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Peripheral nerve block guided by ultrasound

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SUMMARY

During the last years, technological advances have allow us to apply new imaging techniques to perform peripheral nerve blockade with the aim of improving anesthetic quality, as well as patients' security. Therefore, during the 50s these techniques joined ultrasonography (diagnostic sonography) in order to perform peripheral nerve blockade. but this fact has several implications because there are three well-defined existing levels of learning, as follows: the need to know and learn the basis of ultrasonography (sonoanatomy); to get adapted to the modifications in the approaches that we usually take, because the transducers produces a modification in them. And probably the most important task in this learning is to be able to identify the nerve or the plexus through an image in real time. This article is a guideline to get oriented in ultrasound management and the performing of different nerve blockades which are of main interest for anesthesiologists.

Key words: Local anesthesia, peripheral nerve blockade, ultrasound.

RESUMEN

En los últimos años los avances tecnológicos han permitido aplicar nuevas técnicas de imagen a la realización de bloqueos de nervios periféricos en un afán de mejorar la calidad anestésica, así como la seguridad del paciente. Por lo tanto en los años 50 se incorporó la ultrasonografía para la realización de bloqueo de nervios periféricos, pero esto tiene implicaciones varias debido a que existen tres niveles bien definidos de aprendizaje como son: La necesidad de conocer y aprender las bases de la ultrasonografía (sonoanatomía), adaptarnos a las modificaciones de los abordajes que normalmente utilizamos debido a que el transductor produce una modificación de los mismos, y probablemente la tarea más importante en este aprendizaje es el poder identificar el nervio o plexo en una imagen en tiempo real. Este artículo es una guía para orientar en el manejo del ultrasonido y la realización de los distintos bloqueos nerviosos de mayor interés para los anestesiólogos.

Palabras clave: *Anestesia regional, bloqueo de nervios periféricos, ultrasonido.*

INTRODUCTION

It is 100 years ago that Hirschel performed the first percutaneous block of a peripheral nerve[1]; during the next 60 years the regional anesthesia was a true art form. It was necessary to have a complete knowledge of anatomy and pharmacology of local anesthetics. While these two basic sciences remain essential to ensure the role of the block and patient safety, the art of conducting a block has gradually been reconceptualised by science. The key to success was dependent on the shrewdness to perform the proper placement of the needle into the nerve and the injection of local anesthetic. The popular mystique of regional anesthesia was described by the pioneers 30 years ago, until the peripheral nerve stimulator was introduced to assist locating and identifying the peripheral nerves by Ballard Wright[2]. When this technology appeared there were no needles of specific design (isolated); in addition, high levels of current were needed to produce a motor response (3 to 5 mA). Motor stimulation was not very specific and the needle tip to the proximity of the nerve could be quite distant and the unsuccessful block was common. Current techniques of nerve localization on marked surfaces estimate the location of the target structures. However, after inserting the needle, the search for a nerves remains “blind” maneuver, so the location can be frustrating and waste of time. Often there were unsuccessful bocks as a result of the inaccuracy of the needle placement, and sometimes, in inexperienced hands, the error rate could be as high as 10-15%[3]. “Blind” techniques can also cause complications, patient discomfort and extended time of the procedure.

Although uncommon, nerve damage caused by the needle, directly or indirectly can cause serious complications such as neurological damage, spinal cord injury (in the case of interscalenic approach), pneumothorax (supraclavicular approach), vascular puncture, and systemic toxic reactions of local anesthetics[4]. Another type of complication is the trial and error approach for the location of the nerve which often requires multiple attempts to puncture, leading to patient anxiety. The first step in developing ultrasonography in regional anesthesia occurred in 1978 when La Grande[5] et al. reported the use of Doppler to aid in the location and identification of the subclavian vein and artery before placement of the supraclavicular plexus block via brachial. They achieved a success of 98% in identifying the artery in 61 patients. Subsequently, Abramowitz and Cohen[6] used the Doppler to locate the axillary artery, which facilitated the placement of the axillary block in patients in whom artery was not palpable. This step of the technology is not yet in common use in many hospital centers. In subsequent years there was a growing interest in the development of guided imaging such as magnetic resonance[7] and computed tomography[8] which gave excellent anatomical approaches of the brachial plexus but have the disadvantage of being very expensive and inaccessible to the operating room. The fluoroscope[9] is another option, but it is limited to the visualization of bone references and spread of the contrast medium near the neurovascular bundle within the plexus sheath. However, the study that changed the regional anesthesia from art to science was published in 1989 by Ting & Sivagnanratnam[10] who used ultrasound to facilitate placement of a catheter into the axillary sheath in 10 patients and confirmed the spread of the local anesthetic (LA). They achieved 100% success using this technique. Their pioneering work was followed by other prospective works in which ultrasound was used to guide the placement of a catheter within the brachial plexus sheath and confirm the spread of LA[11]. They achieved brachial anesthesia with a success rate of 95% using both the axillary and supraclavicular route, they did not have any complication in all patients studied[12]. However, the total population of the studies so far involves little more than 500 patients.

BASIC ULTRASONOGRAPHY

Equipment and Transducer

The image quality of ultrasound depends mainly on two factors: the capacity of the ultrasound equipment and frequency of the transducer. The composite view provides quality image and resolution by combining echoic signal obtained from some lines of crystal to form a much clearer and sharper image. The obtained image is the result of some post-processed images of adjacent planes. These high quality images are not obtained with previous single crystal transducers. Early studies used low-frequency transducers in the range from 3.5 to 5.0 megahertz (MHz), these transducers allowed a good penetration into the tissue (5 cm or more) and the visualization of the arteries and veins. However, visualization of neural structures was not complete. In recent years, 10-15 MHz linear and high frequency transducers have enabled a clear image of the neural structures and they identify individual fascicles within the nerve sheath. Unfortunately, these transducers have a lower power of penetration (2 to 3 cm) (Figure 1). Fortunately, most of the nerves to be blocked are located with only 3 cm of tissue penetration or less. Other additional features of the current ultrasound scanners is that have a calorimetric flow Doppler unit which allows to differentiate vascular and nerve structures, and even they have a video and filming equipment. With almost all transducers one must be able to identify most of the nerves in a transverse cutting as a central structure - hypoechoic oval (gray) with a thin hyperechoic ring

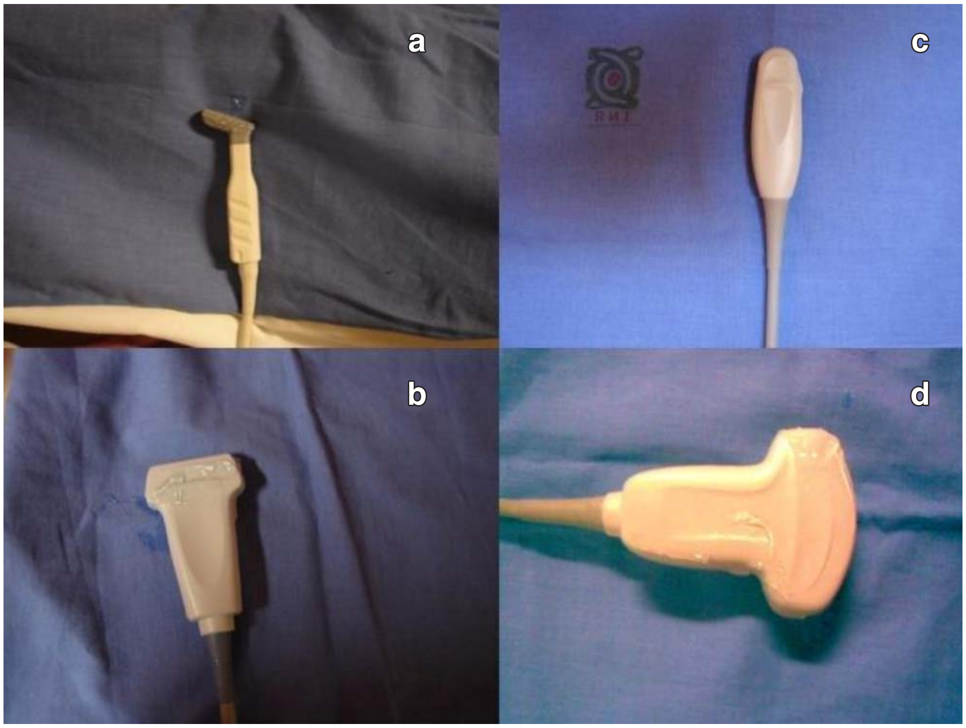

Figure 1. Transducers. **a**: In «hockey stick», **b**: Linear of 38 mm, 13-6 MHz, **c:** Curved of 11 mm, 8-5 MHz, **d**: Curved of 38 mm, 10-MHz.

