GE Healthcare

Ultrasound and Regional Anesthesia

Giorgio IVANI

Valeria MOSSETTI

AUTHORS

Giorgio IVANI
Chairman Division of Pediatric
Anesthesiology and Intensive Care Unit
Regina Margherita Children's Hospital
Turin, Italy
President of ESRA 2006-2009

Valeria MOSSETTI
Medical Staff
Division of Pediatric Anesthesiology
and Intensive Care Unit
Regina Margherita Children's Hospital
Turin, Italy

Alfonso FAUSTO
Medical Assistant
Department of Radiology at IRCCS
Policlinico San Donato
Italy

CONTENTS

3	**Introduction**
4	**What is ultrasonography?**
8	**Minimum requirements for an ultrasound equipment**
9	**Terminology and application methods**
14	**Artifacts**
15	**Advantages of ultrasound in regional anesthesia**
16	**Sterile procedure**
16	**Upper extremity**
16	- Interscalene block
17	- Supraclavicular block
18	- Infraclavicular block
19	- Axillary block
21	- Median and ulnar nerve block at wrist
22	**Trunk**
22	- Ilioinguinal/iliohypogastric nerves block
23	- Paraumbilical block
24	**Lower extremity**
24	- Femoral nerve block
25	- Saphenous nerve block
26	- Sciatic nerve block
26	- subgluteal approach
27	- midfemoral approach
28	- popliteal approach
30	– Ankle block of the tibial and deep peroneal nerves
31	**Perineural catheters**
32	**Suggested readings**

INTRODUCTION

The main objective of locoregional anesthesia is to achieve high efficacy and safety. The transition from the technique of paresthesia to nerve stimulation set a milestone for nerve blockades. Though this transition significantly reduced the risk of nerve and blood vessel damage, this risk still cannot be avoided completely.

However, this risk could be reduced even further by the introduction of ultrasound as a guidance to locate the nerves. This technique with real-time visualization of the needle during its placement makes it the safer approach. Currently in the literature, no data can evidence the advantages of the ultrasound technique over the nerve stimulation technique.

Thus the authors recommend the use of both techniques - especially to those colleagues, who for the first time perform a nerve block under ultrasound guidance. It will not only serve as an educational tool, the muscular twitch induced by nerve stimulation will also help to confirm that the needle has been placed exactly near the nerve.

We thus agree with Vincent Chan whose opinion is expressed in his report in the ASRA Newsletter 2007:
"It is important to emphasize that ultrasound and nerve stimulation techniques are not mutually exclusive. On the contrary, the two techniques complement each other and each has its own strengths and weaknesses. For this reason, residents should be encouraged to learn both techniques. Only time will tell which one of these techniques will become the method of choice for nerve localization pending results of future outcome studies and clinical experience."

It is also advisable to use the needles normally used for nerve stimulation and not „normal" needles, as these are extremely sharp, and it is much more likely that vessels or nerves are injured with them; such needles should be reserved for the more „experienced" anesthesiologists. The present handbook serves as a guide to those colleagues who are enthused by this new and fascinating technique. It is nevertheless imperative to attend specific courses that impart the essential knowledge on this technique and it is also important to acquire in-depth training at hospitals that have ample experience with this technology.

WHAT IS ULTRASOGRAPHY?

HISTORY

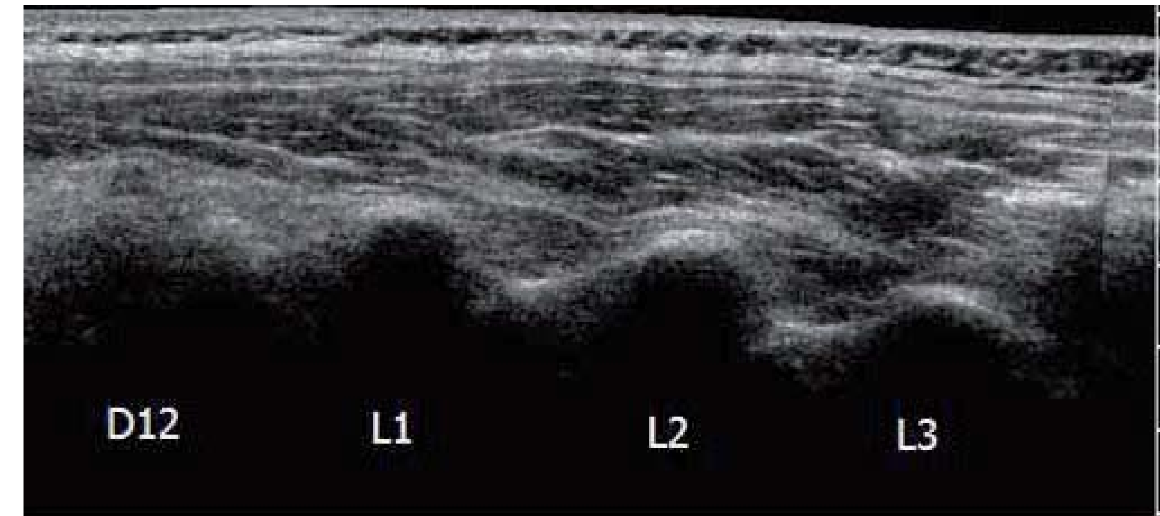
The use of ultrasound as a diagnostic tool is a relatively new method. The first practical application was in 1916 when Paul Langevin developed an ultrasound system for underwater echo ranging intended for military use named SONAR (Sound Navigation and Ranging).
The first use of diagnostic ultrasound in medicine was in 1942 by the scientist Karl Dussik, who discovered, during his investigations of the influence of cerebral ventricles on the shift of the median line of cerebral structures, that changes occurred in the presence of a tumor. In 1949 George Döring Ludwig and Francis Struthers improved the pulse-echo ultrasound methodology for their explorations on detection of foreign objects in soft tissues - in particular the localization of gallstones. Douglas Howry and William Roderic Bliss created the first two dimensional ultrasound image in 1950. In Scotland in 1958, Ian Donald was the first to use two dimensional echography in his discovery of ovarian cysts. Since the first medical use of ultrasound by Dussik in the nineteen forties the quality of ultrasound images has improved enormously. The progress in the technological development of ultrasound in the field of diagnostic imaging has still not reached its end. The next stage is its use in multifrequency transducers and three dimensional imaging.

DEFINITIONS

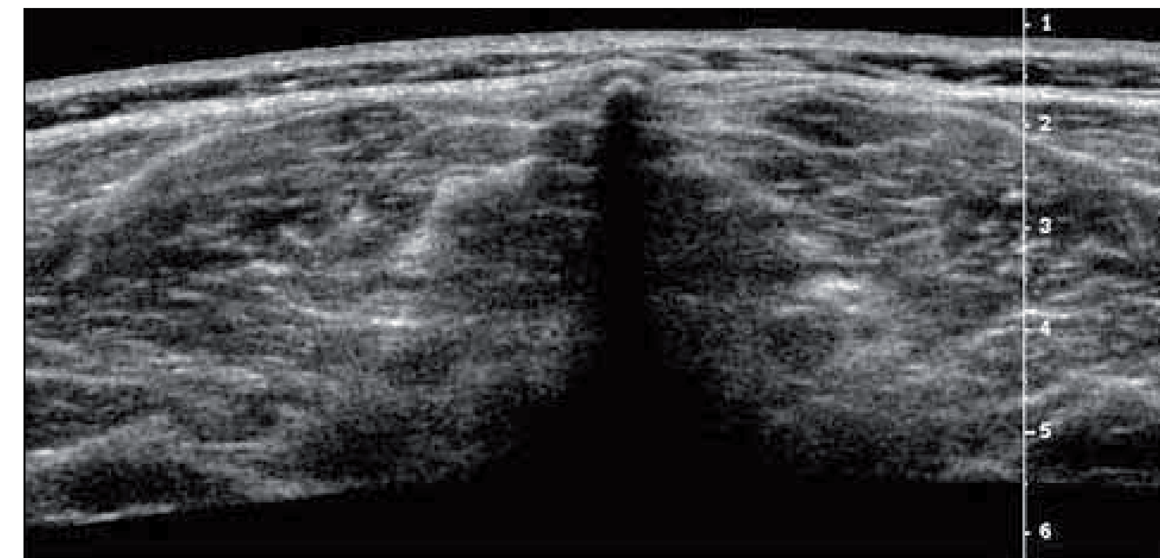
Humans are able to hear sound in the frequency range of 20 to 20,000 hertz (Hz, cycle per second). Ultrasound waves are longitudinal - i.e. the vibratory disturbance of particles (sound) in a medium is parallel to the direction of travel of the wave -, and are generated by a transducer and operate in the megahertz (MHZ) frequency range which is more than the audible range of the human ear. Through a series of longer and shorter intervals in the wave, longitudinal waves transfer energy. Longitudinal wavelengths (?) are between 10 and 100 meters and the propagation velocity (c) depends on the medium it travels through. The capability of ultrasound waves to travel through different media depends on the composition of the medium as well as on its density and elasticity which represent the inherent acoustic impedance of the medium. In human tissue the waves reach a velocity of 1540 m/s. The propagation velocity of a wave is also dependent on its frequency: the greater the frequency the shorter the wavelength and therewith a lower degree of penetration than waves with lower frequencies. The resistance a wave is exposed to in its travel through a medium is called acoustic impedance as already mentioned. As with all waves, when an ultrasound wave reaches a medium with a different acoustic impedance, it changes both its velocity and its direction (refraction and reflection). According to Snell's law, an incident wave and a reflected wave have the same angle of incidence, while the transmitted or refracted wave propagates under a different angle. Refraction is a phenomenon that always occurs when waves reach an obstacle and is relative to the dimension of the obstacle. Furthermore, ultrasound waves are attenuated when traveling through a material, primarily through absorption and scattering.
In radiodiagnostics ultrasound frequencies between 3.5 and 18 MHz are used. In medical use ultrasound waves are generated by the transformation of electrical energy into mechanical energy and vice versa. This transformation is accomplished by quartz crystals and polycrystalline ceramics that possess the so-called piezoelectric effect: the size of the quartz crystal is inversely proportional to the transducer frequency.

THE ECHOGRAPH

Mobile, usually cart-based, echographs consist primarily of a probe (transducer), a computer that controls the transducer, sends the impulse, receives the echo and processes the signal, a visualization system, and a storage device for later digital editing and printing. The most important part of the echograph is the transducer which can take different forms depending on its specific use. The most important technical specifications are its axial and lateral resolution and the frequency achieved. Resolution is the ability to discern two dots as being distinct from each other on the x and y plane: on the (x) axis – which is parallel to the propagation line of the ultrasonic beam –, and on the (y) axis - which is the axis vertical to the ultrasonic beam. Today, due to technological advancement in signal processing software, it is also possible to improve data quality for imaging, and to influence the definition: to counter the phenomenon of signal attenuation, the reflected signals are amplified taking into account the delay with which the signal is received thus allowing statements as to their depth. Finally, it should be kept in mind that the ultrasonic beam transmitted from the transducer results in the two dimensional representation of a three dimensional object. Therefore, recordings from at least two sets of planes are required to be able to reconstruct the object in its original shape.



Panoramic sonography of the lumbar vertebrae in the region D12-L3 with scans carried out parallel to the spine.



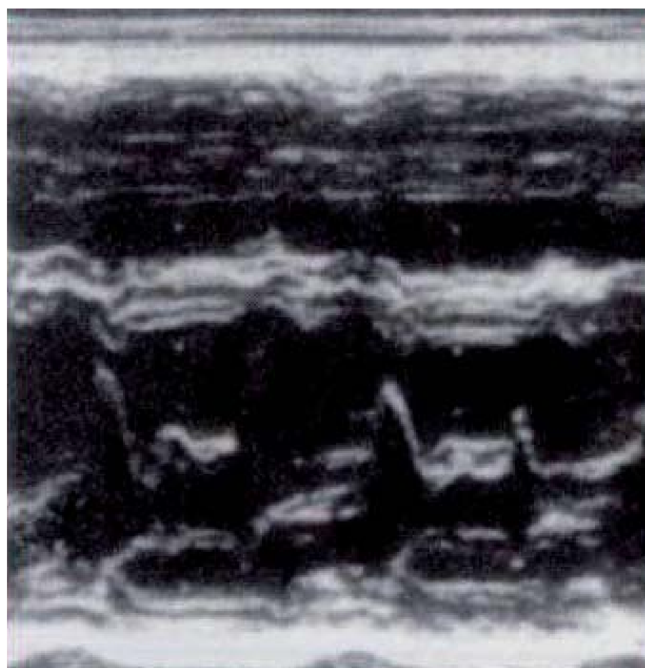
Panoramic sonography of the vertebral column at the level of L1 with scans carried out vertical to the spine.

ECHOGRAPHIC RECORDINGS

Depending on the signal received by the transducer, different depictions of the investigated structures are possible.

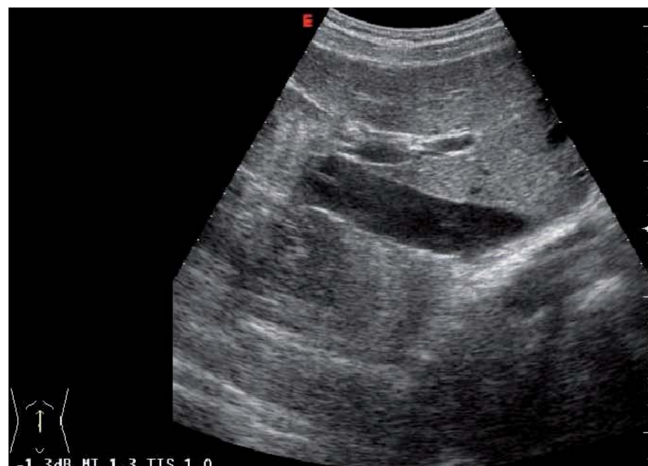
A-mode (Amplitude mode):
Scanning is accomplished along a line from a single source through to the investigated object. Each echo is depicted as a peak, the height of which is equivalent to the intensity of the echo. This method is often employed in ophthalmology and is often used in combination with the B-mode.

TM-mode (Time-Motion):
Scanning is accomplished along a single axis with the images following each other in time sequence in a wave-like manner. This type of songraphic imaging is used in echocardiography for heart valve investigations.



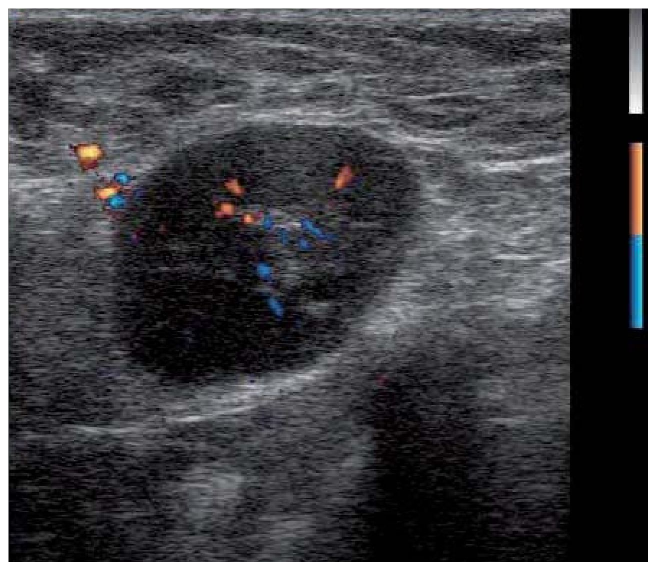
Sonograph at the level of the aortic valve where the motion of the heart valve is depicted.

