damage to articular cartilage.
(10) Maintain traditional safety guidelines, including the presence of standard monitoring and resuscitation equipment.
(11) When applicable, consider a secondary confirmation technique, such as fluoroscopy.
(12) Maintain appropriate US ergonomics.
(13) Maintain appropriate documentation and image storage with an archival system.

References

1. Narouze S, Peng PW. Ultrasound-guided interventional procedures in pain medicine: a review of anatomy, sonoanatomy, and procedures. Part II: axial structures. *Reg Anesth Pain Med*. 2010;35(4):386–396.
2. Narouze SN. Ultrasound-guided interventional procedures in pain management: evidence-based medicine. *Reg Anesth Pain Med*. 2010;35(2 Suppl):S55–S58.
3. Denny NM, Harrop-Griffiths W. Location, location, location! Ultrasound imaging in regional anaesthesia. *Br J Anaesth*. 2005;94(1):1–3.
4. Gray AT. Ultrasound-guided regional anesthesia: current state of the art. *Anesthesiology*. 2006;104(2):368–373.
5. McCartney CJ, Lin L, Shastri U. Evidence basis for the use of ultrasound for upper-extremity blocks. *Reg Anesth Pain Med*. 2010;35(2 Suppl):S10–S15.
6. Salinas FV. Ultrasound and review of evidence for lower extremity peripheral nerve blocks. *Reg Anesth Pain Med*. 2010;35(2 Suppl):S16–S25.
7. Neal JM, Brull R, Chan VW, et al. The ASRA evidence-based medicine assessment of ultrasound-guided regional anesthesia and pain medicine: executive summary. *Reg Anesth Pain Med*. 2010;35(2 Suppl):S1–S9.
8. Huntoon MA. Ultrasound in pain medicine. Advanced weaponry or just a fad? *Reg Anesth Pain Med*. 2009;34(5):387–388.
9. Narouze SN. Ultrasound-guided cervical spine injections. Time to put "outcome" before "income". *Reg Anesth Pain Med*. 2013;38(3):173–174.
10. Nahm FS, Lee CJ, Lee SH, et al. Risk of intravascular injection in transforaminal epidural injections. *Anaesthesia*. 2010;65(9):917–921.
11. Kim do W, Han KR, Kim C, Chae YJ, et al. Intravascular flow patterns in transforaminal epidural injections: a comparative study of the cervical and lumbar vertebral segments. *Anesth Analg*. 2009;109(1):233–239.
12. Narouze SN, Vydyanathan A, Kapural L, Sessler DI, Mekhail N, et al. Ultrasound-guided cervical selective nerve root block: a fluoroscopy-controlled feasibility study. *Reg Anesth Pain Med*. 2009;34(4):343–348.
13. Narouze SN. Ultrasound-guided cervical spine injections: ultrasound "prevents" whereas contrast fluoroscopy "detects" intravascular injections. *Reg Anesth Pain Med*. 2012;37(2):127–130.
14. Balthasar A, Desjardins AE, van der Voort M, et al. Optical detection of vascular penetration during nerve blocks: an in vivo human study. *Reg Anesth Pain Med*. 2012;37(1):3–7.
15. Gofeld M, Bhatia A, Abbas S, Ganapathy S, Johnson M, et al. Development and validation of a new technique for ultrasound-guided stellate ganglion block. *Reg Anesth Pain Med*. 2009;34(5):475–479.
16. Narouze SN, Provenzano D, Peng P, et al. The American Society of Regional Anesthesia and Pain Medicine, the European Society of Regional Anaesthesia and Pain Therapy, and the Asian Australasian Federation of Pain Societies Joint Committee recommendations for education and training in ultrasound-guided interventional pain procedures. *Reg Anesth Pain Med*. 2012;37(6):657–664.
17. Bhatia A, Brull R. Review article: is ultrasound guidance advantageous for interventional pain management? A systematic review of chronic pain outcomes. *Anesth Analg*. 2013;117(1):236–251.
