

# Ultrasound-Guided Punctures in Anesthesia

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In the last few years, the search for better and more precise methods of nerve localization has brought ultrasonography in the field of the anesthesiologic literature. Although already describes for central venous access, ultrasonography never gained such an interest as now. Thanks to portability, bedside accessibility, and most importantly, real-time anatomical examination, ultrasonography is becoming the imaging modality of choice for the anesthetist. Basic knowledge of ultrasonography, description of puncture techniques and their application for vascular access and nerve blocks are hereafter described. Other indications of ultrasonography in anesthesia and future development of this technique are also discussed.

## ULTRASONOGRAPHY

An ultrasound (US) probes generates sound waves and collects their reflection, or echo. Reflection is produced when interfaces between tissues with different acoustic impedance are encountered. The amplitude of the reflected signal is then displayed on a gray scale digital monitoring as varying degrees of brightness corresponding to the tissue location and its degree of echogenicity. As a rule of thumb, body fluids and infiltrations appears as "anechoic" (black); bone, tendons and peripheral nerves as "hyperechoic" (white); soft tissue, vessels wall, muscle and nerve trunks as "hypoechoic" (different gray scale). Air does not conduct US and causes major artifacts if present between the probe and the skin or accidentally injected through the needle.

Sound waves in the frequency range of 2 to 15 MHz are used in medical diagnostic applications. In general, as US wave frequency increases, wavelength decreases and an higher resolution is seen, but with lower tissue penetration. Conversely, lower-frequency US waves result in deeper penetration, but with a lower image resolution. For vessel puncture and most nerve blocks, probes producing frequencies in the range between 5 and 10 MHz are correct. Higher frequencies are preferable for puncture

in infants or for small superficial nerves infiltrations. Lower frequencies with deeper penetration are needed for deeper blocks in obese patient (sciatic block) or for abdominal screening.

Linear array probes are preferred because they give an precise image of the underlying anatomy without distortion. In brief, an ultrasonographic equipment for anesthesiologists should have these characteristics :

- quickly ready to start (no long warm-up)
- easy to use (avoiding unused buttons or functions)
- able to work on battery (in case of difficult electricity plugging)
- portable and resistant to some shocks (will be used in different locations by different persons)
- a standard 5 to 10 MHz linear probes with Color Doppler
- possibility to connect other probes (pediatric, TEE, or an abdominal probe)
- able to save images and to transfer video clips to an external recorder

## PUNCTURE TECHNIQUE

After image optimization by using the right probe, penetration depth and frequency, the first step is to screen the area in order to identify the underlying anatomy. This needs a lot of transducing gel because large movements will indeed be made; nerves need to be followed over a certain distance to confirm their identity; vessels are screened for thrombosis. The finally chosen puncture site depends on the target's visibility and can be different from the puncture site of a classical landmark technique (1).

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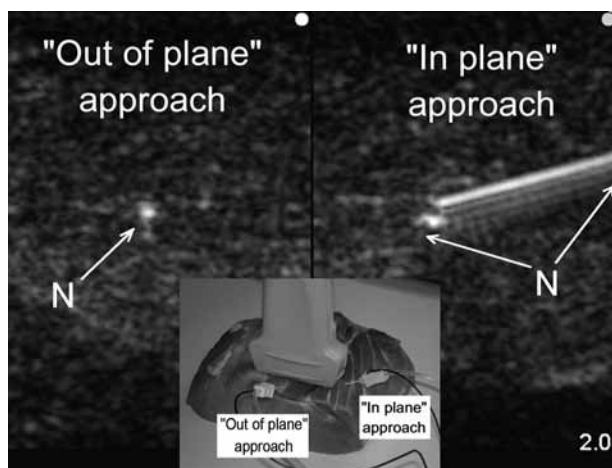


Fig. 1. — The US appearance of a 22ga short-bevel-needle (N). Left : the “out of plane” approach showing a small hyperechoic dot. Right : the “in-plane” approach showing the entire needle from shaft to tip. Training of these 2 techniques is performed on a piece of meat.

The next step is to insert and visualize the needle. Two different approaches are currently used : the “out-of-plane” and the “in-plane” approach (Fig. 1). Characteristics, advantages and disadvantages of these approaches are summarized in Table 1. Rather than choosing only one of these approaches, the anesthesiologists should learn both in order to use their respective advantages according to the puncture to be performed.