B-mode (Brightness mode):
Each echo is depicted as a bright spot with different grey scale intensities indicating varying echo strengths. The waves are transmitted and received in pulses in different directions so that each moment can be ascribed to a certain direction. When image delivery is fast enough (more than 16 images per second) the sonograph of the investigated object is created in real time. This way the whole observed region is visualized in one image. Today, most modern echographs work with this principle.



Oblique view of the liver at the level of the vena cava.

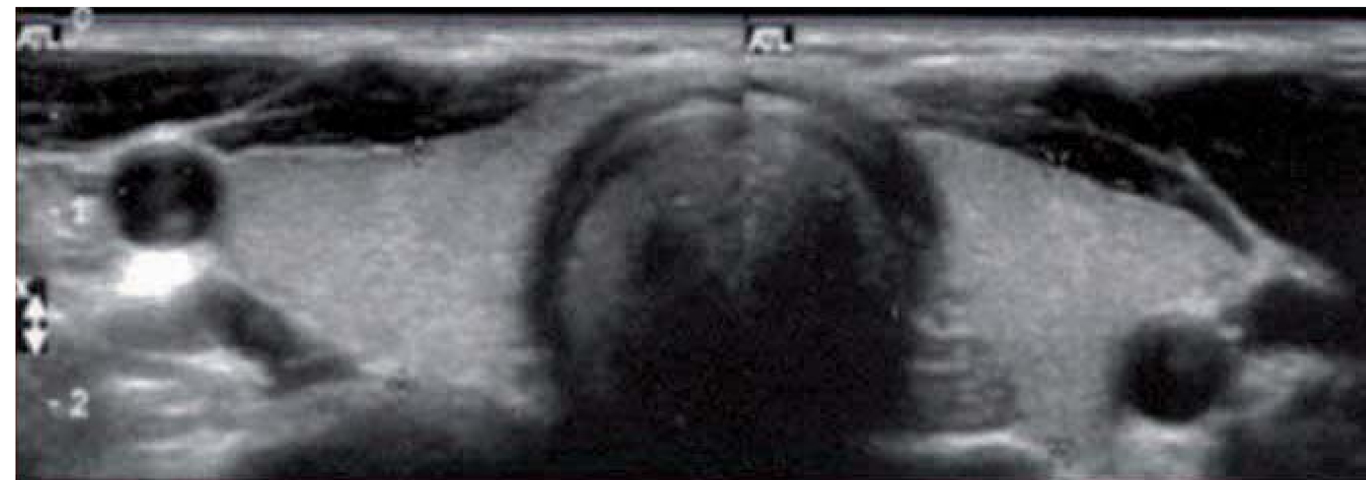
Color Doppler and Power Doppler: Both techniques are based on the shift in frequency between the transmitted and the reflected wave. The frequency shift corresponds to the velocity with which an object moves (Doppler effect). With Doppler measurements along one single axis - the so-called Doppler echograph - two dimens-ional graphs are obtained in which the velocities are depicted as two dimensional peaks that give information on the velocities of the investigated flows. By combining several axes during the investigation of a certain region a color image is generated that is superimposed on the echograph and provides information on flow: Color Doppler method for large blood vessels with high flow velocities and -the Power Doppler for slow flow velocities.



Power Doppler depiction of a metastatic axillary lymph node after breast cancer. The border is massively thickened and blood flow appears slow and anarchic.

ECHOGRAPHY TERMS

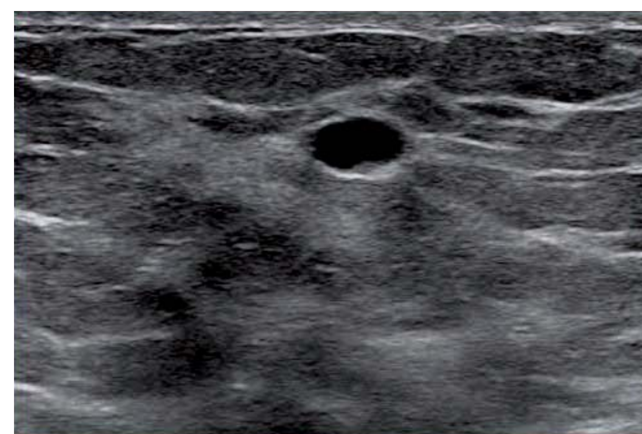
The term isoechogenic refers to a structure displayed in an ultrasound image with a certain intensity on a grey scale.



Depiction of the thyroid parenchyme: isoechogenic and homogenous. The image was created by panorama-typical superimposition: both thyroid lobes are shown in the same image in cross-view to the cervix surrounding the trachea seen in the center of the image.

Formations with low echogenicity are called hypoechoic, formations that do not deliver any echo at all are anechoic, and those formations with high echogenicity are called hyperechoic.

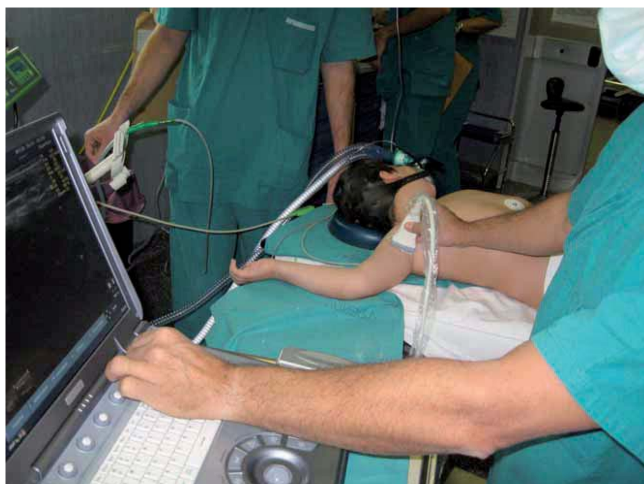
Normally the echogenicity of an investigated structure corresponds to its type and composition, however, not every anechoic structure is fluid nor must every hyperechoic structure be solid. The terms shadow cone and acoustic enhancement refer to structures that inhibit the travel of ultrasound, or respectively, increase its speed. Such situations occur typically in investigations of bone or calcium structures (e.g. gallstones) and formations containing liquid (e.g. liver cysts).



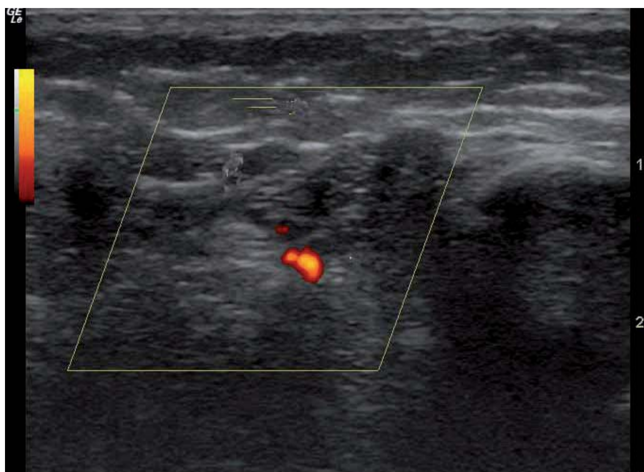
Part of a breast gland with a cyst.

MINIMUM REQUIREMENTS FOR REGIONAL ANESTHESIA ULTRASOUND EQUIPMENT

The ultrasound equipment used in regional anesthesia should be transportable. Portable units as well as compact scanner systems mounted on a cart are commercially available.



These should meet at least the following requirements:
- Color Doppler to identify blood vessels and distinguish them from the surrounding tissues

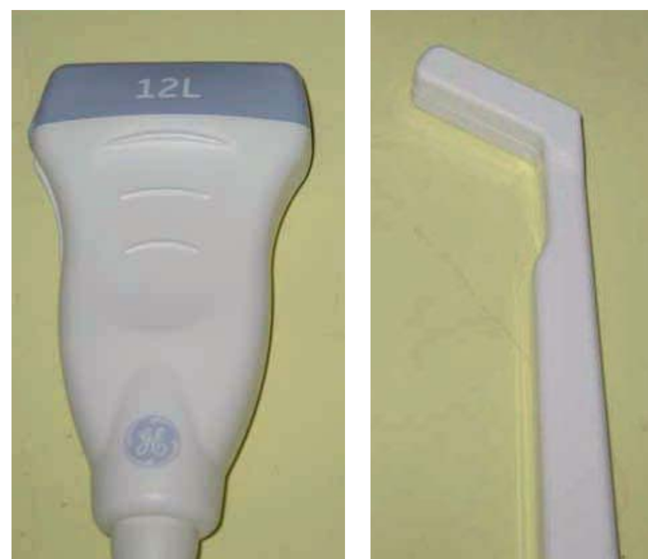


Color Doppler modality. This instrument works with the colors yellow to red.

- Contrast images (gain)
- Sufficient storage capacity for images and preferably also for films
- Linear high-frequency probe, 5-10 MHz or better 7-12 MHz, with a maximum length of 5 cm.

Shorter probes such as the ‚Hockey stick' probe with a length of 2.5 cm are recommended for pediatric use.

LINEAR HIGH-FREQUENCY PROBES



7-13 MHz

5-10 MHz

Curved probe with a lower frequency range (4-7 MHz) to scan structures in deeper locations though image quality will be worse than with high-frequency probes.

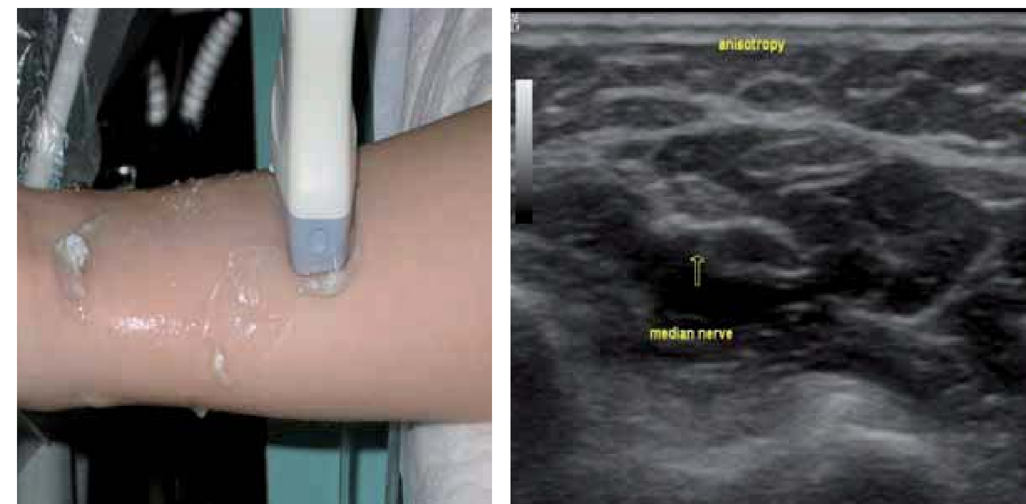
Instrument performance is enhanced and better images can be achieved by paying regard to the following recommendations:

- Select the program for nerve blocks (setting neuromuscolar): better images for nerve structure evaluation are obtained;
- Select probe frequency according to nerve depth:
  - 7 MHz for structures deeper than 5 cm;
  - 10 MHz for structures between 3 and 5 cm deep;
  - 12 MHz for structures maximally 3 cm deep;
- Based on the assumed depth of the nerve, select the depth for the scanning region: 1 cm deeper than the structure to be examined;
- Use the image contrast function: if the image appears too dark, it can be brightened up by pressing the button „gain". By pressing the button „partial gain" the superficial or the deeper layers of the image can be brightened up.
- Use the Color Doppler to locate blood vessels;
- By pressing the button „Freeze" the image is locked and can be saved.

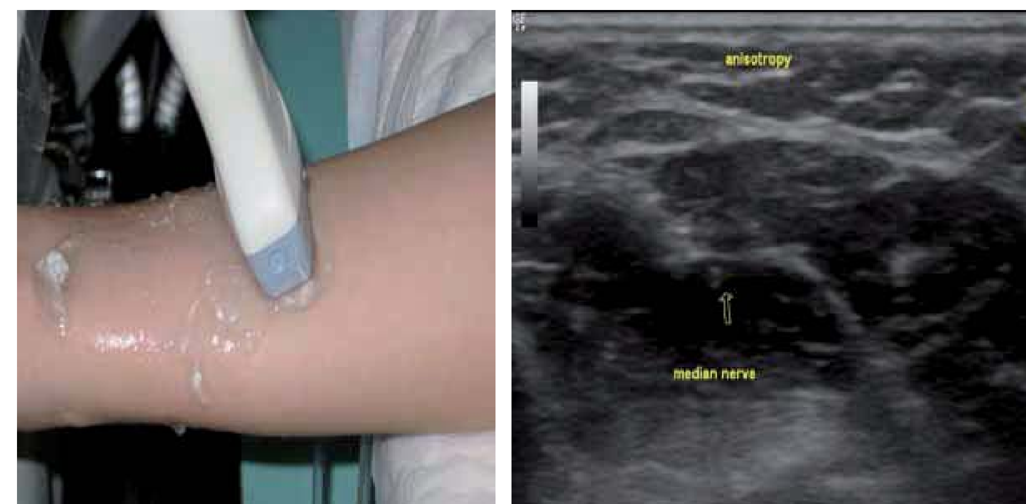
TERMINOLOGY AND APPLICATION METHODS

Optimal images are obtained when the ultrasound beam is directed at the structures in a 90° angle.

Anisotropy:
The property of a structure (e.g. a nerve) to change its echogenicity depending on the angle of entry of the penetrating ultrasound beam.



Anisotropy: The ultrasound beam falls perpendicularly on the median nerve



Anisotropy: The ultrasound beam penetrates the median nerve at an angle of < 90°.

To correctly identify a nerve under ultrasound guidance it is important to proceed as follows:

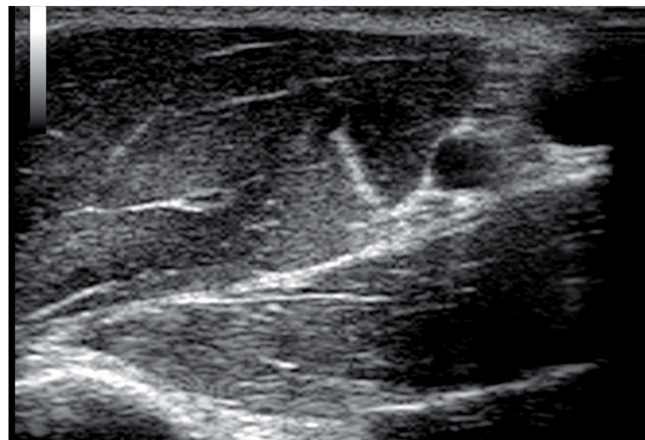
1. **Localize the nerve;**
2. **Move the ultrasound probe;**
3. **Move the block needle.**

1.