(white), the ring corresponds to epineurium. In large nerves, central structure may appear as a honeycomb in which the hypoechoic fascicles are surrounded by hyperechoic connective tissue (Figure 2). The arteries are easily distinguished from the veins due to its pulsating in nature and do not collapse under gentle pressure from the transducer on the skin, while the veins do it. If there is any doubt, the use of Doppler could quickly clarify whether the structure in question is an artery or vein (Figure 3). It is recommended that all people using this technology for the first time get help from an ultrasound technician or radiologist with expertise in this area to assist in the early blocks. With this help, one could dominate ultrasound equipment in only 3 or 4 h. At the start, only the transverse plane is used to facilitate placement of the block in the first 25 or 30 ultrasound-guided blocks[(13)].

The longitudinal axis of the transducer is oriented in the transverse plane, crossing the longitudinal axis of the nerve, artery or vein. The structures in question can be observed in a transverse cutting and appeared as described above. Although some of the early blocks could be placed in neural structures by first intention, in other cases the nerves are accompanied by a pulsating artery, which would allow that once clearly identified the heartbeat of the artery; then the adjacent nerve can be located. This allows us to perform initially the following blocks: axillary, femoral, interscalenic, and popliteal fossa. As one gains more

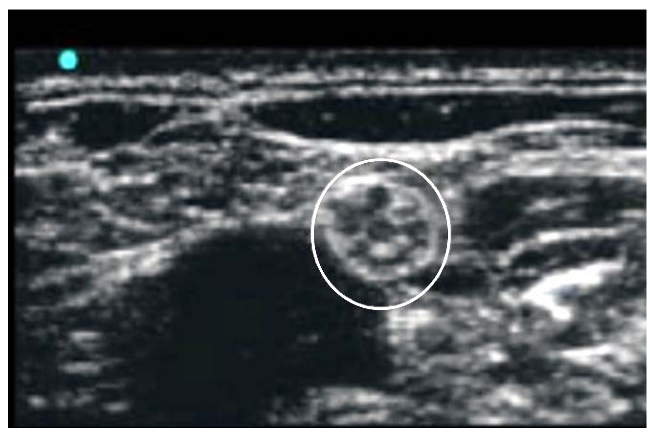

Figure 2. Nervous structure where there are the aces hyperechoic, surrounded by hypoechoic connective tissue.

skill in identifying structures and placing guided blocks, it is possible to make blocks requiring alternative views. In the longitudinal view, the transducer axis is orientated along or parallel to the axis of the nerve, artery or vein. The best blocks performed in the longitudinal axis are central (spinal, epidural, and caudal) neuroaxial blocks and perhaps the sciatic nerve block in a thin limb. Higher or 10-MHz frequency transducers distinguish nerves from tendons based on echotexture. Until 2003 there was still a

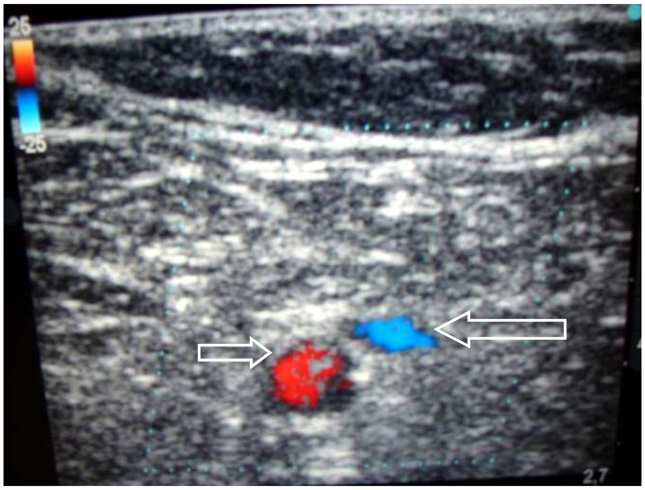

Figure 3. Using color Doppler to identify the vessel, short arrow artery, long arrow vein.

standard layout of the image planes for regional block. The term “short axis” has been used to describe the (cross-sectional) transverse plane image because it is an reference plane image in the esophageal echocardiography[14]. The use of this view has some advantages for the regional block. First, the blocks are relatively easy to identify in the short axis (honeycomb appearance). Second, most stable images are obtained with regard to the handling of the transducer. Third, the short axis view allows evaluation of the circumferential spread of local anesthetic around the nerve.

Definitely, it is necessary to be familiar with the neurostimulation techniques, such techniques can further assist us in the location and placement of peripheral nerve blocks. At the onset of this training, it is necessary to use isolated or non-cutting needles, subsequently non-isolated needles (such as Touhy’s needle) can be used when a wide experience has been obtained. Difficulties in handling guided needles for biopsy[15] have been reported due to their ability to damage tissues, so they are not very popular. After skill has been acquired in identifying structures by ultrasound and guiding the needle placement, then you will be able to start the transition for cutting needles, which can be easily seen on ultrasound; accordingly you will be able to leave or be less dependent on the neurostimulation techniques. The needle always can be best observed when the bezel face is in direction of the transducer surface[16] providing a higher working space for the entry of the needle due to the choice of short needles (1 inch); it is often necessary to insert it into the center and compress the skin and subcutaneous tissue in order that the needle tip is extended to the necessary depth.

PRINCIPLES OF THE TECHNIQUE

Most of the ultrasound-guided locks are performed using images on the short axis of the nerves due to the following reasons. First, it is relatively easy to identify the nerves and fascia associated with this image plane. Second, the image in short axis allows the verification of the circumferential spread of LA around the nerves. Third, if the transducer moves easily, image remains in the field[16,17].

Hold of the Transducer

It should be hold with the thumb, index and half fingers of the NON-dominant hand. By placing the ring finger and the ulnar aspect of the hand on the patient will stabilize the transducer. Firm pressure with the ultrasound transducer will often produce the best image.

Injection test

Test injections should be small (0.5 to 2 mL) to assess the spread of LA, if the spread of the LA is not seen on the monitor, the injection should be stopped. Until the anaesthesiologist -operator does not have any doubt, he/she should suspect an intravascular injection (move the needle, move the transducer or aspire), the injection should be stopped.

Lighting

The light should be dim and soft, dark if possible, which improves the image on the monitor. Illuminate only the work area.

Orientation and placement of the monitor

The monitor screen should observe from left to right in the following order: screen, monitor. The transducer, needle and plane of the image must be placed in view of the operator in the same order. It is recommended that the procedure is routinely performed with the patient awake and able to report paresthesias.

Sterility

Using a transducer protected in a sterile sleeve to reduce the potential risk of infection. The skin can be disinfected as usual with an antiseptic solution of povidone-iodine, always use needles, transparent areas and driving sterile gel, the latter can be prepared in the hospital pharmacy. When one puts a sterile plastic cover, a generous amount of gel should added within the cover lumen and inserted the transducer into the gel. The failures resulted in the inability to produce images. Both the gel as the plastic fields are available in the market.

Approach of the needle

To approach the structures that interest us, the needle insertion can be done in two ways: The first, designated as "in plane" of image in which we can visualize the entry of the needle and see it in its entirety (except the handle), and its advance until the target site. This approach is also known as long-axis, that is in transverse form to the transducer. For this approach, the needle tip should be clearly identified in plane of image before advancing the needle (Figure 4). The second is designated as "out-of-plane" of image where we do not see the entrance of the needle or its advance, we see only the tip thereof passing through the image plane and it is seen as a point white, the target is usually placed in the image center of the field of view. This approach is also designated as short-axis. For this approach, the operator can slide and tilt the transducer to maintain the needle tip within the image plane as much as possible (Figure 5).

Orientation of the needle

For guidance of the needle, it is preferable to have hands-free. A surface approach angle will improve the visualization of the needle. The entry point of the needle should be at a safe distance from the transducer to achieve a proper approach angle. This will also result in less disturbance of contact between the transducer and skin. The best visualization of the needle occurs when the needle is parallel to the active face of the transducer.

Orientation of the bevel

Insert the needle along with bevel directly oriented toward the active face of the transducer; this will give better visibility of the tip of the needle. When the in-plane approach is used, this orientation of the bevel may also reduce the risk of nerve injury.

Manipulation of the transducer

It may require the manipulation of the transducer or the redirection of the lock needle to bring the needle tip within the plane of the image (the patients better tolerate the manipulation of the transducer than the redirection of the needle). On the other hand, doubling the needle can cause discomfort in the patient and thereby hinder the image of in-plane approach.