Factors that influence needle visibility are : the size of the needle, the angle between needle and US beam, the presence of an irregular surface (bevel). Specific “US needle” are coming on the market but at the present time their contribution is

limited. Larger needle, placed as perpendicular as possible to the US beam, with the bevel directed towards the probe will give the best ultrasonographic image (2).

The 3 basic steps of learning US guided punctures are : 1) pattern recognition of the ultrasonographic appearances of nerve, vascular and musculoskeletal structures ; 2) probe handling and scanning skills to capture target images ; 3) manual dexterity to align the needle to the ultrasound beam and move the needle to hit the target. While the two first steps can be learned during hands-on workshops under supervision, eye hand coordination and US needling skills should be acquired on phantoms (gel block, turkey breast or other dummy) prior to patient care (Fig. 1) (3-5).

Placement of central venous line or catheters for continuous nerve block requires a strict sterile technique including sterile gel and a sterile cover for the probe. Single shot peripheral nerve blocks can be performed without sterile cover if the needle is not inserted too close to the probe and if sterile gel is used on a disinfected skin.

#### VASCULAR ACCESS

Reasons for failure to cannulate central venous (CV) lines based on external landmarks are : abnormal vein location, small size or extreme hypovolemia and thrombosis. This is precisely what US are able to highlight : visualization of the vessels, showing their patency, position and residual thrombosis or narrowing due to prior attempts. CV

Table 1

Comparison of two different approaches used for US-guided punctures

	“Out of plane” approach (“Short axis”, “transversal”)	“In plane” approach (“long axis”, “longitudinal”)
Description	The needle is inserted perpendicularly to the probe and crosses the US plane	The needle is inserted in line with the US plane of the probe
Needle appearance	Hyperechoic spot with an acoustic shadow	Hyperechoic line
Advantages	<ul style="list-style-type: none"> <li>– Shorter insertion path</li> <li>– More patient’s comfort</li> <li>– Easier to insert a catheter or a guidewire</li> </ul>	<ul style="list-style-type: none"> <li>– Better needle visibility (shaft and tip)</li> <li>– Ability to continuously track needle advancement</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>- Poorer visualization of the needle</li> <li>- More frequent inadvertent vascular punctures (?)</li> </ul>	<ul style="list-style-type: none"> <li>– Longer insertion path</li> <li>– Less patient’s comfort</li> <li>– “Non-physiologic” catheter insertion</li> <li>– More time consuming (?)</li> </ul>
Difficulty	Differentiation between the tip and the shaft of the needle	Keeping the needle precisely within the image plane
Advices	<ul style="list-style-type: none"> <li>- Perform skin puncture at a certain distance of the US probe</li> <li>- Perform short in-and-out motion with the needle to detect the tip</li> </ul>	<ul style="list-style-type: none"> <li>– Train hands-eyes coordination</li> <li>– Position the US monitor in-line with the skin puncture site</li> </ul>

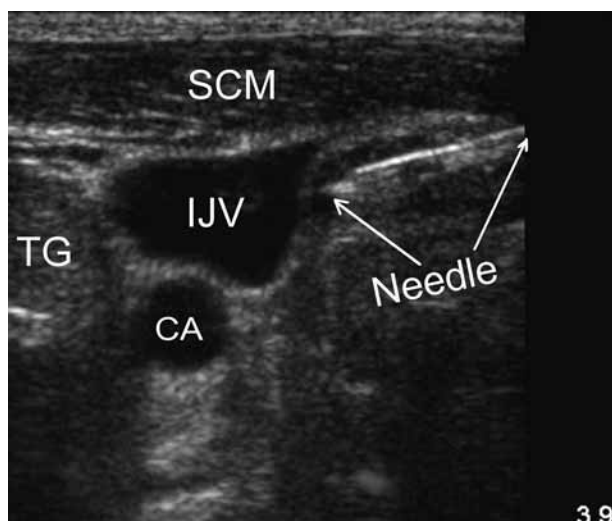


Fig. 2. — Transverse sonogram in the right cervical region showing an “in-plane” technique for internal jugular vein puncture by the posterior approach. Shaft and tip of the 18ga needle is clearly visualized during its advancement. TG : thyroid gland, SCM : sternocleidomastoid muscle, IJV : internal jugular vein, CA : carotid artery.

line-related thrombosis are frequent but underestimated because often asymptomatic and not systematically screened (6). Thrombosis appears as an hypoechoic structure into the anechoic vessel's lumen, reducing its compressibility.