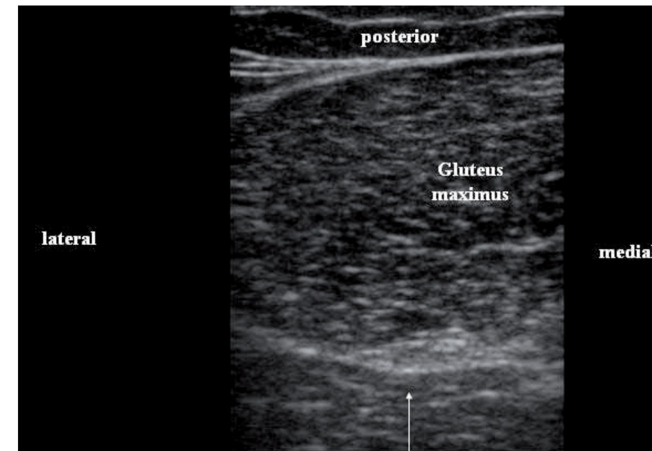
Echogenicity is the ability of a structure to reflect sound waves when targeted by an ultrasound beam.

A tissue can be:
- anechoic: black, non-reflective (all liquids);
- hyperechoic: white, highly reflective (bones, pleura, muscle fascia);
- hypoechoic: darker than the neighbouring tissues, weakly reflective (solid organs).

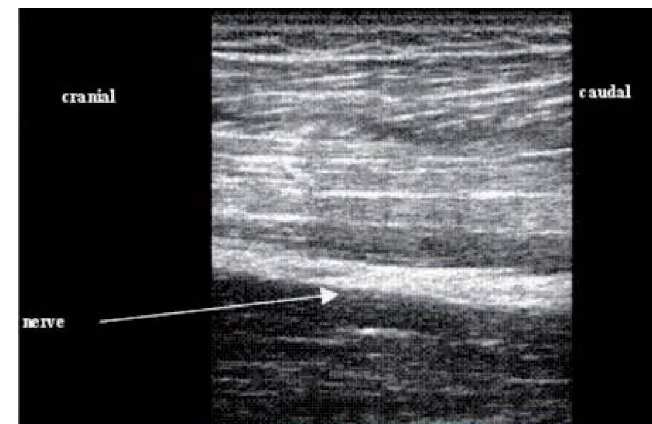
Thus:
- Arteries: anechoic, black, pulsating;
- Veins: anechoic, black, non-pulsating, compressible;
- Muscles: bundles and perimysium hyperechoic, muscle fibres hypoechoic;
- Fatty tissue: hypoechoic;
- Bones: hyperechoic, shadow cone;
- Tendons, pleura: hyperechoic.



Structures such as nerves, tendons or blood vessels can be depicted along their short axis (cross-section) or along their long axis (longitudinal). A cross-section can be changed to a longitudinal section by a 90 degree rotation of the probe.



Transverse view (short axis) of the sciatic nerve



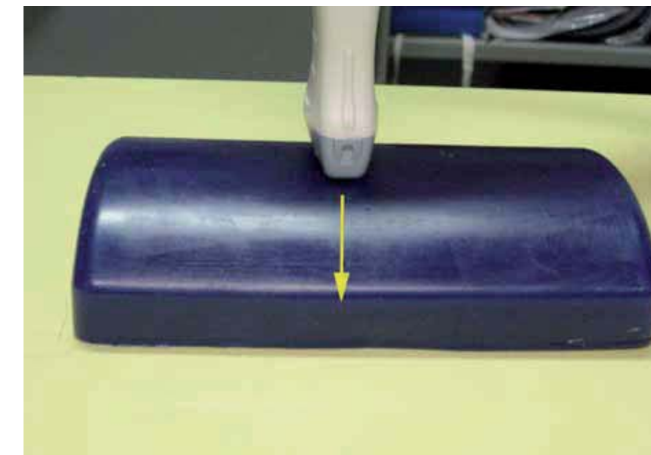
Longitudinal view (long axis) of the sciatic nerve

Cross-sections of nerves in general are depicted as round or oval echographic heterogenous structures mostly hypoechoic in the interscalene and supraclavicular regions, and in the regions further below, largely hyperechoic (honeycomb pattern); the difference can be explained by the existence of connective tissue (hyperechoic) which is why a nerve appears whiter the more connective tissue it contains.

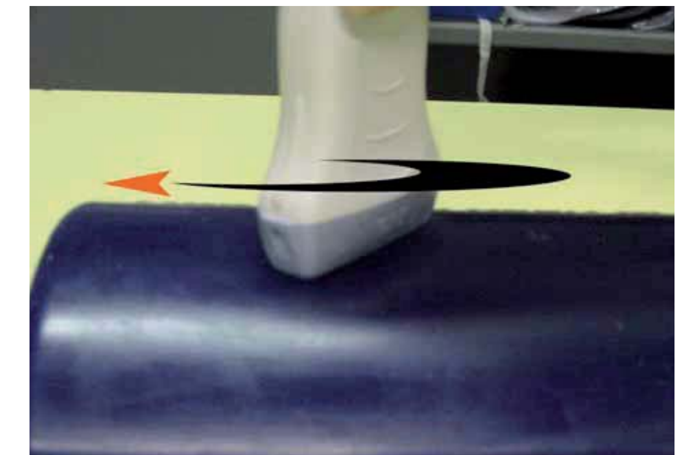
2.

To improve the visualization of a nerve, the following four fundamental motions (PART) should be carried out with the transducer:

- Pressure: Apply pressure on the skin with the transducer to identify compressible structures.


Pressure

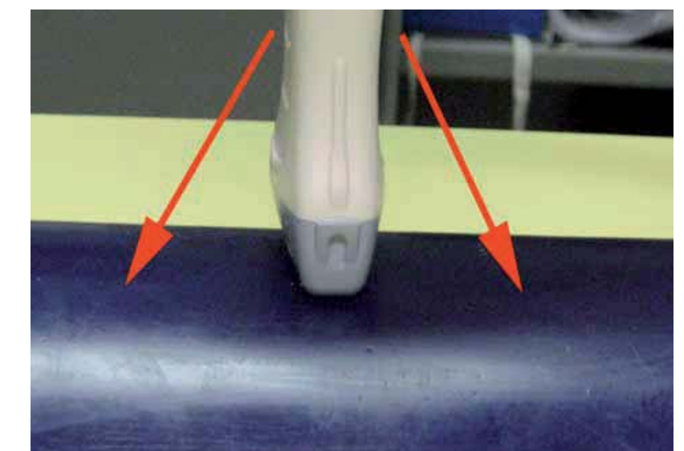
- Rotation: Move the transducer clockwise and anti-clockwise until the ultrasound image is optimised;


Rotation

- Alignment: Navigate the transducer along a nerve pathway until a nerve is localized;

Alignment

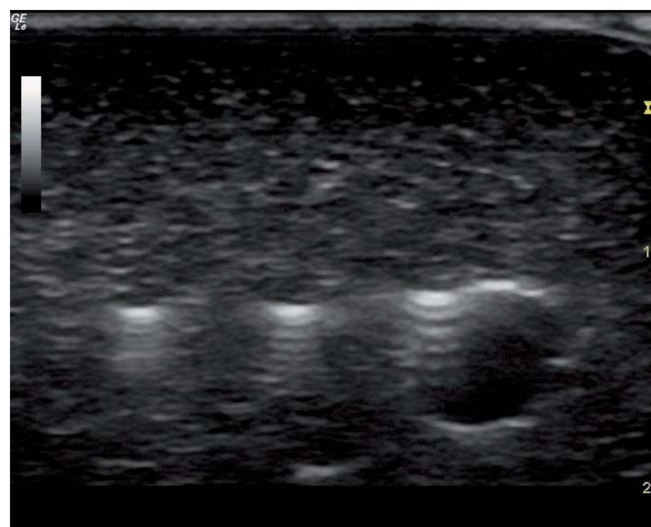
- Tilting: Tilt the transducer back and forth to achieve the best image of the nerve.


Tilting

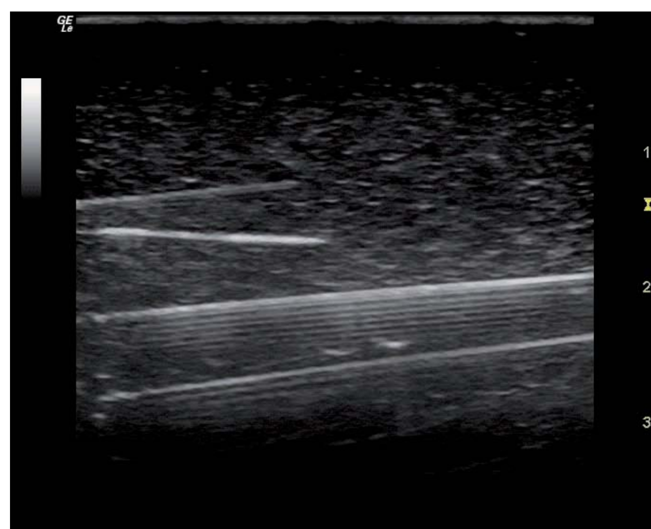
3.

The depiction of needles in the ultrasound investigation is not related to their size; how well they are identified depends on the material of the needle.

- Pressure: Apply pressure on the skin with the transducer to identify compressible structures.



Cross-section of needles of different sizes



Longitudinal section of needles of different sizes

There are 3 ways to align the **transducer with the needle:**

- **In plane (IP):** The transducer is exactly parallel to the needle. In this case one is able to see the whole length of the needle and also where the needle tip is.

  Advantages: Because the needle tip is visualized, it is possible to position it correctly without the risk of injuring nerves or vessels. Disadvantages: Since ultrasound has an extremely narrow beam width, it can be difficult to keep the needle constantly in view.

In Plane (IP)

- **Out of plane (OOP):** The needle and the transducer are perpendicular to each other. In this case one is able to see the cross-section of the needle as a hyperechoic dot, which however, can result from any other needle segment.

  Advantages: The needle cross-section is easily identified.

  Disadvantages: One is not sure where the tip of the needle is. This potentially carries the risk of injury to nerves and blood vessels.

Out of plane (OOP)

- The transducer and needle are partially aligned with each other: part of the needle is seen, but not its tip.

The authors mainly use the IP approach as it offers more safety.

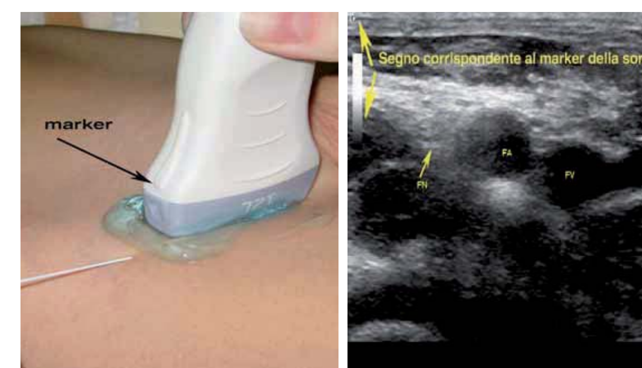
The transducer must be aligned with the investigated anatomical structure in such a way that the ultrasound beam penetrates the nerval structure perpendiculary. The needle can thus be orientated as follows:

- in an axial oblique plane (e.g. interscalene approach);
- in a coronal oblique plane (e.g. supraclavicular approach);
- in a parasagittal plane (e.g. infraclavicular approach);
- in a vertical plane (e.g. femoral nerve approach, or popliteal approach to the sciatic nerve).

Independent of manufacturer or type, every transducer has been provided with a marker on one end so that it is possible to clearly classify an image either when observing an image on the monitor or on a photograph (e.g. to indicate whether it is the left or right limb); therefore it has been agreed upon to orientate the marker as described in the following positions:

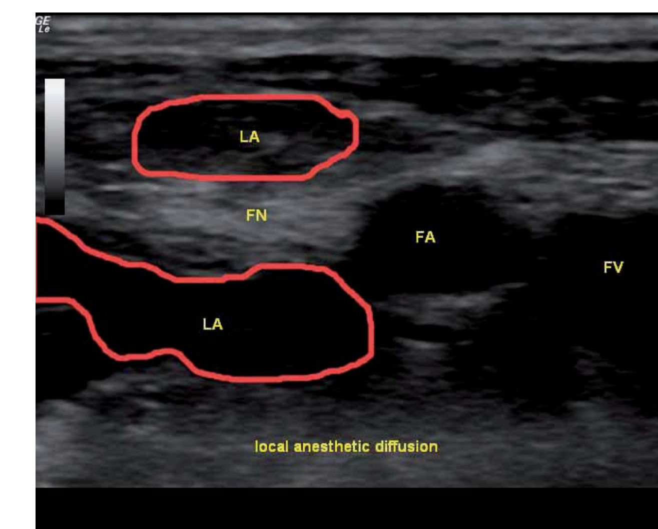
- When scanning in the vertical plane the marker is oriented towards the patient's right body side if the patient is in supine position, and towards the right bed side if the patient is in prone position.
- When scanning in a sagittal plane the marker is orientated towards the patient's head.

While observing the image on the monitor the marker is always shown as a small symbol in the left upper side on the monitor.

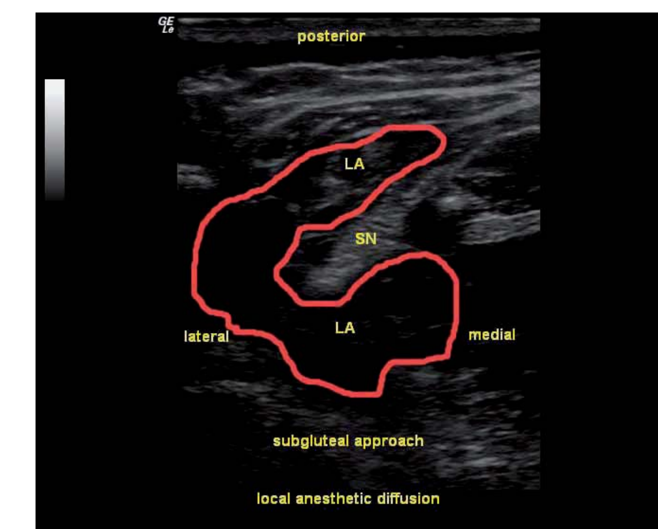


The local anesthetic is seen as an anechoic zone, that is well set apart from the neighbouring tissue. Any air bubbles in the injection syringe will impair the sonographic reading considerably. The possibility to be able to track the distribution of the local anesthetic is one of the huge advantages of this technique. We suggest to first administer 1-2 ml of anesthetic solution; if this volume does not spread optimally, reposition the needle until the complete nerve is surrounded by anesthetic.

Since the distribution of the anesthetic solution can be observed in real time, no doses have been recommended for a nerve block. The optimal dose is the volume that is necessary to completely surround the nerve with anesthetic.