Dispersion pattern

The spread of local anesthetic into the nerve cluster gives two spread patterns: the first is a bolus that pushes the nerves

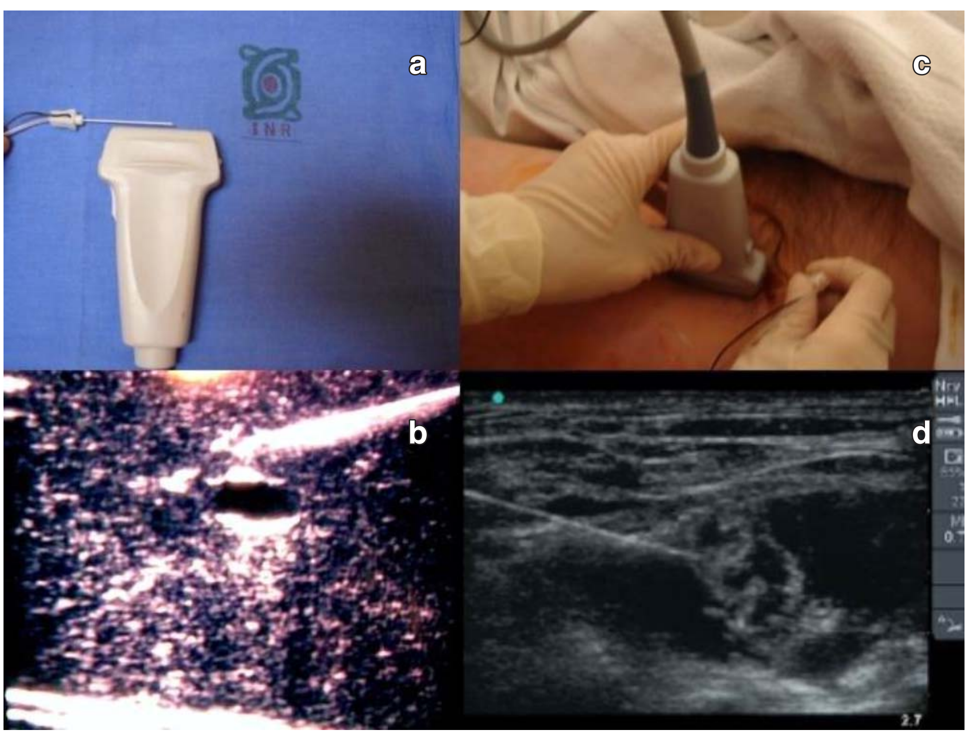

Figure 4. Long axis. **a**: Needle advances of longitudinal form to the transducer, **b**: Sonographic image of needle in blue phantom, **c**: Positioning of needle in long-axis *in vivo*, **d**: Needle in long-axis *in vivo*.

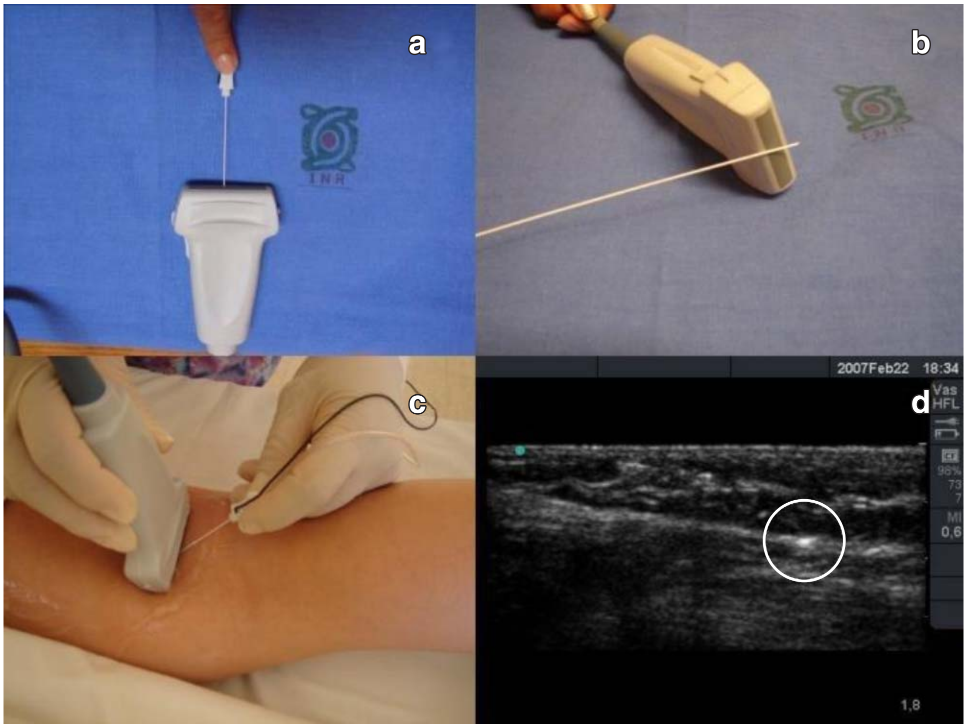

Figure 5. Short axis **a** y **b**: Needle advances in cross-sectional from to the transducer, **c**: Positioning the needle in the short axis *in vivo*, **d**: Sonographic image of the tip of the needle in the short axis.

to the periphery, suggesting a circumferential spread. The expansion of the contents of the neurological compartment is lined by a hyperechoic perimeter; this is representative of the nerve sheath ("U" or donut effect). The second spread pattern is asymmetric, with the anaesthetic in contact, with only some part of the cluster of nerves without producing the image corresponding to the sheath (Figure 6). The bubbles are easily identifiable sonographically and can serve as a useful marker of the needle tip; the bubbles can also spread on the fabric and distal shadows and become a problem(18). All air bubbles must be removed from the solution of local anaesthetic before the injection.

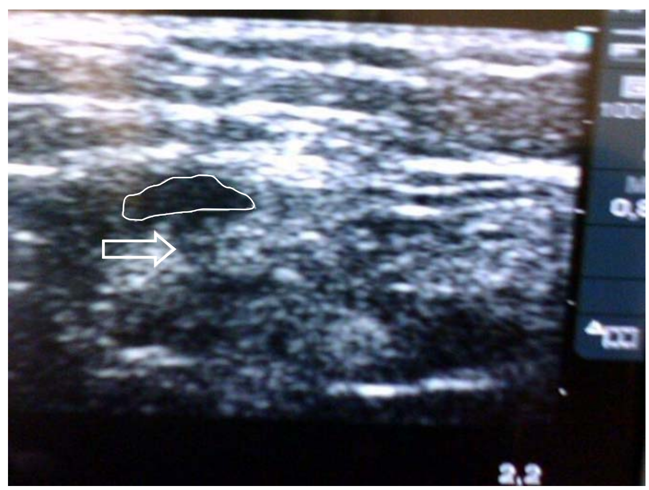

Figure 6. Diffusion of the anesthetic agent where mass effect is observed on the nerve (arrow).

SONOGRAPHIC ANATOMY

On ultrasound the nerve roots such as cervical vertebras have a monofascicular appearance, while the peripheral nerves have an internal fascicular pattern characterized by hypoechoic fascicles and hyperechoic connective tissue around them. When the display is performed through a transverse cut, nerves consistently appear as a circle or oval of hypoechoic shadows in clusters often with pointed form with small internal hyperechoic bands. The study by Silvestre[18] compared the histological structure of the nerve against echotexture obtained through the ultrasound image; the hypoechoic components correspond to the neuronal fascicle, and hyperechoic areas correlate with layers of connective tissue forming the epineurium. The resolution of ultrasound does not allow us to differentiate between the injection within subepineurium or subperineurium[19]. Such internal echogenic fascicular pattern is observed more often on the proximal cords and the trunks, but it is less appreciated at the roots. Small-caliber vessels, lymph nodes and muscle fascias can be mistaken with nerves in the transverse views because they are similar in size and echogenicity (Table I). The phenomenon of anisotropy explains hypoechoic nerves above the clavicle and hyperechoics below the clavicle, i.e., the sound is dispersed without reaching the 100% transducer by increasing spread phenomenon, so refer Sala-Blanch et al[19].

ADVANTAGES OF USG

1. Non-invasive
2. It is able to locate and identify NERVES
3. It displays "dynamic" advance of the needle to the nerve in "Real Time"
4. It displays and prevents vascular structures
5. An unlike of the neurostimulator provides objectivity and consistency
6. Increased precision in size, depth and location of structures
7. Reduction of the amount of local anaesthetic solution
8. "Real time" display of the spread of the local anaesthetic solution
9. Reduction of the procedure time[12]
10. Safety
11. Portable[14]

DISADVANTAGES

This procedure shares risks common to other peripheral nerve blocks, including infection, bleeding and neurological injury[20]:

1. Cost
2. Special training

ULTRASOUND-GUIDED PERIPHERAL NERVE BLOCK OF THE UPPER LIMB

For brachial plexus blocks in interscalenic[21], supraclavicular [22], and infraclavicular[23] approach. Axillary and mediohumeral approach, the patient's position is the conventional, i.e., for supraclavicular or interscalenic scanning, head rotated slightly to the contralateral side; additionally the arm is positioned close to the body. For infraclavicular scanning, the head in neutral position, the hand on the side of the body; for axillary and mediohumeral scanning, head in neutral position with the hand and elbow in 90° flexion and abduction. To get the best transverse view of the brachial plexus, the emission of ultrasound should be in a plane approximately 90 ° with respect to brachial plexus, e.g., the transducer is placed in an oblique axial plane for interscalenic approach; the transducer is placed in a coronal oblique position for supraclavicular approach; the transducer is placed parasagittally for infraclavicular approach; and finally the transducer is placed in a transverse position for axillary and humeral half location[24]. Normally, a strong manual pressure applied to the skin with the transducer can fix the nerve (in particular interscalenic and axillary approach), this reduces the mobility of the nerve and increases the chance of direct contact of the needle. Each location has certain specific characteristics ultrasound, which can make the following considerations:

Table I. Echo texture of different tissues.