US also offers direct guidance for needle puncture (Fig. 2) which can be if necessary synchronized with a Valsava maneuver to maximize the chances of successful cannulation. Ease of compressibility, lack of pulsation and ability to become distended (by a simulated Valsalva, Trendelenburg or liver compression maneuvers) are a few ways to differentiate a vein from an artery (7). The incidence of an accidental arterial puncture is 6 to 10 times lower when US-guidance is used compared with the classical landmark technique.

There is good evidence, particularly for internal jugular CV catheter placement, that the use of US guidance results in higher success rate, fewer mechanical complications and a high “first-pass” success rate, all of which improve patient's comfort. This was reported by a few meta-analyses (8, 9), leading to the UK National Institute for Clinical Excellence (NICE) to recommend the use of US-guidance for insertion of CV catheter in the internal jugular vein in adult and children (10). US imaging should at least always be considered first in these clinical conditions : coagulopathy, neck abnormally (obesity), anatomical deviation due to masses (goiter) and previous vein cannulation or neck surgery.

For subclavian and femoral access, large comparative studies are still needed to prove superiority of US-guidance over the landmark technique. The puncture of the “subclavian” vein (in fact the axillary vein because of a more lateral access) can be guided by US and a few authors describe large series of patients with very good results (11-13). The ability to see the artery and the pleura increase safety and the puncture of the vein before it crosses the clavicle is much more comfortable for the patient. Although used for the puncture of the internal jugular vein in children (14, 15), US-guidance technique is usually described as not useable for the subclavian vein, while it is often the preferred site for long term CVC placement in children. A novel approach making this access possible in infant and children will soon be published and is already routinely used in our institution (16). US-guided access is also used for femoral access and particularly advised in children, obese patient or in case of not palpable artery (17).

Finally arterial line placement, especially in children (18), and peripheral venous lines placement in obese patients (19) can profit from US-guidance.

#### LOCO-REGIONAL ANESTHESIA

There is a rapid growth in the number of publications on US-guided nerve blocks in the recent years emphasizing the potential advantages of US imaging for regional anesthesia (20-26). Obvious advantages are direct visualization of nerves and their surrounding structures, real time needle guidance and assessment of local anesthetic spread adequacy at the time of injection.

In order to identify peripheral nerve structures, the ultrasound beam should scan the known course of the nerve. The optimal image of the nerve will be obtained when the US beam is oriented strictly perpendicular to the nerve axis (anisotropic property) (27). Excellent anatomical knowledge is required to interpret sonoanatomy and identify efficiently nerve structures in their surrounding environment. Nerves appear as multiple round hypoechoic areas (fascicles) encircled by a relatively hyperechoic horizon (connective tissue), giving them sometimes an “honeycomb” appearance. Overall appearance of a nerve can be hyper- or hypoechoic depending on its size, the US frequency, and the angle of the US beam (28). An “hyperechoic” nerve will be differentiated from a tendon by visualizing its entire course ; an “hypoechoic” nerve is differentiated from a

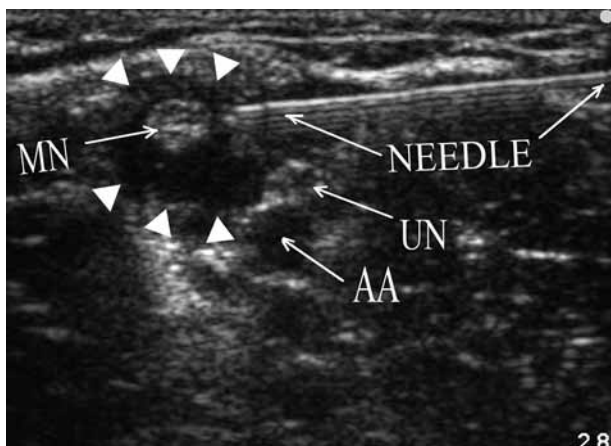


Fig. 3. — Transverse sonogram in the axillary region showing an “in-plan” approach for axillary plexus block. The needle is positioned close to the median nerve (MN) and 3 ml of local anesthetics (D) are deposit around it. UN : ulnar nerve, AA : axillary artery.

vascular structure by its non-compressibility and the absence of Doppler flow.