FN= femoral nerve; FA= femoral artery; FV= femoral vein;
LA= distribution of anesthetic



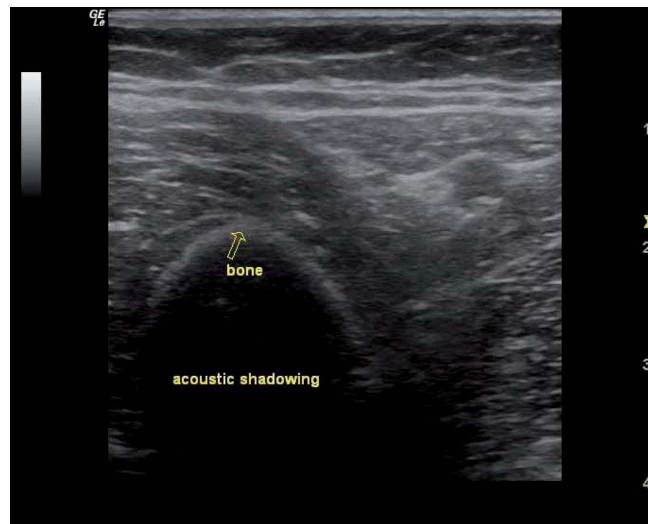
SN= sciatic nerve; LA= distribution of anesthetic

ARTIFACTS

There are two types of acoustic artifacts: absent structures or false reports, and erroneous images.

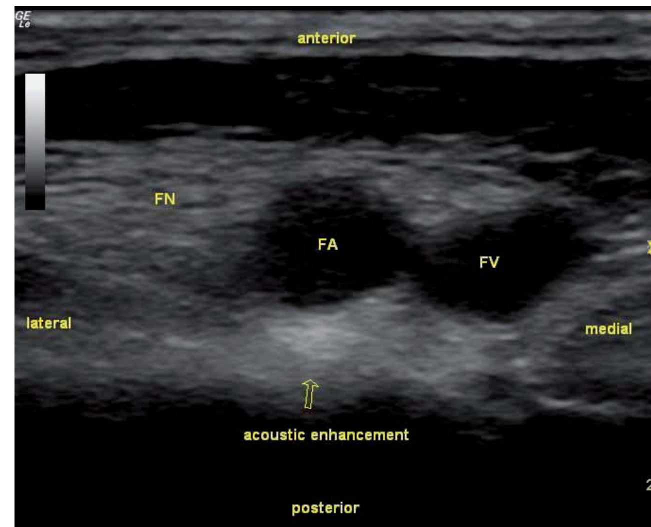
A) Absent structures or false reports.

1. **Excess gain or low gain artifacts**: Total or partial image contrast not used correctly (overall or time gain compensation): if the total or partial image contrast is set too high or too low some structures may appear darkened or may not be visible.
2. **Shadow cone**: This artifact occurs when the investigated structure has a higher attenuation coefficient than the underlying tissue so that the latter will appear less echogenic than it normally is. This is typical for structures located deeper than bone or if air bubbles are injected.



Artifact: Shadow cone. Bone

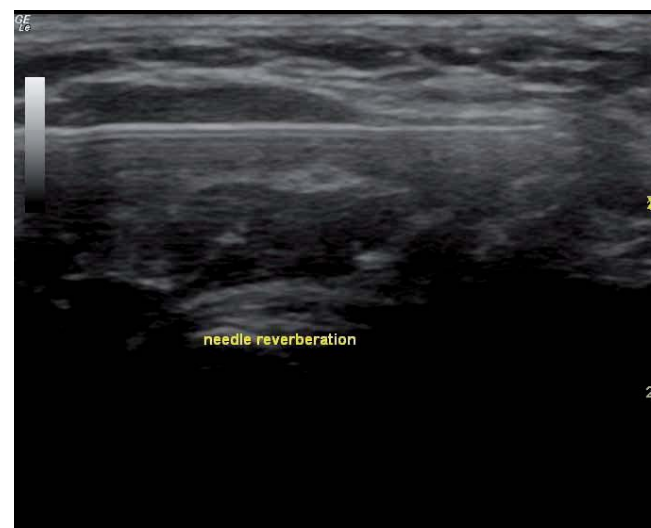
3. **Acoustic enhancement:** This artifact occurs when a region behind a structure that causes weak attenuation generates stronger echos than observed from the neighbouring tissues. This is the case e.g. when the ultrasound beam travels through a blood vessel without any attenuation and therefore causes the image of the tissue that lies underneath to appear enhanced.



Artifact: acoustic enhancement. FN= femoral nerve; FA= femoral artery; FV= femoral vein.

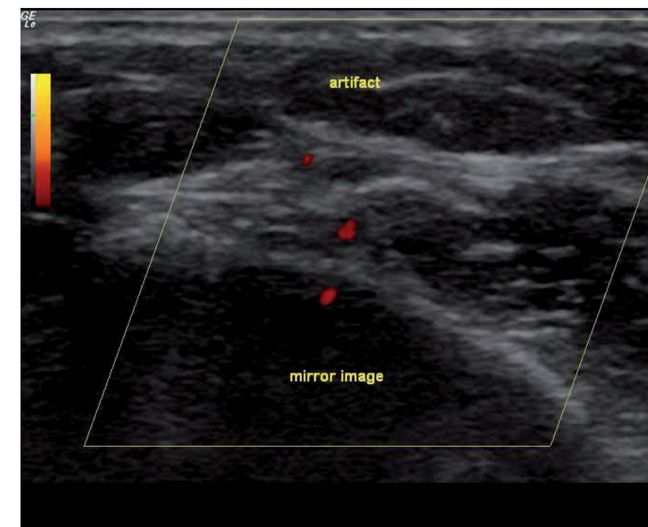
B) Erroneous images.

1. **Reverberation** occurs when ultrasound waves are reflected and refracted by two strongly reflective mirror-inverted structures. This results in many linear hyperechoic zones distal to the reflective structure. This artifact mostly occurs with needles, in particular, if they are exactly perpendicular to the transducer head.



Artifact: Reverberation from needle

Sometimes tissues can cause reverberation or the sound beam is reflected by the lumina of an artery and refracted, thereby generating a double image of the vessel that is actually below the structure (mirror-inverted image).



Artifact: Mirror-inverted image

2. Artifact skin-probe: Occurs when the transducer head is in incomplete contact with the skin and air is inbetween. To avoid this the whole transducer must be covered with a gel.
3. Anatomical artifacts: These artifacts are called pitfall errors and refer to the erroneous interpretation of an image depicting a nerve. Such errors are avoided by navigating along the nerve pathway over a longer section together with a neuro stimulator.

ADVANTAGES OF ULTRASOUND IN REGIONAL ANESTHESIA

Ultrasound-guided blocks provide several advantages:

- It is possible to visualize the nerve structures, especially important in patients whose anatomical landmarks are difficult to establish.
- It is possible to see the position of the needle and, if necessary, to change its direction or depth which means the needle need not be inserted so often, thus relieving the patient of unnecessary distress.
- It is possible to see the structures surrounding the nerves (vessels, pleura), thus reducing the risk of injury to nerves and vessels.
- It is possible to see whether the local anesthetic solution has spread properly; this means shorter onset times, more intensive, complete and sustained blockade with less risk of the block not taking effect, as well as lower required doses of the local anesthetic.

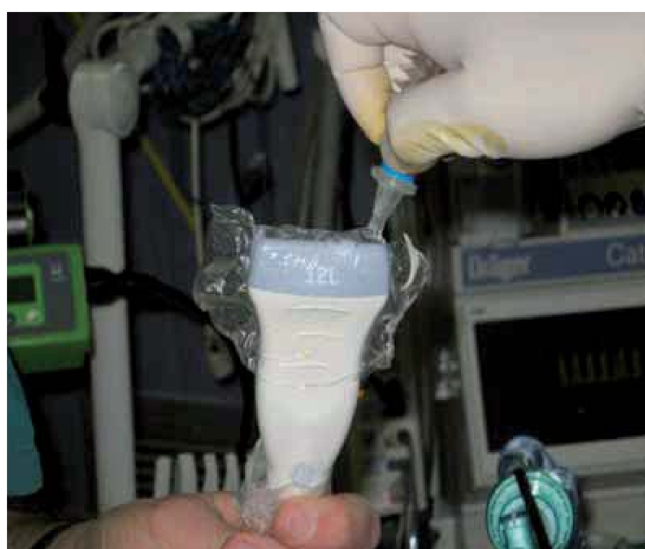
Further advantages in pediatric use are given e.g.,

- because nerve structures are superficial and very easily identified;
- due to the low calcification the peridural space is easier to identify;
- because nerve and vessel structures are very close together in pediatric patients and with this method injury or damage can be better avoided;
- because newborns or babies have a slower metabolism of substances such as local anesthetics and therefore it is extremely important to use the lowest amounts of local anesthetics as possible.

STERILE PROCEDURE

Ultrasound-guided blockades must also be conducted under sterile conditions. The transducer should be sterilized by either covering it with a transparent tape (ie Tegaderm) or with the special sterile probe covering provided.

It is also important to stretch the cover tightly over the transducer to take care that no air is trapped between the probe and the cover as this would result in inferior imaging.



UPPER EXTREMITY

The brachial plexus is formed by the anterior branches of the spinal nerves C5-T1 and reaches from the neck to the axilla. Its roots are in the interscalene groove; C5 and C6 unite distally to form the superior trunk, C7 becomes the middle trunk, and C8 and T1 unite to form the inferior trunk.

At the supraclavicular plane, the trunks separate in anterior and posterior divisions, from which the lateral, posterior and medial cords arise at the intraclavicular plane to surround the axillary artery.

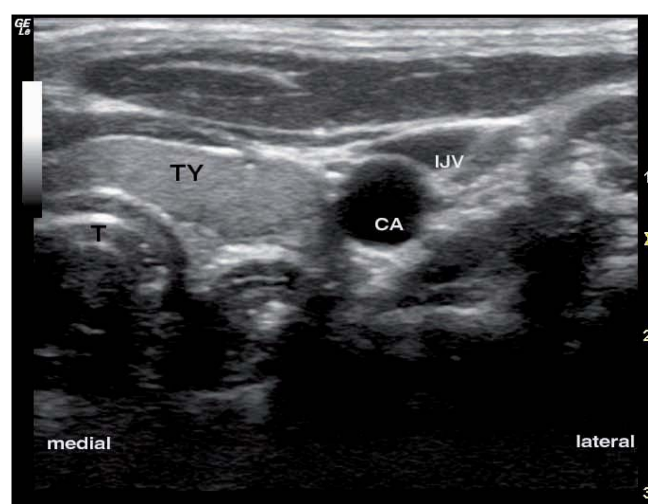
In the axilla the cords separate into the terminal branches: the radial nerve arises from the posterior cord, the musculocutaneous nerve arises further up in the axilla as first from the medial cord, the ulnar nerve from the medial cord and the median nerve partly arises from the medial, partly from the lateral cord.

INTERSCALENE BLOCK

The interscalene roots of the brachial plexus are in the interscalene groove between the anterior and medial scalene muscles, which in turn, are located at the lateral border of the clavicular origin of the sternocleidomastoid muscle.

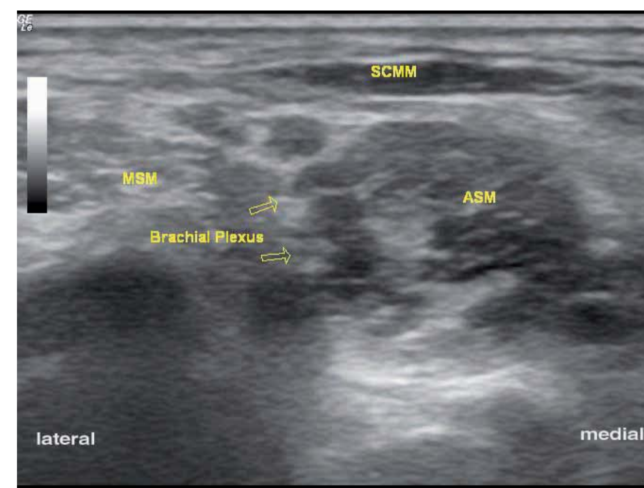
The patient is in supine position, the head is turned away from the side to be blocked.

Use a linear high-frequency probe with 10 or 12 MHz. Place the probe in an axial oblique plane at the neck so that the plexus can be scanned transversely (the marker on the probe is directed towards the patient's right body side). Start by scanning the sonoanatomy of the investigated region, first locating the easily recognizable large vessels, the carotid artery, and the jugular vein.



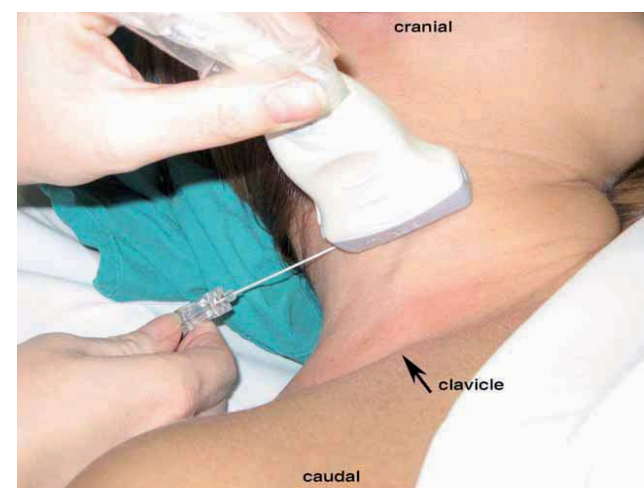
T= trachea; TY= thyroid gland; CA= carotid artery; IJV= internal jugular vein

Then navigate along the triangular-shaped sternocleidomastoid muscle, which is the uppermost superficial structure. Exactly under the tip of these muscles the two scalene muscles - anterior and medial scalene muscles - are visualized, slightly round in shape. The brachial plexus roots lie between the two scalene muscles directly under the tip of the sternocleidomastoid muscle and look like round to oval-shaped hypoechoic structures - normally three in number (the roots C5, C6 and C7) and well distinguishable from each other - that descend from the surface into deeper regions latero-medially. The ultrasound image is quite typical and reminds of a butterfly whose wings represent the two scalene muscles while the body represents the plexus roots.