18. Aldrich JE. Basic physics of ultrasound imaging. *Crit Care Med*. 2007;35(5 Suppl):S131–S137.

19. Sites BD, Brull R, Chan VW, 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(5):412–418.
20. Macfarlane AJ, Tse CC, Brull R. Essential knobology for ultrasound-guided regional anesthesia and interventional pain management. In: Narouze SN, ed. *Atlas of Ultrasound-Guided Procedures in Interventional Pain Management*. New York, NY: Springer; 2011:21–33.
21. Philips iU22 ultrasound system (Philips Healthcare) and PureWave crystal technology. ⟨http://www.healthcare.philips.com/main/products/ultrasound/systems/iu22/index.wpd⟩ ⟨http://www.healthcare.philips.com/pwc_hc/main/shared/Assets/Documents/Ultrasound/Solutions/technologies/Philips_PureWave_crystal_technology.pdf⟩.
22. Karmakar MK, Li JW, Kwok WH, Soh E, Hadzic A, et al. Sonoanatomy relevant for lumbar plexus block in volunteers correlated with cross-sectional anatomic and magnetic resonance images. *Reg Anesth Pain Med*. 2013;38(5):391–397.
23. Popovic J, Morimoto M, Wambold D, Blanck TJ, Rosenberg AD, et al. Current practice of ultrasound-assisted regional anesthesia. *Pain Pract*. 2006;6(2):127–134.
24. Bruyn GA, Schmidt WA. How to perform ultrasound-guided injections. *Best Pract Res Clin Rheumatol*. 2009;23(2):269–279.
25. Provenzano DA, Liebert MA, Steen B, Lovetro D, Somers DL, et al. Investigation of current infection-control practices for ultrasound coupling gel: a survey, microbiological analysis, and examination of practice patterns. *Reg Anesth Pain Med*. 2013;38(5):415–424.
26. Tsui BC. Dextrose 5% in water as an alternative medium to gel for performing ultrasound-guided peripheral nerve blocks. *Reg Anesth Pain Med*. 2009;34(5):525–527.
27. Sites BD, Gallagher JD, Cravero J, Lundberg J, Blike G, et al. The learning curve associated with a simulated ultrasound-guided interventional task by inexperienced anesthesia residents. *Reg Anesth Pain Med*. 2004;29(6):544–548.
28. Langford RA, Hockey B, Leslie K. Monitor position and the accuracy and speed of ultrasound-guided nerve blocks. *Anaesthesia*. 2009;64(8):845–849.
29. Speer M, McLennan N, Nixon C. Novice learner in-plane ultrasound imaging: which visualization technique? *Reg Anesth Pain Med*. 2013;38(4):350–352.
30. Mulchandani H, Awad IT, McCartney CJ. Ultrasound-guided nerve blocks of the lower limb. In: Narouze SN, ed, *Atlas of Ultrasound-Guided Procedures in Interventional Pain Management*. New York, NY: Springer; 2011:239–258.
31. Chin KJ, Perlas A, Chan VW, Brull R, et al. Needle visualization in ultrasound-guided regional anesthesia: challenges and solutions. *Reg Anesth Pain Med*. 2008;33(6):532–544.
32. Niazi AU, Haldipur N, Prasad AG, Chan VW, et al. Ultrasound-guided regional anesthesia performance in the early learning period: effect of simulation training. *Reg Anesth Pain Med*. 2012;37(1):51–54.
33. Pollard BA. New model for learning ultrasound-guided needle to target localization. *Reg Anesth Pain Med*. 2008;33(4):360–362.
34. Bröking K, Waurick R. How to teach regional anesthesia. *Curr Opin Anaesthesiol*. 2006;19(5):526–530.
35. Sites BD, Spence BC, Gallagher JD, Wiley CW, Bertrand ML, Blike GT, et al. Characterizing novice behavior associated with learning ultrasound-guided peripheral regional anesthesia. *Reg Anesth Pain Med*. 2007;32(2):107–115.
