Review Article

Ultrasound-guided central vascular interventions, comments on the European Federation of Societies for Ultrasound in Medicine and Biology guidelines on interventional ultrasound

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Abstract: Central venous access has traditionally been performed on the basis of designated anatomical landmarks. However, due to patients' individual anatomy and vessel pathology and depending on individual operators' skill, this landmark approach is associated with a significant failure rate and complication risk. There is substantial evidence demonstrating significant improvement in effectiveness and safety of vascular access by realtime ultrasound (US)-guidance, as compared to the anatomical landmark-guided approach. This review comments on the evidence-based recommendations on US-guided vascular access which have been published recently within the framework of Guidelines on Interventional Ultrasound (InVUS) of the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) from a clinical practice point of view.

Keywords: Guidelines; intervention; ultrasound-guidance (US-guidance); vascular access; central venous catheters; anatomic landmarks

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Introduction

Sonographic imaging of potential target vessels to determine the most appropriate vessel, the ideal puncture site and the best patient position, is a reasonable approach to identify anatomical variations known to occur in a substantial portion of veins (1-5).

Ultrasound (US) guided catheter placement into the subclavian and internal jugular veins (IJVs) was first described in 1975 (6,7). The first attempts to use a Doppler-controlled needle director as an aid for percutaneous angiography were reported in 1973. More recently US guidance for vascular access has been introduced more widely also as quality parameter to minimize complications (8). Real time ultrasound (RTUS) has proven beneficial in guiding interventional procedures under many circumstances, becoming standard in clinical practice for many years (9). Through technical advances and improvements of image quality, RTUS allows identification of vessel localisation the best target vessel and optimised puncture site (10). Anatomical variations can be easily identified (1-5) and vein thrombosis excluded which is not only of importance in oncological patients (11,12). It is important to exclude vein catheter associated thrombosis in, for example, critical care patients.

The aim of this paper is to summarize and comment on the recently published European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) on interventional ultrasound (INVUS), part VI, US-guided vascular interventions (13), to give practical advice and to illustrate the procedures. We refer also to the current EFSUMB guidelines on INVUS (13-18) on contrast enhanced ultrasound (CEUS) (19-21), elastography (22,23), and comments on the guidelines (24-29).

Basic principles

The three cornerstones for US guided vascular interventions are the patient, the interventionalist and US equipment.

Indications and contraindications

Most importantly the right indication for each kind of vascular access should be justified; this is especially true for central vascular access. The information provided to the patient depends on the situation (emergency) and on their level of consciousness (13).

Establishing central venous access is fundamental for emergency physicians in order to monitor the hemodynamics, central venous pressure (CVP) and pulse contour cardiac output (PiCCO), to deliver vasoactive drugs, hyperosmolar fluids and volume resuscitation (30). In oncological and haematological patients, central venous access is often required for blood sampling and for peripheral stem cell preparation, as well as for administration of blood products, chemotherapy or other drugs (11). Advantages of US-guidance for central venous access have been proved in a variate patient population, including critically ill patients (31,32), ventilated patients (33), both oncological and haematological patients (11,34-37), in situations when a parental nutrition was needed (37) or in haemodialised patients (38,39). Outcomes are improved for experienced as well as inexperienced operators (40). Given a clear indication, there is no absolute contraindication for US-guided vascular access and interventions.

Which central venous access?

Due to coagulation disorders, thrombocytopenia (disease- or therapy-associated) and hemostasis disorders, oncological and hematological patients belong to the high-risk group for central venous access (11,41). Additionally, anatomical changes may be encountered in patients with the primary tumor, metastases or lymphoma in the puncture region (11).

One of the advantages of the subclavian/axillary approach is that it can be used for central venous catheter placement in patients with severe burns on the face, neck, and/or proximal shoulders (42). Still, there are drawbacks related to the smaller diameter and deeper location of subclavian and axillary veins (43).

Risks and complications

The complication rates using the traditional landmark technique range from 0.3% to 18.8%, depending on multiple factors, such as patient population, site of insertion, time taken, number of needle passes and the specific definition of complications used (44-48). Evidence from meta-analyses of RCTs shows that RTUS-guided access to the IJV and subclavian vein (SV) in adults has a significantly lower failure rate as compared to the traditional 'blind' access and that it is associated with a decreased rate of complications, requires a shorter access time and fewer attempts for successful access (30,38,39,49-52). In the meta-analysis of Hind *et al.*, commissioned by the British National Institute for Clinical Excellence (NICE), the relative risk of complications, of failed attempts, and failed first attempt were reduced by 57%, 86%, and 41%, respectively (49). The two most important improvements associated with US guided technique versus landmark technique are lower risks of inadvertent arterial puncture and of local hematoma (37). It is important to recognise however that adverse events may occur also under RTUS-guidance. In particular, improper catheter placement, arterial puncture, hematoma at the puncture place, air embolism, or nerve lesions have been reported (53,54). Pneumo- and/or hemothorax are very rare events if central venous puncture is performed under RTUS-guidance (50,51). Furthermore, catheter misplacement or pneumo-/hemothorax in most cases are recognized by US at the time of intervention (54-63). Thrombosis, arteriovenous fistula and pseudoaneurysms represent possible mid-/longterm complications of central venous catheter placement and all can be easily detected by means of US (64-70). In the study of Kaye *et al.* (n=325 patients undergoing cardiovascular surgery), complication rates after central vein catheterization (including carotid artery puncture and pneumothorax) were significantly higher for the group who received catheter placement without US-guidance, as compared to the group having catheter placement with US (71). Using US-guidance for central venous catheter placement, Cavanna *et al.* reported symptomatic deep-vein thrombosis of the upper limbs in 2.4% of the cases and catheter related infections in 10% of the catheters inserted. Removal of the catheter due to complications was necessary only in 2.9% of cases. No major bleeding, nerve puncture or pneumothorax was reported (34).