SCMM = sternocleidomastoid muscle; ASM= anterior scalene muscle; MSM = medial scalene muscle; arrows= brachial plexus roots

To carry out the block use the IP (in plane) approach. After preparing the investigation area and the sterile probe, introduce the needle latero-medially along the long axis of the transducer (this is safer, since further away from the large vessels) in the same plane as the ultrasound beam. Slowly, continue to advance the needle as parallel as possible to the probe, keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)

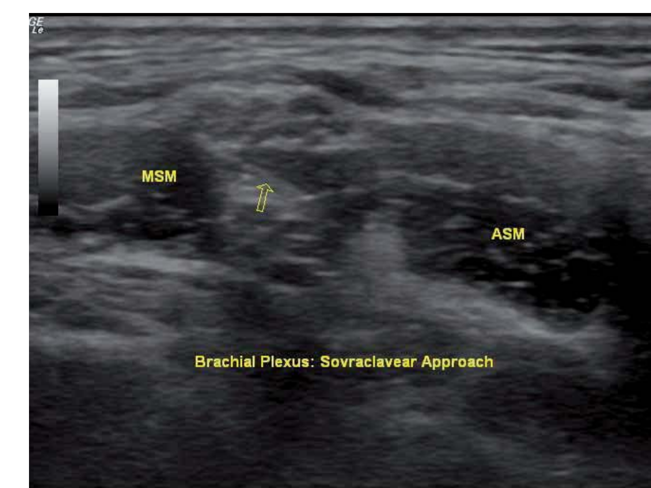


If required, identify the nerves using the nerve stimulator. Now inject the local anesthetic in fractional volumes while constantly controlling whether it is correctly spread around all nerve roots. The drug is depicted as a hypoechoic zone that gradually encompasses the nerves and dilates the scalene groove. If this is not observed, reposition the needle slightly to achieve optimal distribution.

SUPRACLAVICULAR BLOCK

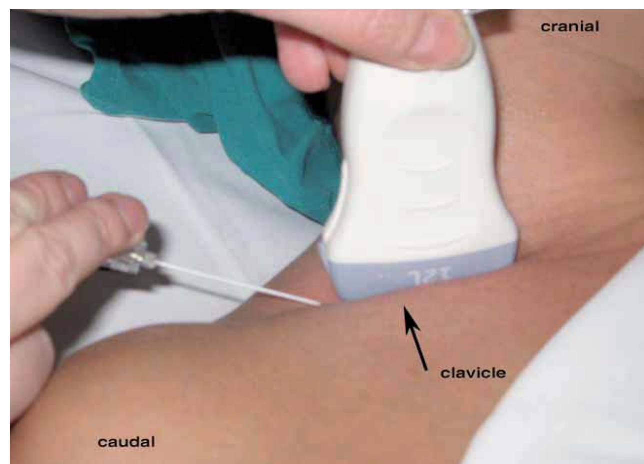
In the supraclavicular plane the plexus consists of trunks and divisions before it branches off under the clavicle. The patient is in supine position, the head is turned away from the side to be blocked. Use a linear high-frequency probe with 10 or 12 MHz. Place the probe in the supraclavicular space in a coronal oblique plane so that the plexus can be scanned transversely (the marker on the probe is directed towards the patient's right body side).

Start by scanning the sonoanatomy of the investigation area and first locate the vessels i.e., the subclavian artery which is identified as a hypoechoic, pulsating area and lies just above the first rib (hyperechoic) lateral to the anterior scalene muscle. Lateral to the artery are the trunks and ramifications of the brachial plexus, visualized as hypoechoic, round or oval-shaped structures clearly distinguishable from each other. Their number may vary strongly (5-7). The ultrasound image is quite typical and resembles the form of a bunch of grapes.



ASM= anterior scalene muscle; MSM= middle scalene muscle; arrows= brachial plexus roots

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle latero-medially along the long axis of the transducer (this is safer, since further away from the large vessels) in the same plane as the ultrasound beam. Slowly, continue to advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



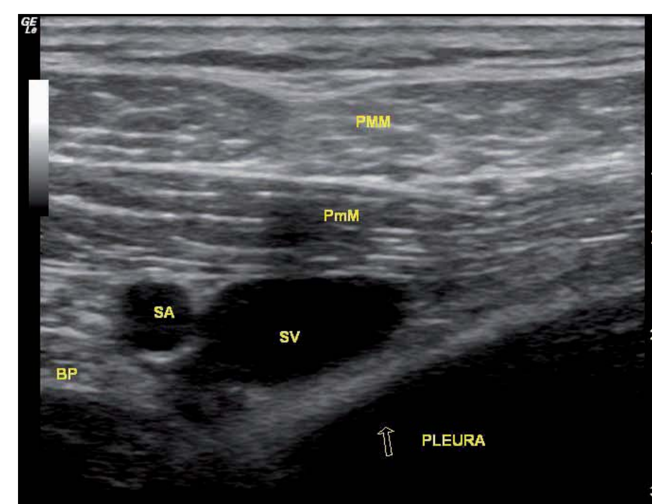
If required, identify the nerves using the nerve stimulator. Now inject the local anesthetic in fractional volumes while constantly controlling whether it is correctly spread around all nerve roots. The drug is depicted as a hypoechoic zone that gradually encompasses the nerves and dilatates the scalene groove. If this is not observed, reposition the needle slightly to achieve optimal distribution.

INFRACLAVICULAR BLOCK

In the infraclavicular plane the cords of the brachial plexus surrounding the axillary artery lie medial to the coracoid process of the scapula; the lateral cord is cephalad and lateral to the artery, the posterior cord is posterior to the artery, and the middle cord posterior and medial to the artery. The axillary vein lies medial to the artery.

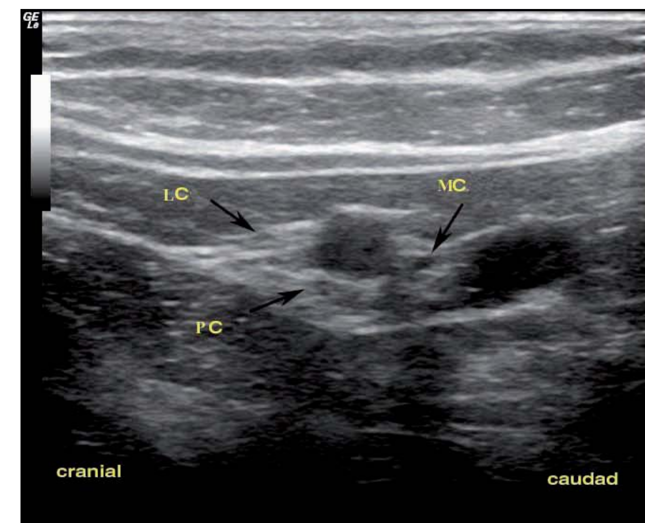
The patient lies supine with shoulders in neutral position and the arms lying at the side. Use a linear high-frequency probe with 7 MHz. Place the probe immediately medial to the coracoid process of the scapula under the clavicle in a parasagittal plane so that the plexus can be scanned transversely (the marker on the probe is directed towards the patient's head).

Start by scanning the sonoanatomy of the investigation area and identify the superficially located pectoralis major and pectoralis minor muscles - two narrow structures directly under the skin. One is first able to identify the large vessels, that is the axillary artery and the axillary vein, both of which are easily identified as hypoechoic structures: the artery is pulsating and the vein is compressible. In this region the acoustic enhancement artifact is often observed caused by the axillary artery. Directly under and medial to the vessels the pleura is identified as a linear hypoechoic structure.



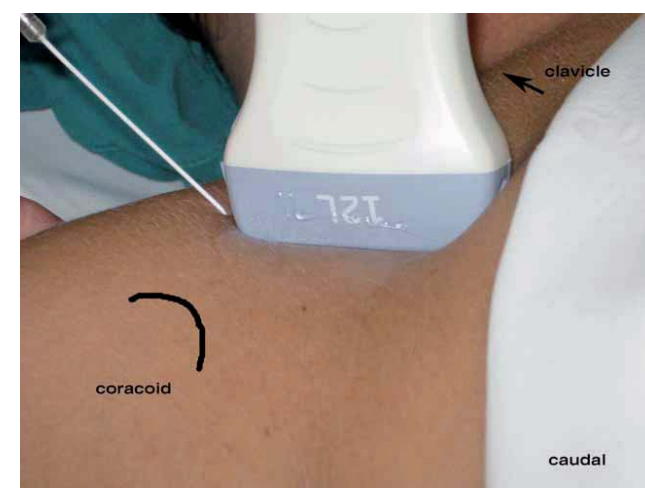
PMM = pectoralis major; PmM = pectoralis minor; SA = subclavian artery; SV = subclavian vein; BP = brachial plexus; arrow = pleura

The plexus cords appear as hypoechoic, slightly round structures surrounding the axillary artery. Usually the lateral and posterior cords are easy to identify; relative to the artery the lateral cord is in 10 o'clock position, the posterior cord is in 6 o'clock position and - if in view - the medial cord is in 3 o'clock position. When the arm is turned outward and abducted, the plexus cords move closer together laterally approaching the artery.



LC = lateral cord; PC = posterior cord; MC = medial cord

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle along the long axis of the transducer cranio-caudally in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



If required, identify the nerves using the nerve stimulator. Now inject the local anesthetic in fractional volumes while constantly controlling whether it is correctly spread around all nerve roots. The drug is depicted as a hypoechoic zone spreading out behind the axillary artery near the posterior cord. Attention: If the local anesthetic spreads in front of the artery or directly under the pectoral muscle, it means that the block has failed. In this case the needle must be repositioned to achieve optimal distribution.

AXILLARY BLOCK

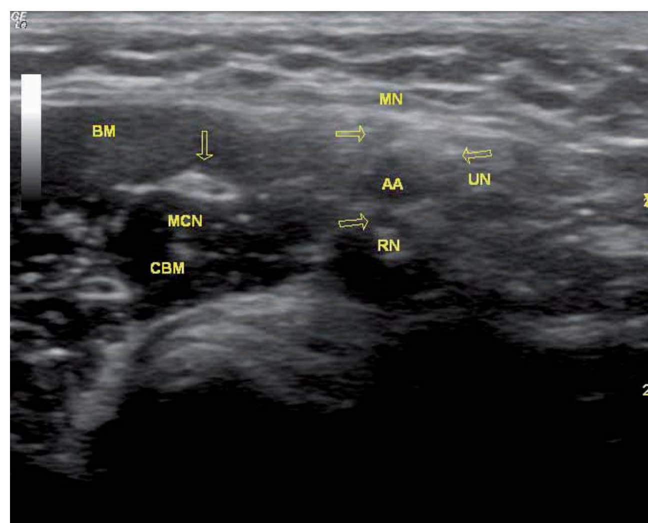
In the axilla, the terminal branches of the brachial plexus (ulnar, median, and radial nerves) meet near the artery. The musculo-cutaneus nerve, however, branches off more proximally from the plexus cords and proceeds from there dorsally and cranially while remaining near the plexus in the axillary region.

The patient is positioned as for a classical axillary approach, i.e. supine with the arm abducted at 90°C and the forearm flexed. Use a linear high-frequency probe with 10 or 12 MHz. Place the probe perpendicularly on the arm as close to the axilla as possible in the hollow formed between the biceps and the pectoralis muscle so that the plexus can be scanned transversely (the marker on the probe is oriented towards the patient's head).

Start by scanning the sonoanatomy of the investigation area. First locate the vessels, i.e. the easily identified hypoechoic axillary artery and then the axillary veins (1-4) which are more difficult to identify (because they are compressed by the transducer). Easy to identify are also the humerus (hyperechoic periosteum with a anechoic zone behind it), as well as, in a more superficial area, the biceps, and the coracobrachialis muscle, and the triceps medially more deeply under the artery.

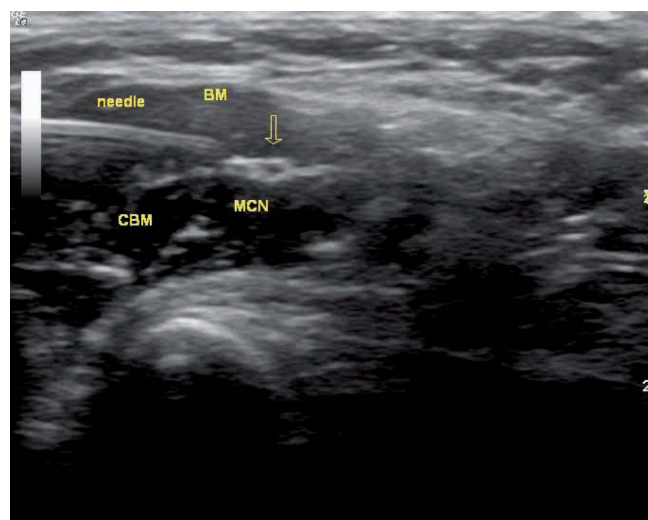
The nerve are visualized as hypoechoic, tubercular, round or oval-shaped structures surrounded by an internal hyperechoic ring (perineurium) that emits echos from the center (nerve fascicles). This ultrasound image of the individual nerves is quite typical and is also referred to as a honeycomb image.

The nerves are distributed quite differently around the artery; the median nerve is approximately in 7 to 12 o'clock position, the ulnar nerve in 12 to 3 o'clock position usually between the artery and the vein, the radial nerve in 3 to 7 o'clock position, though it is not always visible due to the artifact caused by the axillary artery (acoustic enhancement).



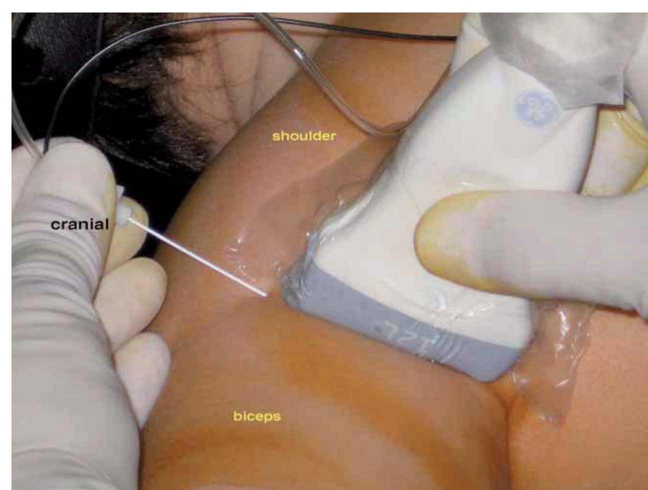
BM = Biceps muscle; CBM = coracobrachialis muscle; AA = axillary artery; MCN = musculocutaneus nerve; RN = radial nerve; UN = ulnar nerve; MN = median nerve

The musculocutaneus nerve is not located directly next to the artery, but is either within the body of the coracobrachialis muscle or between the coracobrachialis and biceps muscles. The nerve is easily identified: seen in cross-section it has a slender appearance. It is depicted as a hyperechoic structure with several internal hypoechoic zones.



CBM = coracobrachialis muscle; BM = biceps muscle; MCN = musculocutaneous nerve; Needle

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer cranio-caudally in the same plane as the ultrasound beam.
Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



If required, identify the nerves using the nerve stimulator. Now inject the local anesthetic in fractional volumes while constantly controlling whether it is correctly spread - starting at the musculocutaneous nerve (doughnut sign) - around all nerves . The drug is depicted as a hypoechoic zone that gradually spreads around the nerve. If this is not observed, the needle must be repositioned to achieve optimal distribution.