Tissue	Echo texture
Veins	Anechoic (but compressible)
Arteries	Anechoic (but pulsed)
Fat	Hypoechoic
Muscle	Hypoechoic
Tendons	Hyperechoic
Bone	Very Hyperechoic
Cartilage	Anechoic (with fine bands)
Fascias	Hyperechoic
Nerves	Hyperechoic

Interscalenic localization

The patient's head should not rest on a pillow because it affects the ultrasound image. The scan starts at the oblique-axial plane (to get a transverse-perpendicular image to the roots, as well as in both scalene muscles); the sternocleidomastoid muscle is the structure of higher consistency in this point; its shape resembles a triangle with its apex located laterally. In a more profound plan is in the anterior and middle scalene muscle (anterior scalene mildly and middle scalene laterally to the plexus). At the level of cricoid cartilage, we locate interscalene groove. Depending on the transducer angle, it is more common to identify the three hypoechoic structures at this level. They vary in depth but generally they can be found about 1 cm. When the scan is performed above the cricoid cartilage in the axial plane, the nerve roots can be observed when they leave from the transverse process of the cervical vertebra. Roots within the neural foramen can not be observed due to the shadows of bone structures. When the scan is performed in caudal direction, nerve roots are now moved to a more superficial location. Other identifiable structures are the carotid artery and internal jugular vein located anteriorly and medially to the brachial plexus and occasionally to the vertebral artery[25]. After identifying the nerve roots and infiltrating the skin with local anaesthetic, a 50 mm x 22 G needle is introduced by the side of the transducer, the needle is moving along the axial axis of the transducer and at the same plane of emission of ultrasound, allowing adequate visualization of the needle. In this way the needle moves smoothly until the tip is in the interscalene groove and in close contact with the roots. To verify the proper placement of the needle tip, stimulation can be started with a 0.5 mA voltage; after obtaining an adequate muscular response, it is aspirated and gradual local anesthetic injection is initiated, the spread of the solution can be confirmed indirectly by distension of the groove and increase in the nervous edges. However, if it is not observed with a small volume of solution, the tip of the needle must be repositioned. Occasionally, the images are hard to find in short, broad, and thick neck. The recommended volume is 0.5 mL/kg up to 40 mL with a linear transducer.

Supraclavicular location

With the head 45º contralateral to the side to be blocked, the scan is started with a convex transducer in an oblique coronal plane, positioned in the supraclavicular fossa, to visualize both the subclavian artery and the brachial plexus, this in a transverse view around 90°. The obtained image shows the first rib joined immediately above the subclavian artery. At this plane, the subclavian artery appears as a hypoechoic and pulsatile structure, and the first rib appears as a hyperechoic linear curve. The brachial plexus is seen as a bunch of grapes that is lateral to it, although in many cases it is cephalic to the subclavian artery. Various rings and annular forms make up hypoechoic nerve structures, which vary in number, size, and appearance. The average distance between the skin and the nerve is 0.9 ± 0.3 cm at this level. By scanning more medially, the subclavian vein and anterior scalene muscle are observed. The pleura appears hyperechoic and often it is observed from either side of the first rib. The movement of the pleura and the lung can be observed during respiration. After sterilizing the skin, the 50 mm x 22 G needle is introduced as outside and lateral as possible of the transducer, it is advanced along the axis of the transducer at the same plane of the ultrasound emission; once reached the cluster of brachial plexus, stimulation is started from 0.5 to 1.5 mA to produce a muscle contraction, 20 mL of local anesthetic are administrated gradually over a period of 5 minutes. If the spread is not observed in real time to the 20 mL, it is stopped and the needle is replaced before depositing the remaining half. The whole procedure lasts approximately 9 minutes, as described Chang[26] even in the hands of residents. An anatomical examination prior to the block can define the optimal approach site to prevent a vascular or pleural puncture. The entry of the needle out of the transducer in a medial or lateral direction is due to two main reasons: Firstly, the transducer has limited space on the medial side to manipulate the needle when maneuvers are performed in the supraclavicular fossa; secondly, the brachial plexus is located lateral to the subclavian artery, then the lateral approach is the most logical and direct option[21,27].

Location infraclavicular

A 12-15 MHz linear transducer is used for this approach, it is placed 2 cm medial to the coracoid process. Unlike other locations, we can only locate the brachial plexus in 27% of cases and the average distance from the skin to the nerve is 2.0 ± 0.7cm. The brachial plexus (presumably cords) in this location are in a plane deep to the major and minor pectoralis muscle, in close proximity to the axillary artery and vein. The axillary vessels are not seen clearly at a depth greater than 4 cm, indicating that it has reached the limited penetration of the transducer. Structures may be scanned with the 4 to 7 MHz transducer, or balance between image quality and depth of penetration may be found with more experience. A comparative study by Arcand[28] suggests that the infraclavicular is easier than supraclavicular approach as image view is faster and the radial nerve block is smaller. The infraclavicular location has not gained clinical popularity because

Figure 7. Sonoanatomy of the interscalenic approach.

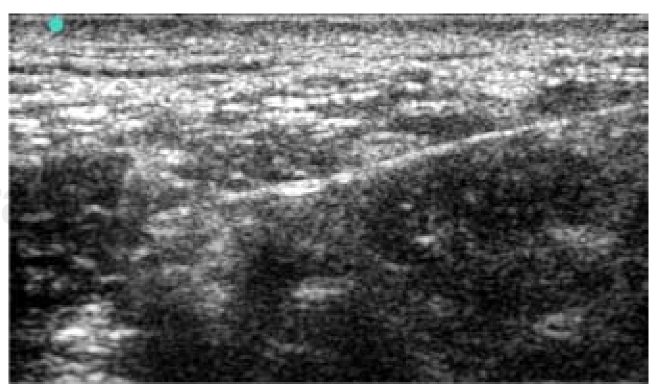

Figure 8. Advance of needle in the supraclavicular approach.

of the uncertainty of the anatomical references and the perception that it is a painful block.

Axillary location

When the scan is performed using a linear transducer, the branches of the brachial plexus and axillary region, with the hand out of the stretcher, are easily identified in close relation to the axillary artery and veins (sometimes we can find one or two). Veins differ from arteries because they are easily compressed by the transducer and Doppler color flow. Typically, the axillary vein is in posterior and medial to the artery. The ultrasound image shows three different terminal branches of the brachial plexus (ulnar, median and radial nerve), and in some cases only two branches can be seen. The average distance between the nerve and the skin is 0.6 ± 0.3 cm. The location of these nerves in most of the time is lateral or medial to the radial artery, more rarely directly anterior to the artery. Other identified structures are the biceps, coracobrachialis, and triceps muscles.

Middle-humeral location

The transducer is placed at the junction of the middle and upper third of upper limb out of the stretcher. At this level the images that are identified are the ulnar and medial nerves along the artery. The average distance from the skin to these nerves is 0.7 ± 0.3 cm. Musculocutaneous and radial nerves are not observed. Other identified structures are the humerus, biceps, and triceps muscles.

Ulnar nerve block

For analgesia of the hand, the ulnar nerve block is a very useful option, particularly in 1st metacarpal fractures. However, many authors have not defined the block on this site due to the risk of nerve injury, particularly when paresthesia is used. Several blocks of the upper limb may provide analgesia in the territory of the ulnar nerve, but also this type of distal block can impact positively on the postoperative pain management and eliminate the need for immobilization of the whole limb[29]; the image with the short axis (transverse cut section) shows the presence of an ulnar nerve fascicle and nerve's joint to the ulnar artery in the forearm and its joint in the medial side. The injection takes place near this joint to improve the nerve image and provide further confirmation of identification. The elevation of the wrist and elbow with supination facilitates medial entry for a needle into the image plane and parallel to the active face of the transducer (long axis). Because the ulnar nerve is medial to the ulnar artery in the forearm, the medial or lateral access, with the needle entry on the medial side, reduces the risk for puncture of the ulnar artery, additionally this access causes paresthesia increasing the success of the procedure, although in this site the needle entry is distant (medial side of the forearm) to the image surface (the palmar side of the forearm). "V"-shaped redirections are performed of the needle for injection of local anaesthetic on the palmar and dorsal portion of the nerve. The needle direction is parallel to the fibers of the ulnar nerve in order to reduce the risk of neurological injury[30,31].