36. Siemens Acuson Freestyle™. ⟨http://cardiogenicsltd.com/system/files/203/original/freestyle-datasheet.pdf?1378567573⟩.
37. Marhofer P, Chan VW. Ultrasound-guided regional anesthesia: current concepts and future trends. *Anesth Analg*. 2007; 104(5):1265–1269.
38. Beaulieu Y, Marik PE. Bedside ultrasonography in the ICU: part 2. *Chest*. 2005;128:1766–1781.
39. Sites BD, Brull R, Chan VW, 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*. 2010;35:S81–S92.
40. Morillas P, Ortega-Romero A, de Diego P, Del-Olmo C, Rouco R, et al. Power Doppler sonography: clinical applications in regional anaesthesia. *Reg Anesth Pain Med*. 2007;32:103 [abstract].
41. Marhofer P, Harrop-Griffiths W, Kettner SC, Kirchmair L, et al. Fifteen years of ultrasound guidance in regional anaesthesia: part 1. *Br J Anaesth*. 2010;104(5):538–546.
42. Warman P, Nicholls B. Ultrasound-guided nerve blocks: efficacy and safety. *Best Pract Res Clin Anaesthesiol*. 2009;23(2):313–326.
43. Narouze S. Ultrasonography in pain medicine: a welcomed addition to fluoroscopy and other imaging techniques. *Tech Reg Anesth Pain Manag*. 2009;13(3):109.
44. Tsui BC, Dillane D. Needle puncture site and a "walkdown" approach for short-axis alignment during ultrasound-guided blocks. *Reg Anesth Pain Med*. 2006;31(6):586–587.
45. Chin KJ, Chan V. Ultrasound-guided peripheral nerve blockade. *Curr Opin Anaesthesiol*. 2008;21(5):624–631.
46. Maecken T, Zenz M, Grau T. Ultrasound characteristics of needles for regional anesthesia. *Reg Anesth Pain Med*. 2007;32(5): 440–447.
47. Chapman GA, Johnson D, Bodenham AR. Visualisation of needle position using ultrasonography. *Anaesthesia*. 2006;61(2): 148–158.
48. Schafhalter-Zoppoth I, McCulloch CE, Gray AT. Ultrasound visibility of needles used for regional nerve block: an in vitro study. *Reg Anesth Pain Med*. 2004;29(5):480–488.
49. Souzdalnitski D, Lerman I, Halaszynski TM. How to improve needle visibility. In: Narouze SN, ed. *Atlas of Ultrasound-Guided Procedures in Interventional Pain Management*. New York, NY: Springer; 2011:35–75.
50. Bloc S, Ecoffey C, Dhonneur G. Controlling needle tip progression during ultrasound-guided regional anesthesia using the hydrolocalization technique. *Reg Anesth Pain Med*. 2008;33(4): 382–383.
51. Lee TG, Knochel JQ. Air as an ultrasound contrast marker for accurate determination of needle placement: tumor biopsy localization and other applications. *Radiology*. 1982;143(3): 787–788.
52. Dream RK, Kluger R, Barrington MJ, McCutcheon CA, et al. Investigation of new echogenic needle for use with ultrasound peripheral nerve blocks. *Anaesth Intensive Care*. 2007;35(4):582–586.
53. SonoMBe™ Advanced Needle Visualization option (Sonosite Inc). ⟨http://www.sonosite.com/needleguide http://www.alternativeangles.org.uk/cms/uploads/docs/ANV%20Quick%20Guide%20v2.pdf⟩.
54. Choquet O, Abbal B, Capdevila X. The new technological trends in ultrasound-guided regional anesthesia. *Curr Opin Anaesthesiol*. 2013;26(5):605–612.