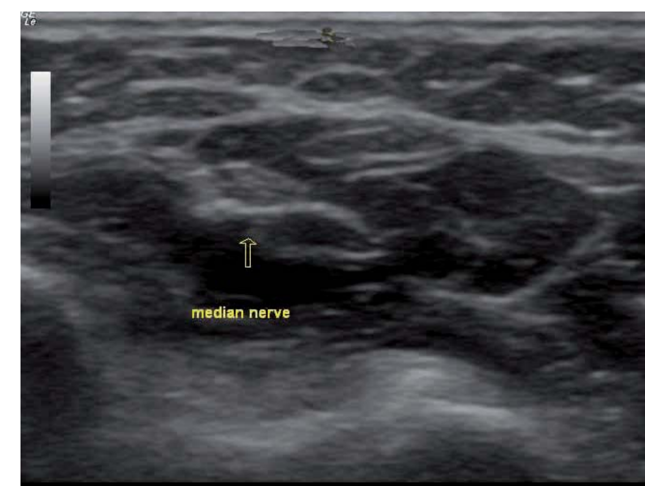
MEDIAN AND ULNAR NERVE BLOCK AT WRIST

MEDIAN NERVE

The median nerve is in the middle between the palmaris longus tendon and the flexor radialis carpi tendon. This nerve can be easily followed up to the elbow to find the best position for the block.

The patient is in supine position, the arm abducted at an angle of 90°C with the palm of the hand facing upward. Use a linear high-frequency probe with 10 or 12 MHz. Place the probe on the interior side of the wrist in a tangential plane so that the nerve can be scanned transversely (the marker on the probe is directed towards the patient's head).

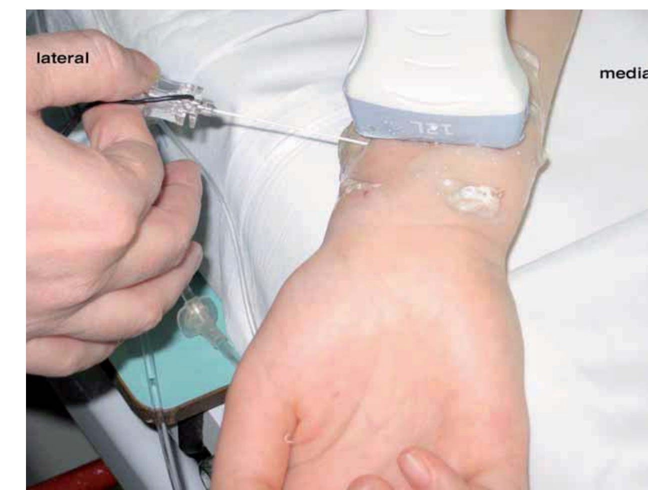
The median nerve is depicted as a well defined, independent, round and hyperechoic structure. In correspondence with the nerve fascicles (honeycomb image) hypoechoic signals are identified within the structure.



Median nerve at wrist (fig9)

The nerve is easily mistaken for a tendon though these deliver stronger echos; to clearly identify the nerve it is possible to just follow its course proximally which in contrast to that of a tendon does not change.

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



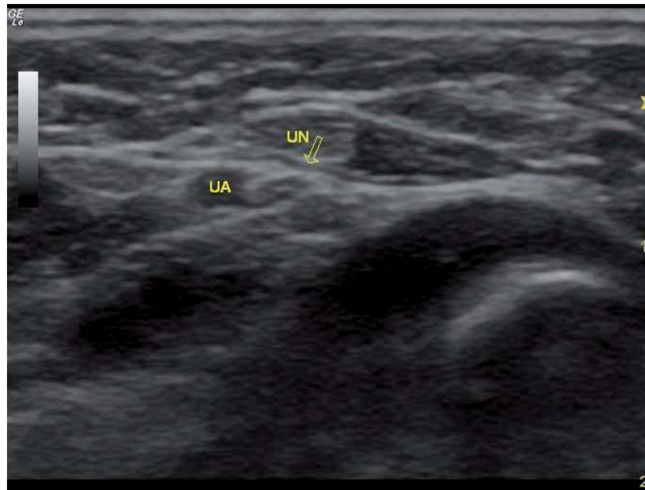
If required, identify the nerves using the nerve stimulator. Now inject the local anesthetic while constantly controlling whether it is correctly spread. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign). If this is not observed, the needle must be redirected toward the other side of the nerve to achieve optimal distribution.

ULNAR NERVE

The ulnar nerve at wrist is lateral to the ulnar artery. This nerve can be easily followed up to the elbow to find the best position for the blockade. The patient is in supine position, the arm abducted at an angle of 90°.

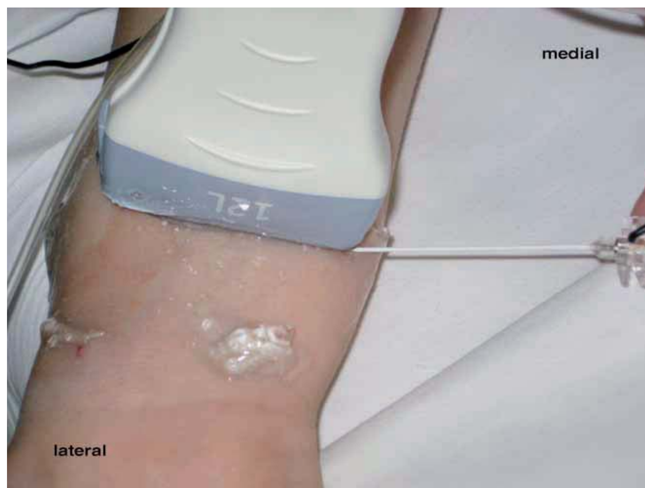
Use a linear high-frequency probe with 10 or 12 MHz. Place the probe on the interior side of the wrist in a tangential plane so that the nerve can be scanned transversely (the marker on the probe is directed towards the patient's head). The ulnar nerve is depicted as a well defined, independent, round and hyperechoic structure. In correspondence with the nerve fascicles (honeycomb image) hypoechoic signals are identified within the structure.

The nerve is easily mistaken for a tendon though these deliver stronger echos; to clearly identify the nerve it is possible to just follow its course.



UA= ulnar artery; UN= ulnar nerve at the wrist

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



If required, identify the nerves using the nerve stimulator. Now inject the local anesthetic while constantly controlling whether it is correctly spread. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign). If this is not observed, the needle must be redirected toward the other side of the nerve to achieve optimal distribution.

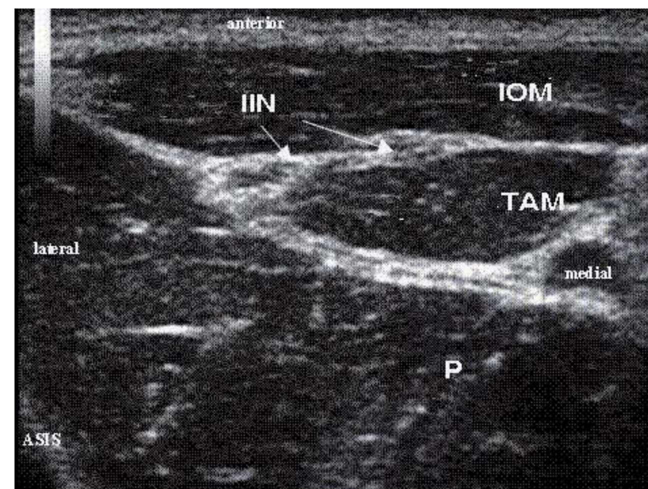
TRUNK

ILIOINGUINAL AND ILIOHYPOGASTRIC NERVES BLOCK

The ilioinguinal and iliohypogastric nerves are branches of the lumbosacral plexus that penetrate the lumbodorsal fascia from the sideward margin of the musculus quadratus lumborum and continue along the abdominal wall between the internal oblique muscle and the transversus abdominis muscle.

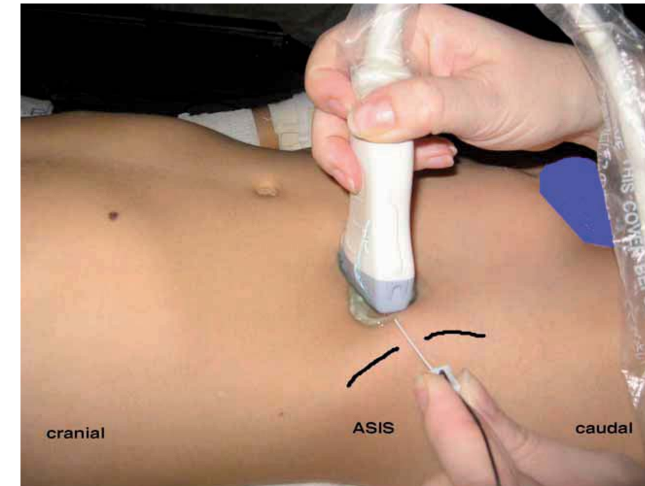
The patient is in supine position. Use a linear high-frequency probe with 10 or 12 MHz. Place the probe on the abdomen near the anterior superior iliac spine in a tangential plane so that the nerves can be scanned transversely (the marker on the probe is directed towards the patient's right side).

Start by scanning the sonoanatomy of the investigation area. First locate the hyperechoic image of the anterior superior iliac spine then the muscles of the front abdominal wall, or more precisely, the more superficial internal oblique muscle and the deeper transversus abdominis muscle. The (hyperechoic) peritoneum can be seen directly under the transversus abdominis muscle. The ilioinguinal und iliohypogastric nerves are depicted as well defined, independent, slender hyperechoic structures.



IOM = internal oblique muscle; TAM = transversus abdominis muscle; P = peritoneum; IIN = ilioinguinal and iliohypogastric; ASIS = anterior superior iliac spine

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer latero-medially in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



Now inject the local anesthetic in small volumes while constantly controlling whether it is correctly spread. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign). If this is not observed, the needle must be redirected toward the other side of the nerve to achieve optimal distribution.

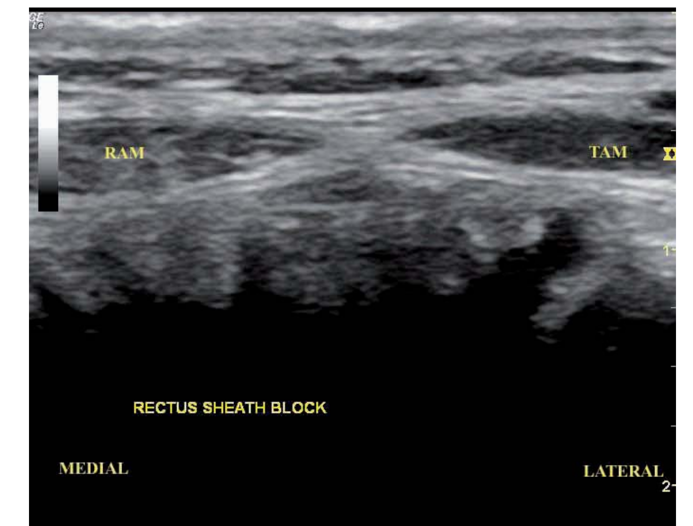
PARAUMBILICAL BLOCK

The paraumbilical block is generally used in pediatric surgery to correct umbilical hernia. For this purpose the tenth intercostal space nerve in the umbilical region is blocked. The patient is in supine position.

Use a linear high-frequency probe with 10 or 12 MHz. Place the probe on the abdomen near the umbilicus in a tangential plane so that the abdominal muscles can be scanned transversely (the marker on the probe is directed towards the patient's right body side). The blockade is performed bilaterally.

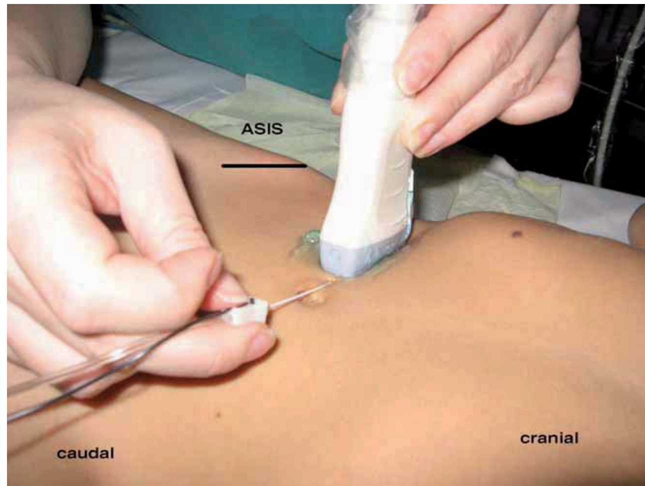
Start by scanning the sonoanatomy of the investigation area (first on the left side then on the right side of the umbilicus) to locate the rectus abdominis muscle. Then follow the belly of this muscle to its lateral border; on the outside the aponeuroses of the internal oblique muscle and the transverse muscle can be identified.

Since the tenth intercostal space nerve cannot be visualised by ultrasound, the blockade is performed by injecting the local anesthetic between the lateral border of the rectus abdominus muscle and the aponeuroses of the internal oblique muscle and the transverse muscle.



RAM= rectus abdominus muscle; TAM= transversus abdominis muscle

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



Now inject the local anesthetic in small volumes while constantly controlling whether it is correctly spread.

LOWER EXTREMITY

The lower extremity is supplied by the nerves of the lumbo-sacral plexus which are the femoral nerve, the ilioinguinal and iliohypogastric nerves, the obturator nerve, the lateral femoral cutaneous nerve and from the sacral plexus by the sciatic nerve which divides in the lower third of the thigh into the tibial nerve and the common peroneal nerve.

FEMORAL NERVE BLOCK

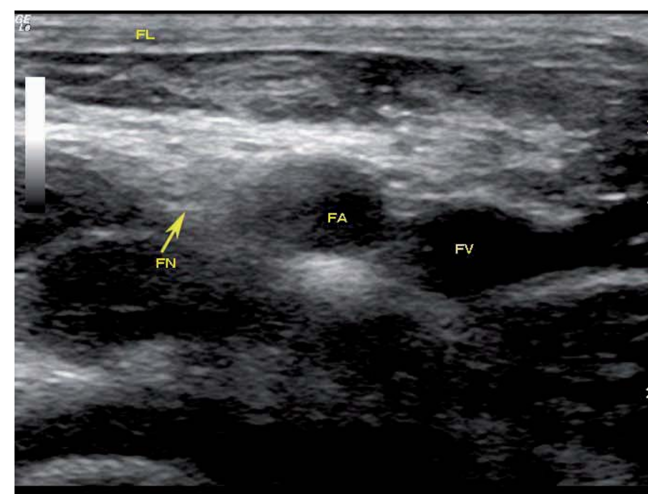
The largest branch of the lumbosacral plexus is the femoral nerve. It arises from the psoas muscle and continues under the inguinal ligament lateral to the femoral artery covered by the fascia iliaca. Here one can distinguish two divisions: the deeper branches that innervate the quadriceps muscles, and the superficial branches that innervate the sartorius muscle, the pectineus muscle, and the skin.

The patient lies supine with hands in neutral position.

Use a linear high-frequency probe with 10 or 12 MHz. Place the probe in the inguinal crease in a perpendicular plane so that the nerves can be scanned transversely (the marker on the probe is directed towards the patient's right body side).