ULTRASOUND-GUIDED PERIPHERAL NERVE BLOCKS OF THE LOWER EXTREMITY

Femoral nerve

The nerve echotexture is characterized by hypoechoic fascicles around hyperechoic connective tissue. The fas-

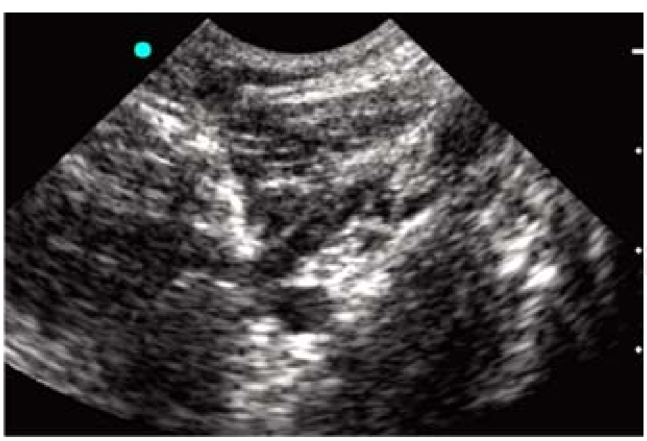

Figure 9. Sonoanatomy of the intraclavicular approach.

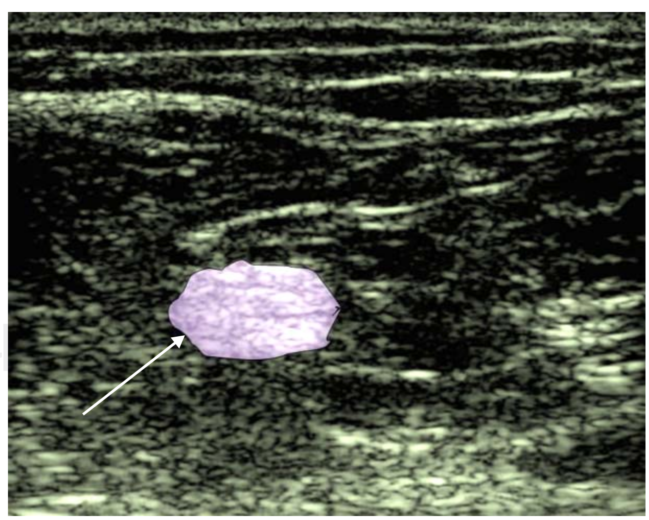

Figure 10. Sonoanatomy of the femoral nerve.

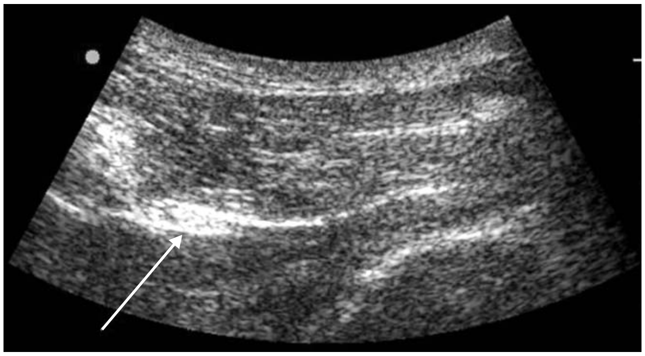

Figure 11. Sonoanatomy of the sciatic nerve.

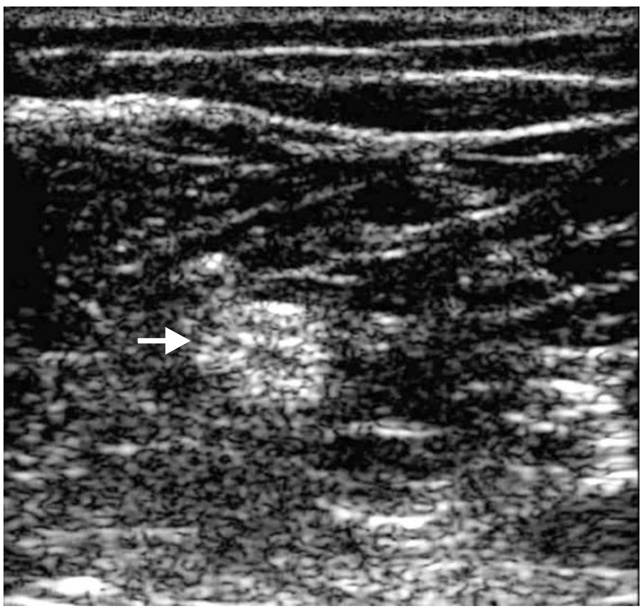

Figure 12. Sonoanatomy of the sciatic nerve corcerning the popliteo fossa.

cia lata separates the subcutaneous tissue from the thin layers of muscles and vessels, surrounds the iliopsoas muscle and also covers the femoral nerve. The iliac fascia is medially contiguous with the pectineal fascia, and it is composed of two layers. Due to the round shape of the psoas muscle in a cross cut, edge between this muscle and the iliac muscle is medially in a form 'C'. Psoas muscle has a ultrasound appearance similar to the femoral nerve but it is more deeply attached to the femoral artery due to its structures of origin, which it separates the femoral artery from the hip joint. The patient is placed supine with the leg externally rotated to perform the femoral nerve block. In obese patients, a pillow in the hip, retraction of the fat pad and placement of the patient in Trendelenburg position may improve the exposure of the femoral nerve; the block is performed distally to the inguinal ligament to reduce the possibility of retroperitoneal bleeding into the possible event of arterial puncture. The thin fascia lata joins the femoral nerve. An advantage of performing laterally the nerve approach is to avoid trauma to the femoral artery or nerve. Frequently short-axis approach is used into the soft tissues on the lateral side of the femoral nerve (the middle side is also very close to the femoral artery). The needle tip must be placed within the space between the fascia lata and the iliopsoas muscle, by confirming and repositioning the needle as needed using the local anesthetic injection test. A wide scanning using the transducer will allow the simultaneous display of the femoral artery, the femoral nerve and medial to lateral edge of the iliopsoas muscle[32]. The long-axis approach from lateral to medial has been described briefly, it may be advantageous in that the needle tip can be visualized. However, if we use large-gauge and long needles for the placement of catheters, the needle can rub along the iliac fascia rather than penetrate it. The spread of local analgesic below of the femoral nerve (at the deep) is typically viewed as a "U" or said spread will be perceived completely surrounded. Both patterns of spread confirm that the block will be successful. The distribution of the local analgesic below the femoral nerve may indicate an injection superficial to the iliac fascia, as well as failed block. The femoral block has failed in some cases where the femoral nerve is not identified, so the visibility is very important[33].

Femorocutaneous nerve block

It is a sensory nerve consisting of 1 to 4 branches extending in medial and anterior direction to superior iliac spine with an average distance of 20 mm with an range from 3 to 46 mm[34]. It is located superficially across the sartorius muscle. The block may be useful to treat paresthetic meralgia. Although it has been reported the nerve ultrasound image, the nerve is usually very small (3 mm diameter) and ultrasound visualization can be difficult[35]. The approach of femorocutaneous nerve is performed by the short axis by infiltrating the local anesthetic along the lateral and medial edge in the form of 'V'; alternatively the anesthetic can be placed on both sides of the fascia lata and iliac fascia[34].

Lumbar plexus block

In the deep blocks -such as lumbar plexus block- low frequency transducers (3 to 5 MHz) are used to increase penetration, since a proper deep release it is necessary in the majority of adult patients[33]. The lumbar plexus block in the psoas compartment can provide superior analgesia for femoral nerve block. It has been reported that this block reduces pain and blood loss after total hip arthroplasty. However, serious complications and limited success rates have also been reported(36). The ultrasound allows a clear delineation of the greater psoas muscle in most subjects(38). The estimated position of the lumbar plexus is in the union of two anterior thirds with the posterior third of the greater psoas muscle. The fascia planes of the lumbar plexus contain femoral and femorocutaneous nerve, but they may not contain the obturator nerve. There are limited reports of ultrasound imaging to facilitate the blocking of the lumbar plexus within the psoas compartment. There are limited reports of ultrasound imaging to facilitate the lumbar plexus block within the psoas compartment. It is performed between the L4-L5 transverse process, where the higher psoas muscle has an area of maximum cross cut(38). Prone position with a pillow under the abdomen allows a stable image. L4-L5 transverse processes can be viewed in short axis (cephalo-caudal longitudinal plane). The needle placement in this longitudinal plane -out of the caudal cut of the L4 transverse process- is suitable for needle placement into the psoas muscle(39).