Direct guidance of the advancing needle is safer because dangerous areas, like vessels or pleura, are visualized and can thus be avoided. Needle tip or catheter tip identification is not always easy. Injection of little fluid is helpful to confirm needle tip localization (2). When the “test” injection is not seen, aspiration should be made because inadvertent intravascular injection in one of the possibilities. If nerve stimulation is used, dextrose 5% in water should be injected as it sustains and even enhance the evoked motor response (29). Nerve stimulation can be used during the learning curve, in case of bad nerve or needle visibility or for didactic purpose. On the contrary, when an motor response is impossible to evoke (30) or experienced as painful (trauma patients or children) US guidance appears as a blessed technique. If several nerves have to be infiltrated in the same area (i.e. axillary block), the deeper nerve should always be infiltrated first to avoid the appearance of artifacts - due to accidental air bubbles injection - on the US image. The monitoring of local anesthetic spread around the nerve and the possibility to reposition the needle in case of incorrect distribution is the major advantages of US imaging (Fig. 3). Faster onset, higher success rate, patient comfort and use of lower volumes of local anesthetics (31) are the clinical endpoints described. A description of US assistance can already be found in the literature for every peripheral nerve block. Moreover, prelimi-

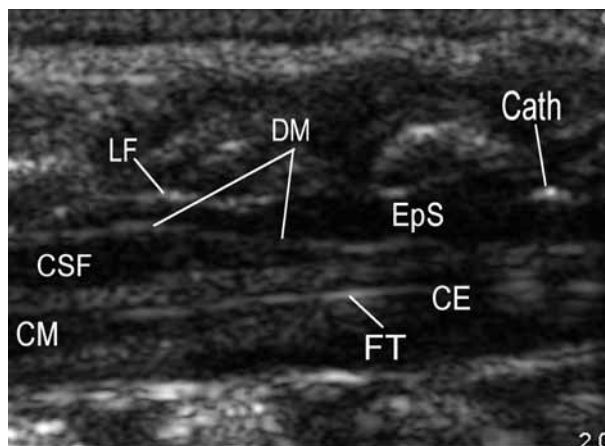


Fig. 4. — Longitudinal sonogram of neuraxial anatomy in a 3 kg neonate. A 24ga epidural catheter (Cath) placed at the lumbar level is confirmed to be correctly placed by the injection of a small amount of local anesthetic. The ventral displacement of the posterior dura mater (DM) by the filling of the epidural space (EpS) are the classical US signs. CSF : cerebrospinal fluid, LF : ligamentum flavum, CM : conus medullaris, CE : cauda equina, FT : filum terminale.

nary studies using US for pain therapy are also reported (32-35).

Concerning neuraxial blocks, benefit of US has been described in adult (36) but major clinical applications are experienced in the young pediatric population (less ossification). During an US controlled caudal block, injection of a test bolus will expand the epidural space displacing the dura ventrally and ensure correct disposition of the local anesthetic (37). Identification of vertebral level, depth to epidural space and angle of insertion are interesting informations before epidural puncture (38). Once inserted, catheters tip can be localized by injecting local anesthetics and observing the ventral displacement of the posterior dura (Fig. 4) (39).

Besides helping clinical practice, ultrasonography raises a few new questions :

1. Is motor-nerve stimulation sensitive enough to be safe (40-42) ? “US-users” often see the needle touching the nerve without eliciting a motor response at an amplitude of 0.5 mA. The amplitude of stimulation and the nerve to needle proximity seems to correlate poorly. Spatial distribution of sensitive and motor fibres in the nerve itself seems to play an important role.
2. Do we have adequate knowledge of nerve anatomy in children ? The location of the ilioinguinal nerve in children highlighted this topic. Anatomical cadavers finding performed on a small group of adults were inappropriately

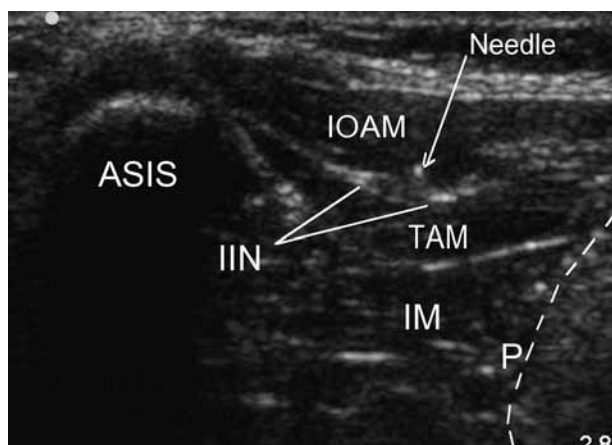


Fig. 5. — Cross-sectional US view of the ilioinguinal nerve (IIN) between the internal oblique (IOAM) and transverse (TAM) abdominal muscles in a 5 years old boy. An “out of plane” approach shows the needle approaching the nerve. ASIS : anterior superior iliac spine, IM : iliac muscle, P : peritoneum.

extrapolated to children leading to decades of high failure rates based on these landmarks. At this time, we know from new pediatric cadaver (43) and US studies (44, 45) that the nerve is located much more laterally, closer to the iliac spine. Safer and more efficient blocks should be performed in the future with (Fig. 5) or without US, by using new landmarks.