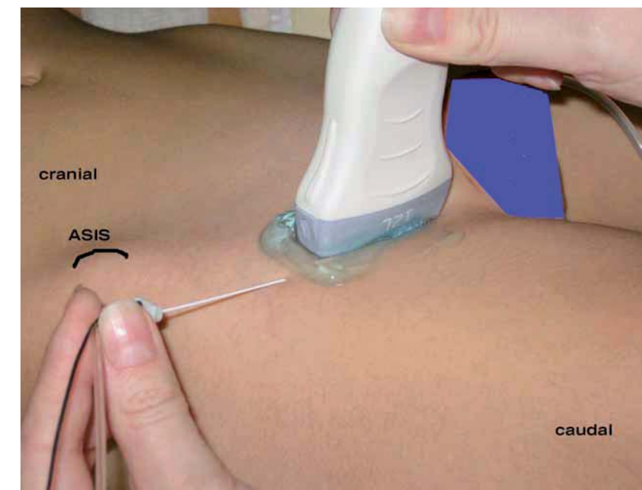
Start by scanning the sonoanatomy of the investigated region. First locate the large vessels, the lateral femoral artery, and the medial femoral vein. These are easily identified hypoechoic structures; the former is pulsatile, the latter is compressible. In this region acoustic enhancement is often observed caused by the femoral artery.

The nerve-vessel bundles are located very close to the skin, above the hyperechoic fascia lata, then the fascia iliaca which lies deeper and separates the femoral nerve from the femoral artery. Directly lateral to the artery, the femoral nerve is identified as a hyperechoic, triangular, indistinct structure. This is because the nerve immediately divides into its terminal branches.



FL = fascia lata; FA = femoral artery; FV = femoral vein;
FN = femoral nerve

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer latero-medially (this is safer, since further away from the large vessels) in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



If required, identify the nerves using the nerve stimulator.

Now inject the local anesthetic in fractional volumes while constantly controlling whether it is correctly spread around the nerves. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign). If this is not observed, the needle must be redirected toward the other side of the nerve to achieve optimal distribution. One of the main reasons for block failure here, is that the anesthetic does not penetrate the fascia iliaca and is not distributed around the nerve but remains in the upper layers.

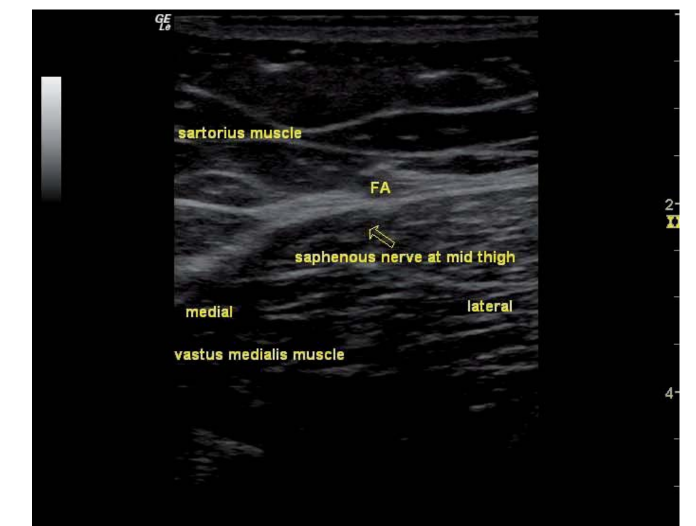
SAPHENOUS NERVE BLOCK

The saphenous nerve is the final sensory branch of the femoral nerve. The saphenous nerve travels with the femoral artery; the course of both structures can be followed along the medial aspect of the thigh. About half way up the thigh the femoral artery passes toward the popliteal crease; the saphenous nerve, however, lies between the sartorius muscle above and the vastus medialis below. The diameter of this nerve varies considerably.

The patient lies supine with the leg in neutral position.

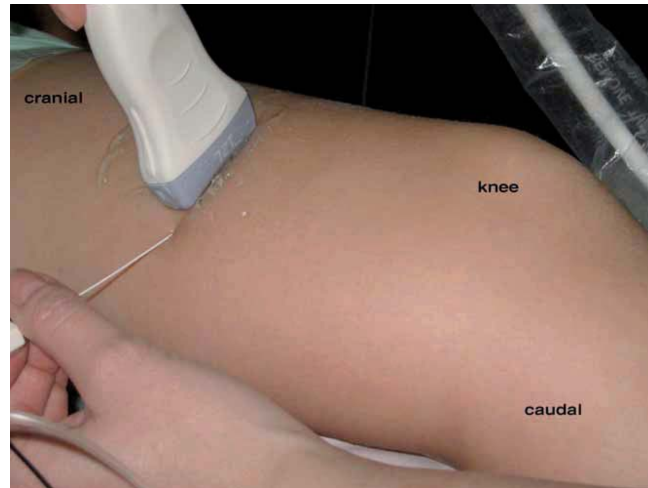
Use a linear high-frequency probe with 10 or 12 MHz. Place the probe on the medial side of the thigh lateral to the sartorius muscle in a perpendicular plane so that the nerve can be scanned transversely (the marker on the probe is directed towards the patient's right body side). Start by locating the femoral artery that is identified as a hypoechoic, pulsating structure.

Then proceed deeper where the muscle bundles of the sartorius muscle and the vastus medialis can be identified. The saphenous nerve is identified as a hyperechoic, slender structure with internal hypoechoic signals (honeycomb image). It is encompassed by the posterior bundle of the sartorius muscle.



FA = arteria femorale; freccia = nervo safeno;
sartorius muscle = muscolo sartorio;
vastus medialis muscle = muscolo vasto mediale

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)



Now inject the local anesthetic in small fractionatal volumes while constantly controlling whether it is correctly spread around the nerve. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign) or dilatates the muscle bundle. If this is not observed, the needle must be redirected toward the other side of the nerve to achieve optimal distribution.

SCIATIC NERVE BLOCK

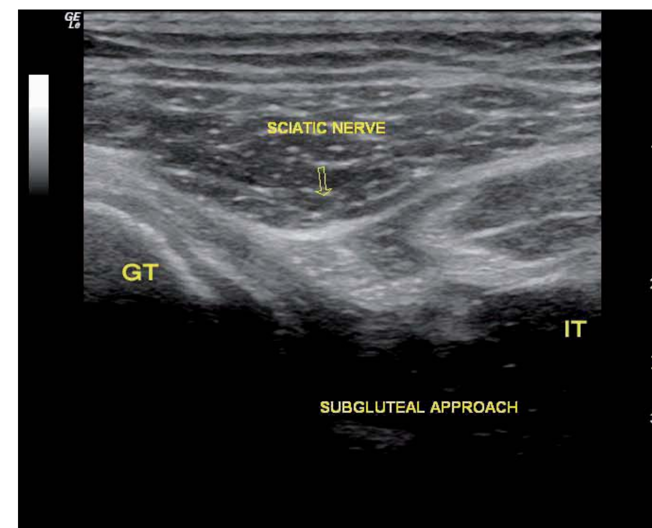
The sciatic nerve originates from the lumbosacral plexus (L4-S3). The nerve enters the gluteal region through the periformis muscle lateral to the ischial tuberosity where it is above the obturator muscle and the gemellus muscle and below the gluteus maximus muscle. From there it descends in a medial line to the posterior popliteal space of the thigh until it divides in the popliteal groove into its terminal branches which are the tibial nerve and the common peroneal nerve. The level at which this division takes place varies considerably. Generally the division is between 7 and 10 cm above the popliteal crease but can also lie half way up the thigh. The sciatic nerve can be blocked at any level.

SUBGLUTEAL APPROACH

The sciatic nerve which is covered proximally by the gluteus maximus muscle lies in the middle between the ischial tuberosity and lateral to the great trochanter. The patient is in prone or in lateral position with the uppermost leg to be blocked slightly flexed. Use a linear high-frequency probe with 7 MHz. Place the probe on the line between the ischial tuberosity and the great trochanter in a perpendicular plane so that the nerve can be scanned transversely. (The marker on the probe is directed towards the right side of the bed.)

Start by scanning the sonoanatomy of the investigated region. First locate the hyperechoic contours of both bone structures by moving the probe in medial and lateral directions.

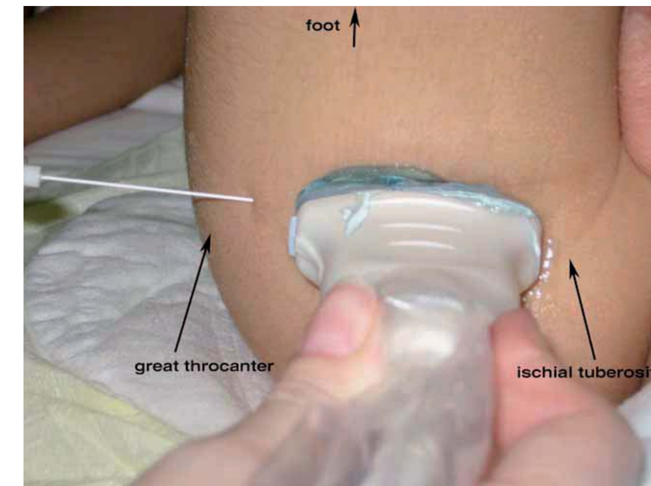
Then the large muscle belly of the gluteus maximus muscle can be identified; in the middle beneath the muscle, the nerve can be seen visualized as a well defined, hyperechoic structure and is band-shaped and flattened, because it is compressed between two muscles (gluteus maximus muscle and quadratus femoris muscle.



IT = ischial tuberosity ; GT = great trochanter

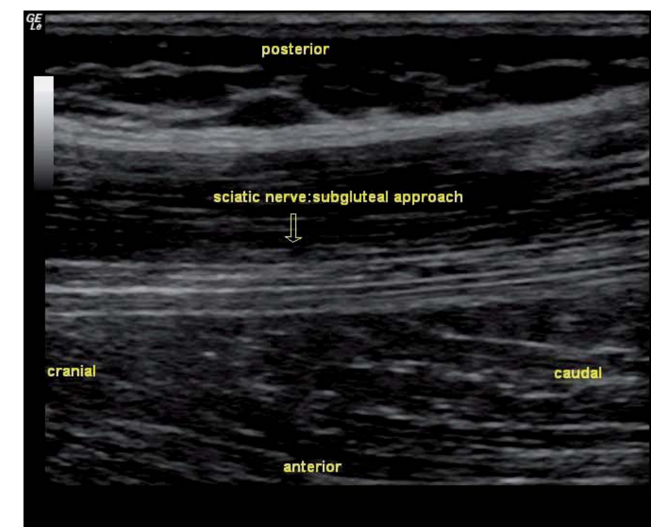
To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer latero-medially in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)

Since this nerve is relatively large, it can also be easily scanned longitudinally by simply rotating the probe by 90 degree This way it is possible to use always the in plane approach. One only needs to advance to the nerve along its long axis. This approach is preferable, if a cather is to be placed.



Locate the nerve with help of nerve stimulation.

Now inject the local anesthetic in small fractional volumes while constantly controlling whether it is correctly spread concentrically around the nerve. For this purpose, it is necessary to first position the needle under and then above the nerve. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign).



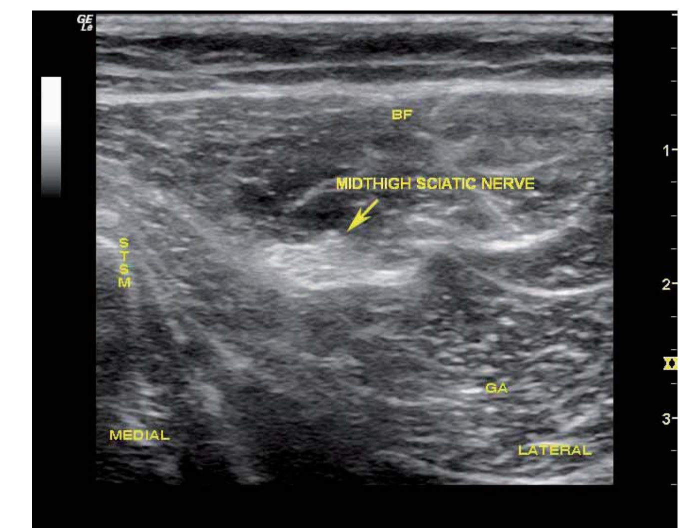
Arrow = sciatic nerve

MIDFEMORAL APPROACH

The sciatic nerve is easily located and can also be blocked half way up the thigh. In this area the nerve is largely concealed by the biceps femoris and medially slightly by the semimembranosus and semitendinous muscles; underneath lies the adductor magnus.

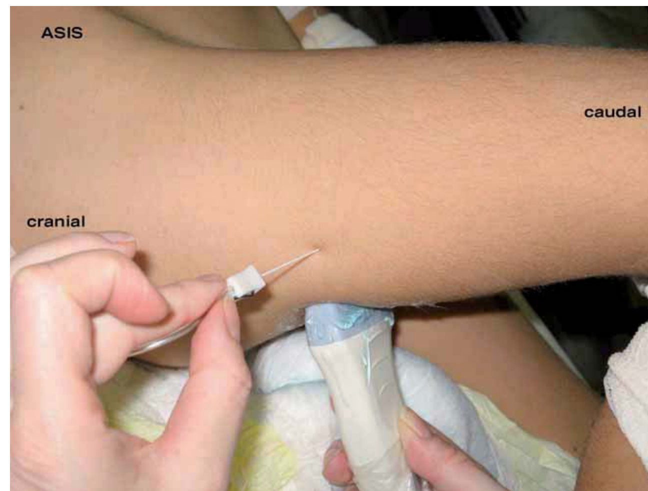
The patient is in prone or supine position with the leg to be blocked slightly flexed. Use a linear high-frequency probe with 7 MHz. Place the probe perpendicularly on the median line of the posterior part of the thigh so that the nerves can be scanned transversely. (If the patient is in prone position orientate the marker towards the right side of the bed, if the patient is in supine position to the patient's right body side.)

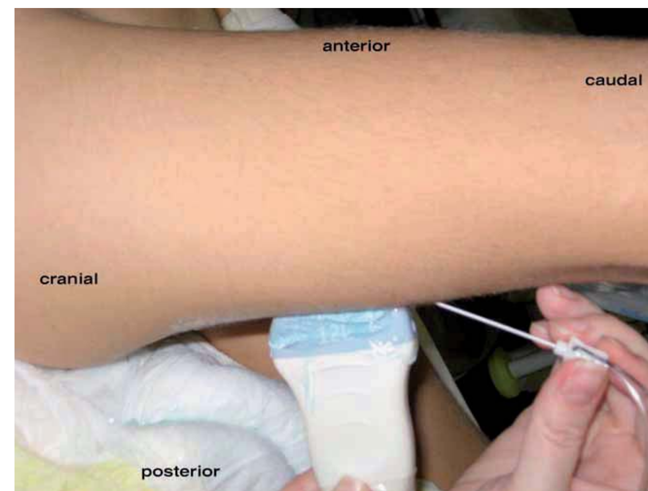
Start by scanning the sonoanatomy of the investigation area. Locate the bellies of the two muscles that encompass the nerve: the biceps femoris and the adductor magnus. In this plane the nerve appears as a well defined, hyperechoic structure that is either triangular or oval in shape.