Sciatic nerve block

It is useful in acute postoperative pain management, combined with femoral nerve block in knee surgery, the diagnosis of nerve entrapment syndromes, neuropathy, nerve tumors, complex regional pain syndrome, and phantom member pain. A 7.5-12 MHz curve transducer is required, but it has been reported the use of 3.5-5 MHz linear transducers; it is recommended the use of 10-12 MHz in patients 60 to 80 kg, although it may be useful even in patients of 100 kg. 7.5 MHz transducers are used for patients weighing over 100 kg. This nerve is not close to a vein or artery, unlike other approaches(40). The patient is placed in Sims' position and bone references are localized such as the greater trochanter and the ischiatic tuberosity, midpoint is located between the two structures and the transducer is placed on this site (subgluteus region), the average depth until the nerve is 5 to 8 cm, the needle is inserted in the short axis. Depending on the level at which the nerve is localized, its sonographic image changes; as at the ischiatic spine this nerve is seen as an hyperechoic elliptical structure, while at the ischiatic tuberosity it has an oval appearance. At subgluteus level and in the zone proximal to muscle are the optimal sites for localizing it(41). Neurostimulation is used to differentiate peroneal or tibial components according to found motor response. The spread of local anesthetic is usually presented as a ring around the nerve(42).

Sciatic nerve block at the popliteal fossa

The patient is placed in prone position and the marks are drawn to delimit the popliteal triangle, a 5-7 MHz linear transducer is used and placed at 8 cm from the base of the triangle. The sciatic nerve is visualized as an oval structure surrounded by a hyperechoic structure and located 1-2 cm lateral to the popliteal artery, which has a depth of 3 to 4 cm. Additionally, the femoral biceps muscle is observed laterally and semitendinosus and semimembranosus muscle is observed medially. The approach is done in the short axis with a 5-cm insulated needle. The needle is inserted into the lower part of the nerve and by depositing the anesthetic, it surrounds the nerve and produces the characteristic mass effect (43).

Saphenous nerve block

The saphenous nerve gives sensory innervation to the medial side of the leg and internal malleolus(44). It accompanies the saphenous vein below the knee and it is superficial to the fascia lata. Although the saphenous nerve is small, it is displayed directly next to the tibial tuberosity(45). For saphenous nerve block, any axis can be used (both short and long) but the short-axis approach is preferred for thin patients as there is a small space between the saphenous vein and fascia lata. Saphenous vein puncture must be avoided because there could be vascular absorption of the anesthetic. A soft tourniquet can be applied if the saphenous vein is difficult to visualize. If multiple veins are identified in the medial aspect of the leg, the transducer is close until they collapse. If the saphenous vein is not identified, a diffuse infiltration immediately superficial to the fascia lata over the medial side of the leg is performed, if necessary the patient is instructed to contract the leg muscles to emphasize the fascia lata as interface layer between the subcutaneous tissue and muscle sub-line(46).

Obturator nerve block

It is a sensory and motor nerve that divides into two branches: the anterior and posterior. The anterior branch sends sensory branches to the hip joint, the posterior branch is responsible for motor function of the larger adductor, external obturator and short adductor muscles, additionally it provides branches sensitive to the knee joint. The obturator nerve block has been determined by different authors as a technique difficult; this block caused a variety of locations and accessory branches in studies carried out in cadavers. The need for blocking this nerve is that it prevents the obturator reflex, reduces muscle spasm in multiple sclerosis and paraplegia, äditionaly it is adequate control of pain in obturator neuralgia. We must not forget that this block is necessary for the management of knee surgery postoperative pain. The patient is placed in dorsal decubitus with the leg in external rotation, a 14 MHz transducer is used, the sonographic image is placed on musculoskeletal mode, the transducer is placed 2 cm lateral and 2 cm caudal to the pubic symphysis: 3 muscle layers are viewed in this point, the two divisions are in this 3 muscle layers. The anterior division is in between the long and short adductor, the posterior division lies between the short and higher adductor. The distance from the skin to each of the divisions is 15.5 mm and 29.3 mm, respectively. The introduction of the needle is performed in the short axis. As it is a long nerve, the sonographic image is of hypoechoic fascicles (honeycomb)[48].

ULTRASOUND-GUIDED PERIPHERAL NERVE BLOCKS IN OTHER LOCATIONS

Iliohypogastric and ilioinguinal nerve block

This technique described both for intraoperative and postoperative analgesia in inguinal, testicular, and low abdominal surgery, has proven to be superior in terms of cost-effectiveness when compared with subarachnoid block or general anesthesia. Additionally, the use of this type of block is indicated in the patient with chronic pain, as it is useful in the differential diagnosis between inguinal pain and ilioinguinal neuralgia (by differentiating the somatic component from neuropathic component after hernioplasties) or abdominal pain. Pain after hernioplasty is a common cause of chronic pain with an incidence of up to 54% in postoperative patients. Ilioinguinal nerve block is a simple technique which unfortunately has a high failure rate, approximately 10-25%; complications of the blind application of this technique include bowel injury, bladder puncture and femoral nerve injury, so the visualization through the sonographic guide presents a adequate quality block and reduces the risk of complications. The ilioinguinal nerve arises from the first lumbar nerve, and emerges at the lateral psoas muscle border just below the iliohypogastric nerve; both pass by the lumbar square and iliac, penetrate into the transverse muscle on the iliac crest from where they descend medially and caudally along with the spermatic cord through the inguinal ring.

The ilioinguinal nerve penetrates the transverse muscle in 90% of cases and the iliohypogastric nerve penetrates it in 95% of cases; both nerves are between the transverse and internal oblique muscle in 90% of the time. Anatomical marks are drawn: anterosuperior iliac spine, inguinal ligament and navel, a line joining the iliac spine and the navel is drawn. A (13-6 MHz) transducer of 38 mm in width is used, a sonographic examination of the inguinal region is performed, the search starts from 1 to 3 cm of the iliac spine; it is tried to locate the ilioinguinal nerve among the internal and transverse oblique or external oblique muscles; iliohypogastric nerve lies just below and slightly medially to the ilioinguinal nerve.

The needle is inserted laterally to the transducer, i.e., in the transverse direction (long-axis); a 38 mm 25-gauge hypodermic needle or a 22-gauge Quincke spinal needle can be used in thin people. The injection of the anesthetic agent causes a mass effect in or around the nerve, resulting in a change in the hypoechoic appearance, which distinguishes it from the surrounding fat which is hyperechoic. When the nerve cannot be viewed properly, we can use the color Doppler, which will facilitate the placement of the needle, as a branch of the deep circumflex iliac artery lies between the internal and transverse oblique muscles in a point nearly parallel to ilioinguinal nerve. This artery is located easily, so the 2 to 3 cc injection of anesthetic adjacently to it causes a block of both nerves. If nerves adjacent to the artery cannot be located, interspace is located between the internal and external oblique muscles and between the internal oblique and transverse muscle. Additionally, 5 cc of local anesthetic are deposited in these interspaces to achieve the block of each nerve[48-50].

Intercostal nerve block

The intercostal nerve block is a useful tool in the pain control after thoracic/upper abdominal surgery such as cholecystectomy as well as in the sternum or rib fractures, neuralgia and lithic blocks due to tumor invasion of the rib wall. The main complication is pneumothorax occurring in up to 0.5% of cases, so the use of ultrasound for locating it should improve this expectation, although controlled clinical trials are needed. The patient is placed in lateral decubitus position with the side to be blocked up, asepsis is performed in the region and the ribs 5 to 12 are exposed. A 13 to 16 MHz transducer is used, and the top and bottom edges of the ribs are located. The ideal site of puncture to avoid nerve damage is in the top edge of the rib of the lower nerve to be blocked. The approach is performed 1 to 2 cm posterior to the middle axillary line. The needle is inserted in long axis and observed up to it penetrates the internal intercostal muscle where generally there is a loss of resistance. The pleura is seen clearly under sonographic vision, and the distance between the pleura and the needle must be monitored to ensure that to be sure in every breath. In addition, a scan in search of pneumothorax data can be performed to complete the procedure using the same ultrasound equipment, as well as the intact pleural space can be visualized, which prevents additional radiological studies such as chest Rx[51].

Lumbar medial branch block (facets)

Facet syndrome is a cause of back pain that resides in the facet joints and the only way to confirm diagnosis is through the articular infiltration. The facet joint innervation is multisegmentary, because it comes from the own level, at a higher level and at lower level. This innervation is derived from primary posterior branch of spinal nerve from this level; it provides a medial branch to innervate facet articulation from this level, ascending branch for cranial articulation and other descending branch for caudal articulation. The patient is placed in prone position with a pillow under the hip to compensate for the lumbar lordosis. There are 2 techniques for performing the approach: In the first technique, curved 3.5 MHz transducer is used, initially a scan of the lumbar region is performed to identify the transverse processes and superior articular process; the approach is performed in short axis. A 22-gauge spinal needle is introduced to 6 cm of the middle line in real time up to coming to the cephalic margin of the transverse process adjacent to the superior articular process; the needle is advanced up to introduce it with the intervertebral foramen; with this method it is achieved to place the needle in correct place in 95 % of the cases corroborated by fluoroscopy. For this technique, it is not required high-quality sonographic images. For the second technique, a 15 MHz linear transducer is required; the transverse process of third lumbar vertebra is located, and it is placed in the center of the image, in this time the transducer is rotated 90 degrees, a 21-gauge spinal needle is introduced from 6 cm laterally to the middle line with an angle of 45 degrees from lateral to medial until making contact with the vertebral body; in this point, a lateral movement of the needle is performed to place it on the cranial edge of the transverse process; after placing it, the transducer is rotated again to verify its proper position. Unlike the other peripheral blocks in which the nerves are in superficial, the block of these nerves is a deep approach, usually greater than 5 cm. Additionally, this block is difficult to perform in obese patients with a BMI greater than 36 kg/m2 because sharpness is lost in the image[52,53].