3. Are trunks and nerves surrounded by a real sheath? Nerve sheaths were never detected by US. A recent CT scanning study of the brachial and sciatic nerves also failed to individualize them showing only anatomical tissue planes (46). This is supported by US imaging showing that local anesthetics disappears very quickly after injection. The theory that larger volume will produce longer block, acting as a reservoir into the nerve sheath, seems doubtful.

#### OTHER ULTRASOUND GUIDANCES

Chest US screening, using the “lung sliding” sign, has been found to be a valuable tool in *pneumothorax* diagnosis, with diagnostic effectiveness well beyond X-ray and almost similar to CT (47,48). Because US is harmless and readily available at the patient’s bedside, excessive radiation exposure or missed diagnosis leading to a dangerous treatment delays can be avoided.

Bladder US monitoring can be used to assist with the diagnosis and management of *urinary retention*. The frequency of unnecessary bladder catheterization can be reduced, explanation for

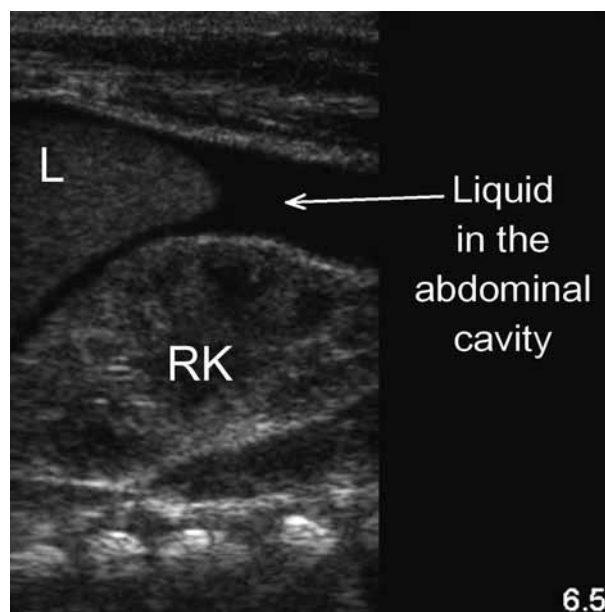


Fig. 6. — US detection of intraperitoneal fluid during FAST examination on a 4 kg baby. An anechoic image is seen between the liver (L) and the right kidney (RK).

postoperative agitation can be found rapidly and the probability of prolonged overdistention is reduced (49-50).

Pretracheal US can assist *percutaneous dilatational tracheotomy* by screening the tracheal anatomy (midline, possible tracheal deviation, level of the tracheal rings, tracheal diameter) and the pretracheal region (distance from the skin to the trachea, presence of vascular anomalies, venous engorgement or a goiter) (51, 52). By using US, the safety is improved, the right size of tracheostomy tube can be chosen and the need for open surgery for vascular ligation can be identified.

US scanning of the *trauma patient* described by the FAST (focused assessment with sonography for trauma) is a bedside test consisting of four main views to interrogate potential spaces. These potential spaces (the pericardial, perihepatic, perisplenic and pelvic areas) can harbor pathologic fluid collections (Fig. 6). Bedside or even prehospital FAST has been shown to change subsequent management in an appreciable number of patients (53). Knowledge of this protocol can be crucial if a radiologist is not quickly available in the emergency or ICU department.

#### DEVELOPMENT IN ANESTHESIA

The introduction of a new technology always encounter some resistance. In this case, the learning

curve and the price of the equipment are the major criticism. The learning curve for US-guided punctures seems fortunately much shorter than for dynamic echocardiographic assessment. Five supervised US-guided puncture seems enough to improve speed and accuracy for internal vein cannulation, ten for a peripheral nerve block and 25 for the FAST (54-56). US guided puncture appears cost effective over classical techniques when analyzing all the factors : cost of lost theater time (difficult punctures, longer onset or failed block) and treatment costs associated with the excess of complications if landmarks technique is used (57, 58). The purchase of such an equipment will be justified by its multiple indications. The future availability of an US device in an anesthesiology department will probably improve patient's care not because it will become a gold standard for locoregional techniques but because it facilitate the anesthesiologist's daily clinical practice by offering him a new diagnostic tool, like a modern stethoscope...

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