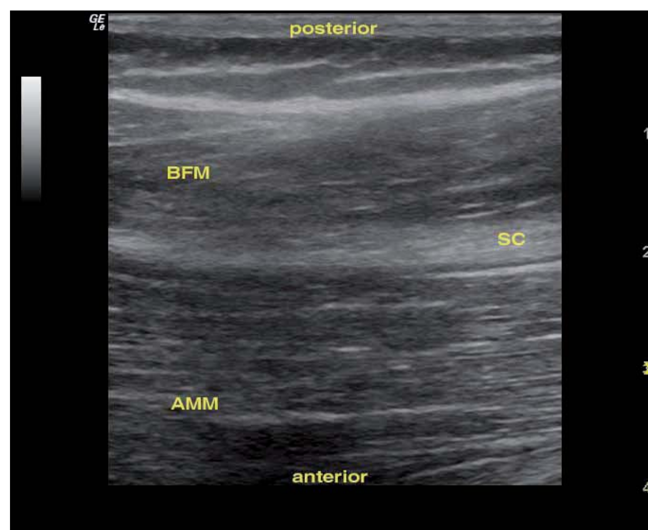
BF = biceps femoris; GA = adductor magnus;
STSM = semitendinosus and semimembranosus muscles

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer latero-medially in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)





Since this nerve is relatively large, it can also be easily scanned longitudinally by simply rotating the probe by 90 degree This way it is possible to use the in plane approach. One only needs to advance to the nerve along its long axis. This approach is preferable, if a cather is to be placed.



BFM = biceps femoris; AMM = adductor magnus; SC = sciatic nerve

Locate the nerve with help of nerve stimulation. Now inject the local anesthetic in small fractional volumes while constantly controlling whether it is correctly spread concentrically around the nerve. For this purpose, it is necessary to first position the needle under and then above the nerve. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign).

POPLITEAL APPROACH

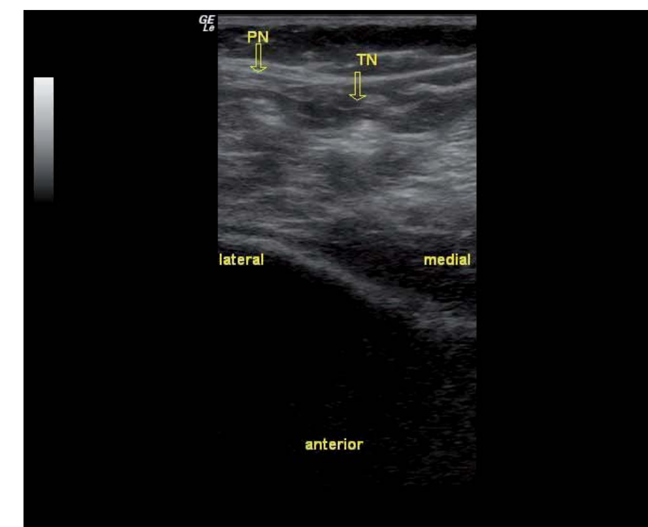
The sciatic nerve is circumscribed in the popliteal groove superolaterally by the long head of the biceps femoris muscle and superomedially by the semitendinosus and semimenbranosus muscles. At this level the sciatic nerve divides into its terminal branches the tibial nerve and the common peroneal nerve.

The patient is in prone or supine position with the leg to be blocked slightly flexed. Use a linear high-frequency probe with 7 MHz. Place the probe perpendicularly in the hollow of the knee so that the nerve can be scanned transversely. (If the patient is in prone position orientate the marker towards the right side of the bed, if the patient is in supine position to the patient's right body side.)

Start by scanning the sonoanatomy of the investigation area. Locate the popliteal artery (hypoechoic, pulsating, easily identified with a Color Doppler) and the bellies of the muscles that encompass the nerve: the biceps femoris, the semitendinosus and semimembranosus muscles as well as the adductor magnus beneath.

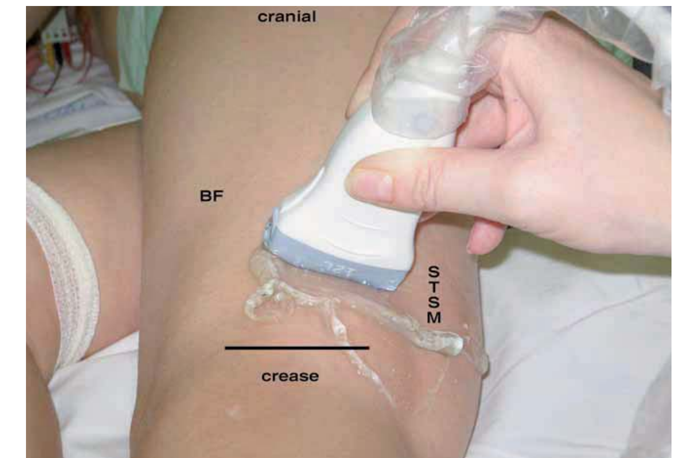
The nerve is lateral to the popliteal artery and appears as a hyperechoic structure with internal well-defined, oval-shaped areas. It is important to follow the nerve's course upward and downward to establish the exact position where the nerve divides. Our aim is to block the nerve before the point of its separation.

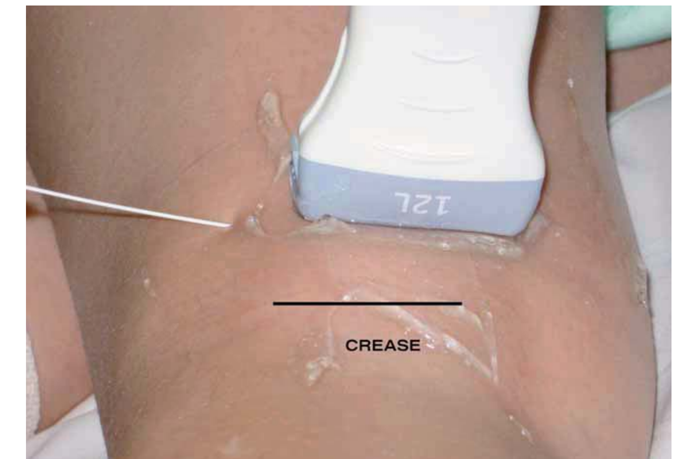
Popliteal crease level; arrow = sciatic nerve



TN= tibial nerve; PN= peroneal nerve

To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer latero-medially in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)





Since this nerve is relatively large, it can also be easily scanned longitudinally by simply rotating the probe by 90 degree. This way it is possible to use the in-plane approach. One only needs to advance to the nerve along its long axis. This approach is preferable, if a cather is to be placed.
Locate the nerve with help of nerve stimulation.
Now inject the local anesthetic in small fractional volumes while constantly controlling whether it is correctly spread concentrically around the nerve. For this purpose, it is necessary to first position the needle under and then above the nerve. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign).

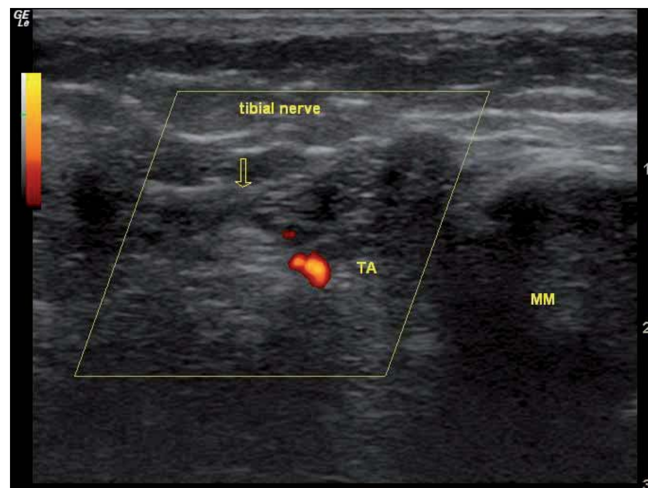
ANKLE BLOCK

The sciatic nerve divides into four terminal branches for the innervation of the ankle. These are: the tibial nerve, the deep peroneal nerve, the superficial peroneal nerve and the sural nerve. Only two of these nerves can be depicted sonographically: the tibial nerve and the deep peroneal nerve. To block the saphenus nerve see under the relevant section.

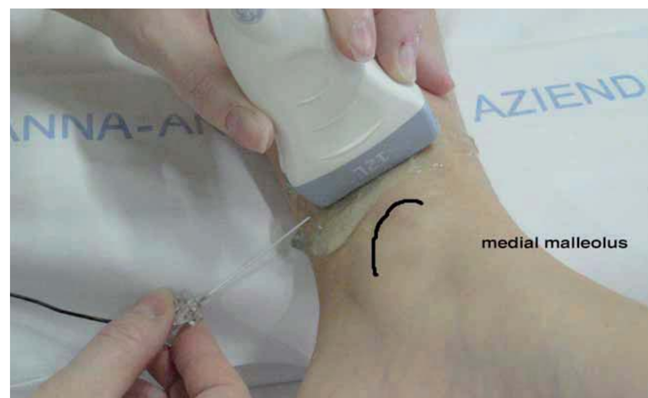
TIBIAL NERVE BLOCK

The patient is in supine position.

Use a linear high-frequency probe with 10 or 12 MHz. Place the probe above the medial malleolus in a perpendicular plane so that the nerve can be scanned transversely (orientate the marker on the probe towards the patient's right body side). Start by scanning the sonoanatomy of the investigation area. Locate the posterior tibial artery (hypoechoic, pulsating, easily identified with a Color Doppler) that lies medial to the malleolus. The tibial nerve is posterior to the popliteal artery (5-7 o'clock position) and appears as a hyperechoic, round, well-defined structure.



TA = tibial artery; MM = medial malleolus; arrow = tibial nerve



To carry out the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer latero-medially in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.) It is possible toocate the nerve with help of nerve stimulation.

Now inject the local anesthetic while constantly controlling whether it is correctly spread concentrically around the nerve. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign).

DEEP PERONEAL NERVE BLOCK

The patient is in supine position.

Use a linear high-frequency probe with 10 or 12 MHz. Place the probe medially above the medial malleolus on the anterior part of the leg in a perpendicular plane so that the nerve can be scanned transversely (orientate the marker on the probe towards the patient's right body side).

Start by scanning the sonoanatomy of the investigation area. Locate the dorsalis pedis artery (small, hypoechoic, pulsating, easily identified with a Color Doppler) lateral to the malleolus. The deep peroneal nerve is exactly lateral to artery and appears as a small, hyperechoic, circular structure.

MM = medial malleolus ; DPA = dorsal pedis artery; arrow deep peroneal nerve

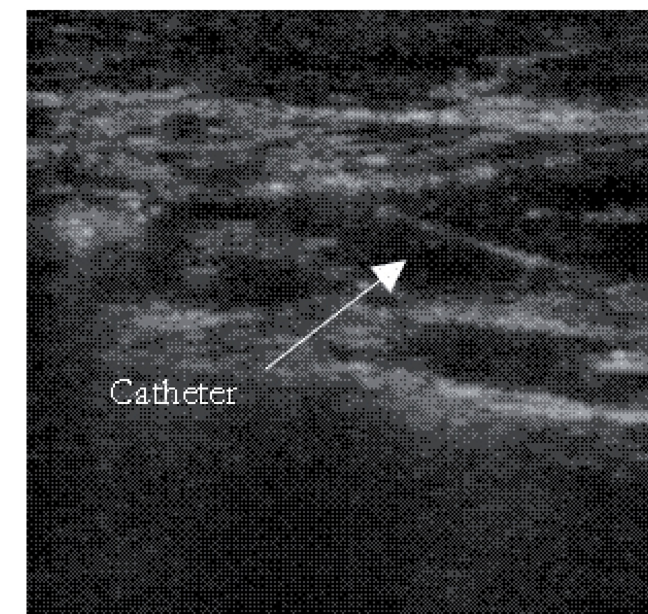
To perform the block use the IP approach (in plane). After preparing the investigation area and the sterile probe, introduce the needle in line with the long axis of the transducer latero-medially in the same plane as the ultrasound beam. Slowly, advance the needle as parallel as possible to the probe keeping the needle tip visible at all times. (Do not insert the needle, if the tip is not clearly visible.)

Now inject the local anesthetic while constantly controlling whether it is correctly spread concentrically around the nerve. The drug is depicted as a hypoechoic zone that gradually spreads around the whole nerve (doughnut sign).

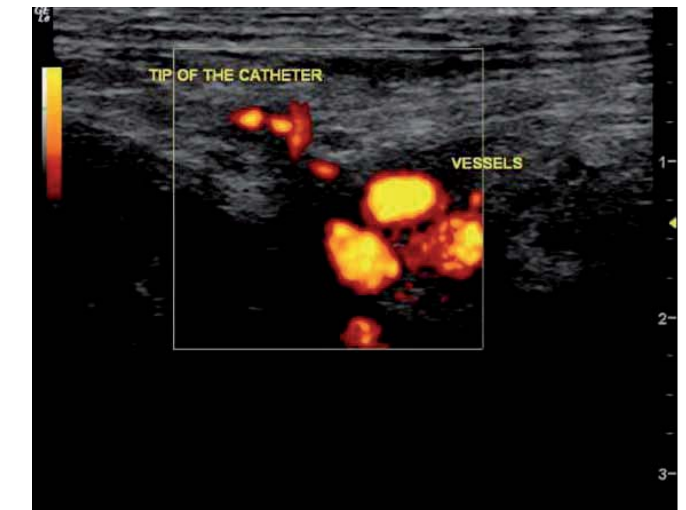
PERINEURAL CATHETER

For a longer pain treatment the placement of a perineural catheter is recommended. The catheter is not always identifiable by ultrasound technique, usually its position
is indirectly established during placement. However, there are some possibilities that facilitate its identification.

1. In pediatrics catheters are often equipped with a metal stylet. This is easy to identify with ultrasound.



2. In the adult patient, the tip of the catheter can de identified with the Color Doppler while injecting 1 ml of local anesthetic or dextrose.



Tip of the catheter; vessels

It is recommended to introduce the catheter in line with the long axis of the nerves. This especially applies to the femoral and sciatic nerves, because they are also identifiable in the longitudinal approach. In any case the needle is always introduced with the IP approach.

In the upper limb however, it is extremely difficult to identify the nerves along their long axis; therefore when placing a catheter here, the same approach should be chosen that one applies for a single shot. The OOP approach can be used alternatively.

EUROPE
GE Ultraschall Deutschland GmbH
Beethovenstr. 239
D-42655 Solingen
T 49 212-28 02-0
F 49 212-28 02 28

UNITED KINGDOM
GE Medical Systems Ultrasound
2, Napier Road
Bedford MK41 0JW
Phone: (+44) 1234 340881
Fax: (+44) 1234 266261

AMERICAS
GE Medical Systems
Milwaukee, WI, USA
Fax: (+1) 262 544-3384

ASIA
GE Medical Systems
Tokyo, Japan
Fax: (+81) 3-3223-8524
Shanghai, China
Fax:(+86) 21-5208 0582

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