Third occipital nerve block

This block is useful in the diagnosis of headache due to cervical causes. It is performed by placing the patient in lateral decubitus, using a high-definition ultrasound (14 MHz) with a linear transducer. Examination is started from the mastoid process, by moving the transducer caudally and looking the transverse process of C1, following the artery until it disappears in the transverse foramen of C2, the C2-C3 articulation appears at once. Once in this location, articulation is observed like a convexity and the neck muscles like foils. The apex of the convexity is the site where the needle should be placed. Once located the structures, the transducer is rotated 90 degrees to obtain a longitudinal view. The nerve expands about 1 mm of bone, it presents a typical oval hypoechoic image with a surrounding hyperechoic area. A 22 g spinal needle is used and placed in short axis. One potential complication is the formation of a subcutaneous hematoma that unfortunately hinders visibility[54].

Rectus sheath block

It is a technique that began in 1899 to provide relaxation to the abdominal wall, in addition to adequate analgesia in umbilical plasty, pylorotomy, laparoscopic surgery and other in the abdominal midline, its application is mainly in pediatric patients. A 5-10 MHz "hockey stick" linear transducer is used for this technique, the puncture site is on both sides of the navel; a short needle is used and the approach is done in the ultrasound short axis. Firstly, anterior rectus sheath is identified, and subsequently the rectus abdominis muscle and below it the posterior sheath is seen. The depth to the first sheath is 3.8 (1.6-5.5) mm, the muscle thickness is 4.35 (2.4-7.8) mm and the distance from the posterior sheath is 8 (0.5-13.8) mm. If the needle advances more than a centimeter can cause complications such as intestinal puncture. The local anesthetic is applied between the abdominis rectus and the posterior sheath[55].

PUDENDAL NERVE BLOCK

This block is useful for urogenital perineal pain management and differential diagnosis of neuralgia by compression of the same. This approach has been described through the use of electromyography, fluoroscopy, or computerized axial tomography[56]. The patient is placed in prone position and the gluteus region is scanned in dorsal direction using longitudinal and perpendicular planes to locate the internal pudendal artery at the ischial spine and sacrospinous ligament level. A color Doppler and 3.5 MHz curved transducer are used to locate it. The average depth up to the nerve is 5.5 cm and is shown by

ultrasound as a small, oval, hypoechoic, and 3.5 mm structure. The distance from the pudendal artery to the tip of the ischial spine is 7.1mm in side direction and 8.9 mm in medial direction, the distance from the pudendal nerve to the tip of the ischial spine is from 0.1 to 15.3 mm[57].

NEUROSTIMULATION AND ULTRASONOGRAPHY

The neurostimulation technique is performed without direct visualization of the needle-nerve duet; but it is useless to detect proximity in the absence of a response. There is also evidence suggesting that this method may have a low sensitivity and specificity[(58)], as well as a poor correlation between paresthesia and neurostimulation, which may reveal some inaccuracy and inconsistency[(29)]. Interesting findings are described by the Perlas team[(58)] where the study of electric current leads to the inconsistency of the stimulated-nerve muscle contraction; that is, when the needle, visually in the monitor, is in contact with the nerve sometimes there is no neurostimulaton response. This ultrasonographic evidence of nerve contact in a transverse view does not cause a muscle contraction when using an 1.5 mA electric current. It is recommended not to move beyond the needle, as it could pass through the nerve. A motor response can be provoked if fine adjustments are done by moving longitudinally the needle tip along of nerve path. Such facts support other author's studies[(59)] where the response disparity between paresthesia and muscle contraction by nerve stimulation is shown[(60)].

COMPLICATIONS

Due to the "real time" visualization of needle's tip, its advance, and the visual verification of its position, the complication rate must be reduced. The controversial study by Bigeleisen[(61)] suggests that the intraneural injection (seen by an halo of edema using ultrasound) does not invariably imply neurological damage. On the other hand, when the needle's tip does not pass through the first rib or pleura in the ultrasound image, the pneumothorax risk is practically eliminated; however, when the structures cannot be recognized, needle penetration can puncture the subclavian arter[(26)]. In the interscalene and supraclavicular approach, the reported complications by guided ultrasound are as follows: Horner's syndrome and unilateral block of the phrenic nerve respectively and side effects reported with other techniques. The demonstration that the needle's tip is not within a major vessel or central-neuroaxial structure is apparent. But the development of this new technique is too recent to have any data which supports the hypothesis that the guided ultrasound improves the success rates and decreases the complication rates related to each block area. It is clear that additional, controlled, long term, clinical studies are required in order to explain these doubts and appreciate the full value of this localization technique[(62)].

CONCLUSION

Successful regional analgesia depends not only on the technique used but on the proceduralist experience, block observation time, the type and amount of local anesthetic , anatomic variation, patient motivation and on the definition of a successful block. The ultrasound technology provides high-quality images for suitably locating the nerves and plexus, by guiding "movement to movement" the needle penetration until finding the nerve desired.

The practice of ultrasound is still in the development stage, many anesthesiologists are still at the middle stage of the learning curve in regards to the neurostimulation and ultrasound combination; some other are discussing what are the main and basic images. Future studies are required to determine the ultrasound clinical usefulness in the pain therapy.

The use of the new imaging techniques has been described as "Critically important for the future" of regional analgesia[(48)]. The future of the ultrasound-guided blocks will depend on the clinical benefits associated to the imaging technology to justify the cost of procurement of equipment.

REFERENCIAS

1. Hirschel G. Local and Regional Anesthesia. William Wood and Company. New York, 1914.
2. Wright B. A new use for block-aid monitor. Anesthesiology 1969:30:336-337.
3. Sia S, Bartoli M, Lepri A, Marchini O. Multiple injection axillary brachial plexus block: A comparison of two methods of nerve localization: nerve stimulation versus paresthesia. Anesth Analg 2000:91: 647-651.
4. Borgeat A, Ekatodramis G, Kalberer F, Benz C. Acute and nonacute complications associated with interscalenic block and shoulder surgery: A prospective study. Anesthesiology 2001;95:875-880.
5. La Grange P, Foster P, Pretorious L. Application of the Doppler ultrasound blood flow detector in supraclavicular brachial plexus block. Br J Anaesth 1978:50:965-976.
6. Abramowitz HB, Cohen CH. Use of Doppler ultrasound guided axillary block. Anesthesiology 1981:5:603.
7. Wong G, Brown DL, Miller GM, Cahill DR. Defining the cross-sectional anatomy important to interscalene brachial plexus block with magnetic resonance imaging. Reg Anesth Pain Med 1998;23:77-80.
8. Kapral S, Krafft P, Klemens E. Ultrasound-guided supraclavicular approach for regional anesthesia of the brachial plexus. Anesth Analg 1994;78:507-513.
9. Moorty SS. Fluoroscopic imaging during supraclavicular lateral paravascular brachial plexus block. Reg Anesth Pain Med 2000;25:327-328.
10. Ting PL, Sivagnanratnam V. Ultrasonographic study of the spread of local anesthetic during axillary brachial plexus block. Br J Anaesth 1989:63:326-329.
11. Chan VW. Nerve localization-seek but not so easy to find? Reg Anesth Pain Med 2002;27:245-24.
12. Williams SR, Chouinard P, Arcand G. Ultrasound guidance speeds execution and improves quality of supraclavicular block. Anesth Analg 2003;97:1518-1523.

13. Shanewise JS, Cheung AT, Aronson S, Stewart WJ, Weiss RL, Mark JB, Savage RM, Sears-Rogan P, Mathew JP, Quinones MA, Cahalan MK, Savino JS. ASE/SCA guidelines for performing a comprehensive intraoperative multiplane transesophageal echocardiography examination. Anesth Analg 1999;89:870-884.
14. Fornage BD, Sneige N, Edeiken BS. Interventional breast sonography. Eur J Radiol 2002;42:17-31.
15. Hopkins RE, Bradley M. *In vitro* visualization of biopsy needles with ultrasound: A comparative study of standard and echogenic needles using and ultrasound. Clin Radiol 2001;56:499-502.
16. McGahan JP. Laboratory assessment of ultrasonic needle and catheter visualization. J Ultrasound Med 1986;5:373-377.
17. Gebhard RE, Al-Samsam T, Greger J, Khan A, Chelly JE. Distal nerve blocks at the wrist for outpatient carpal tunnel surgery offer intraoperative cardiovascular stability and reduce discharge time. Anesth Analg 2009;95:351-355.
18. Silvestri E, Martinoli C, Derchi LE, Bertolotto M, Chiaramondia M, Rosenberg I. Echotexture of peripheral nerves: Correlation between US and histologic findings and criteria of differentiate tendons. Radiology 1995;197:291-296.
19. Borgeat A. Regional Anesthesia, Intraneural injection, and nerve injury. Anesthesiology 2006;105:647-648.
20. Gruber H, Peer S, Kovacs P. the ultrasonographic appearance of the femoral nerve and cases of iatrogenic impairment. J Ultrasound Med 2003;22:163-172.
21. Yang WT, Chui PT, Metrewelli C. Anatomy of the normal brachial plexus revealed by sonography guidance in anesthesia of the brachial plexus. Am J Roentgenol 1998;171:1631-1636.
22. Kapral S, Krafft P, Eibenberger K. Ultrasound-guided supraclavicular approach for regional anesthesia of the brachial plexus. Anesth Analg 1994;78:507-513.
23. Sandhu NS, Capan LM. Ultrasound-guided infraclavicular brachial plexus block. Br J Anaesth 2002;89:254-259.
24. Perlas A, Chang VW, Simona M. Brachial plexus examination and localization using ultrasound and electrical stimulation. Anesthesiology 2003;99:429-435.
25. Perlas A, Chan VW. Ultrasound-guided interscalene brachial plexus block: 2004;8:143-148.
26. Chan VW, Perlas A, Rawson R, Odukoya O. Ultrasound-guided supraclavicular brachial plexus block. Anest Analg 2003;97:1514-1517.
27. Kapral S, Krafft P, Eibenberger K. Ultrasound guided supraclavicular approach for regional anesthesia of the brachial plexus. Anesth Analg 1994;78:507-513.
28. Arcand G, Williams St, Chouinard Ph, Boudreault D, Harris P, Ruel M, Girar F. Ultrasound-guided infraclavicular versus supraclavicular block. Anesth Analg 2005;101:886-890.
29. Williams A, McMahon SB. Peripheral nerve injury caused by injection needles used in regional anaesthesia: Influence of bevel configuration, studied in a rat model. Br J Anaesth 1992;69:433-438.
30. Fanelli G, Casati A, Garancini P, Torri G. Nerve stimulator and multiple injection technique for upper and lower limb blockade: Failure rate, patient acceptance, and neurologic complications. Study on Regional Anesthesia. Anesth Analg 1999;88:847-52.31.
31. Gray AT, Schafhalter-Zoppoth I. Ultrasound guidance for cubital nerve block in the forearm. Reg Anesth Pain Med 2003; 28:335-339.
32. Nielsen KC, Klein SM, Steele SM. Femoral nerve blocks. Techn Reg Anesth Pain Manag 2003;7:8-17.
33. Gray A, Collins A, Schafhalter-Zoppoth I. An introduction to femoral nerve and associated lumbar plexus nerve blocks under ultrasonic guidance. Tech Reg Anesth Pain Manag 2004;8:155-163.
34. Hospodar PP, Ashman ES, Traub JA. Anatomic study of the lateral femoral cutaneuos nerve with respect to the ilioinguinal surgical dissection. J Orthop Trauma 1999;13:17-19.
35. Peer S, Bodner G (eds). High-resolution sonography of the peripheral nervous system, Berlin, Springer Verlag, 2003.
36. Breslin DS, Macleod DB. Central nervous system toxicity following the administration of levobupivacaine for lumbar plexus block: a report of two cases. Reg Anesth Pain Med 2003;28:144-147.
37. Kirchmair L, Entner T, Wissel J. A study of the paravertebral anatomy of ultrasound-guided posterior lumbar plexus block. Anesth Analg 2001;93:477-481.
38. Reid JG, Livingston LA, Pearsall DJ. The geometry of the psoas muscle as determined by magnetic resonance imaging. Arch Phys Med Rehabil 1994;75:703-708.
39. Capdevila X, Macaire P, Dadure C. Continuous psoas compartment block for postoperative analgesia after total arthroplasty: new landmarks, technical guidelines, and clinical evaluation. Anesth Analg 2002;94:1606-1613.
40. Raj PP, Parks RI, Watson TD, Jenkins MT. New single position suppine approach to sciatic-femoral nerve block. Anesth Analg 1975;54:489-493.
41. Chang V, Nova H, Abbas S, McCartney C, Perlas A, Xu D. Ultrasound examination and localization of the sciatic nerve. 2006:104:309-314.
42. Shackleford M, Broadman L. An introduction to ultrasonic-guided sciatic neuroblockade. Techniques in regional anesthesia and pain management 2004:8:167-170.
43. Sinha A, Chan V. Ultrasound imaging for popliteal sciatic nerve block. Reg Anesth pain Med 2004:29:130-134.
44. Stone BA. Transcutaneous stimulation of the saphenous nerve to locate injection site. Reg Anesth Pain Med 2003:28:153-154.
45. Gray AT, Collins AB. Ultrasound-guided saphenous nerve block. Reg Anesth Pain Med 2003:28:148-153.
46. Ilfeld BM, Morey TE, Wang RD, Enneking FK. Continuous popliteal fossa block for postoperative pain control at home. Anesthesiology 2002:97:959-965.
47. Soong J, Schafhalter I, Gray A. Sonographic imaging of the obturator nerve for regional block. Reg Anesth Pain Med 2007:32:146-151.
48. Gofeld M, Christakis M. Sonographically guided ilioinguinal nerve block. J Ultrasound Med 2006:25:1571-1575.
49. Eichenberger U, Greher M, Kirchmair L, Curatolo M, Moriggi B. Ultrasound-guided blocis of the ilioinguinal and iliohypogastric nerve: accuracy of a selective new technique confirmed by anatomical dissection British Journal of Anaesthesia 2006:97:238-243.
50. Willshke H, Marhofer P, Bosenberg A, Johnston S, Wanzel O, Cox G, Sitzwohl C, Kapral S. Ultrasonography for ilioinguinal/iliohypogastric nerve blocks in children. British Journal of Anaesthesia 2005:95:226-230.
51. Byas-Smith M, Gulati A. Ultrasound-guided intercostal nerve cryoablation. Anesthesia and Analgesia 2006:103:1033-35.
52. Kwang J, Cheon J, Yoon K, Kim W, Yoon D. Ultrasound-guided lumbar medial-branch block: A clinical study with fluoroscopy control. Reg Anesth Pain Med 2006:31:451-454.
53. Greher M, Scharbert G, Kamolz L, Beck H, Gustorff B, Kirchmair L, Kapral S. Ultrasound-guided lumbar facet nerve block a sonoanatomic study of a new methodologic approach. Anesthesiology 2004;100:1242-1248.
54. Eichenberger U, Greher M, Kapral S, Marhofer P, Wiest R, Remonda L, Bogduk N, Curatolo M. Sonographic visualization and ultrasound-guided block of the third occipital nerve. Anesthesiology 2006:104:3003-3008.
55. Willschke H, Bosenberg A, Marhofer P, Johnston S, Kettener S, Wazel O, Kapral S. Ultrasonography-guided rectus sheath block in pediatric anaesthesia a new approach to and old technique British Journal of Anaesthesia 2006:97:244-249.
56. Calvillo O, Skaribas I, Rockett C. Computed tomography-guided pudendal nerve block a new diagnostic approach to long-

term anoperineal pain A report of two cases. Reg Anesth Pain Med 2000:25:420-423.
57. Kovacs P, Gruber H, Piegger J, Bodner G. New simple ultrasound-guided infiltration of the pudendal nerve. Dis Colon Rectum 2001:44:1381-1385.
58. Perlas A, Chan VWS, McCartney C. Ultrasound assement of paresthesia and electrical stimulation of nerve localization: A sensitivity study. Reg Anesth Pain Med 2004;29:178, A33.
59. Urmey WF, Stanton J. Inability to consistently elicit a motor response following sensory paresthesia during interscalene block administration. Anesthesiology 2002;96:552-554.
60. Williams S, Chouinard P, Arcad G, Harris P, Ruel M, Boudreault D, Girard F. Ultrasound guidance speeds execution and improves the quality of supraclavicular block. Anesth Analg 2003;97:1518-1523.
61. Bigeleisen P. Nerve puncture and apparent intraneural injection during ultrasound-guided auxiliary block does not invariably result in neurologic injury. Anesthesiology 2006;N105:V4:779-783.
62. Wedel DJ. Regional anesthesia and pain management: reviewing the past decade and predicting the future. Anesth Analg 2000;90:1244-1245.