Despite US-guidance, posterior vessel wall puncture may occur as a complication of venous catheterisation (72,73). Factors influencing the risk of posterior wall penetration are the particular access technique (transverse *vs.* longitudinal approach), the speed of needle insertion, the distance between needle entry and transducer, and the angle of insertion (74).

Tips and tricks (how to avoid risks and complications)

Here are some important points to avoid unsuccesful punctures:

- Check the equipment and its function during preparation;
- Optimise the B-mode picture of the target vessel;
- Optimise positioning of the patient (e.g., Trendelenburg position), of the examiner and of the US device relative to the puncture site (aim for a comfortable working environment for the interventionalist);
- Choose the most appropriate head position in order to locate the target vein laterally rather than anterior to the artery;
- Skills training on appropriate phantoms and in normal patient conditions prior to emergency situations;
- In hypovolemic patients: give intravenous fluid before puncture;
- The indication for central lines must be well considered—sometimes peripheral vascular access meets the needs of the condition.

Patient informed consent

Each procedure intended for diagnosis or treatment must be undertaken only after informed consent has been obtained from the conscious patient (75) or legal representative, after receiving comprehensible and understandable information about the procedure's goal and benefits, potential risks, alternatives and complications (76). There is no legal requirement for consent to be written, or be in a particular setting, however, a signed written consent form provides documentary evidence. Consent may be withdrawn at any time, even after the form has been signed, and should lead to immediate discontinuation of a procedure. It is the responsibility of the doctor to be aware of the valid legislation and ethical guidelines in their region. The European Society for Cardiovascular and Interventional Radiology and the Society of Interventional Radiology provide information on many interventional radiology procedures on their website (www.cirse.org). The Royal College of Radiologists (UK) and the British Society of Interventional Radiology has similar information at www.rcr.org.

Interventionalist

Adequate teaching, education and training are necessary for a successful procedure. The degree of US experience significantly influences complication rates (71,77). Several studies have shown that simulation-based learning of US-guided central venous access increases skills in simulated central venous catheter insertion and is more effective than traditional bedside teaching (78-81). Moreover, a recent meta-analysis of 20 comparative studies gave proof of significant improvement in performance not only at simulators but also in some clinical outcome parameters, in particular number of needle passes to achieve central venous access and frequency of pneumothorax (82). Comparable results were reported in a meta-analysis of prospective comparative cohort-studies (83). Therefore, simulation training should be included in training programs for RTUS-guided central venous access to improve the real clinical performance of trainees.

Which US equipment?

The US equipment should allow good to excellent near field resolution. Particular presets for e.g., cervical, brachial and femoral vessels are helpful.

Which transducer?

High frequency (5–17 MHz, in practice 7–12 MHz) linear transducers with a relatively small aperture of less than 4–6 cm are recommended for superficial locations. In

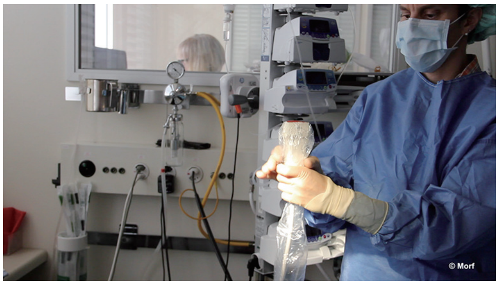

Figure 1 Sterile covering of the transducer before US-guided vascular access. US, ultrasound.

deeper locations (e.g., femoral vessels), particularly in obese or oedematous patients, the use of a curved array abdominal probe may be necessary.

Transducer guides

Transducers may offer vendor-dependent needle guides but only a limited number of transducers are useful and most punctures will be done free hand.

Hygiene

Sterile covers

For vascular access under US-guidance, after probe decontamination, a sterile barrier is needed, which must cover both the transducer and the cable (43). Sterile covers are mandatory according to hygiene recommendations and to avoid contact of the transducer membrane with alcohol or other disinfection fluids. It is generally required to use sterile, disposable probe covers made of latex-free material and applied under aseptic conditions, following manufacturers' instructions (84) (*Figure 1*). Random testing of the batch may be done in order to assess package integrity (85). If no sterile transducer covers are available, a sterile glove may be used. In a similar fashion contact gel will be placed inside, and the flat palm surface of the glove will be used to cover the scanning surface of the transducer. Attention must be paid to eliminate any air bubbles possibly interposed between the scanning surface of the transducer and the cover or glove (43).

Sterile US gel

Only sterile US gel should be used in interventional procedures, packed in small packages matching the gel requirement for one examination and a new sachet should be used for each patient (86-94). Residual product should not be used on further patients since it may be a potential vehicle for nosocomial infections. Disposable probe covers filled with sterile gel are also available (84,86-89,91,93-95). Alternatively, disinfectant solutions may be used to ensure acoustical coupling between the skin surface and the covered transducer.

Transducer decontamination

Sterile transducer covers do not eliminate the need for transducer decontamination (96-98). Sterilization of the transducer after use is necessary in procedures with a high risk of contamination. The cleaning technique of transducers using disinfection varies between manufacturers. For more details see the EFSUMB guidelines on interventional procedures (13-18,24,99).

US guiding techniques

Definition

US-guidance for venous cannulation can be performed using different approaches. Therefore, some definitions will be discussed in the following paragraphs including "landmark technique", "direct" and "indirect" methods, US-assistance and US-guidance, free hand technique, puncture transducers and transducer mounted devices. The "direct" technique implies needle placement under permanent real-time RTUS control (US-guidance). The needle is visualized on the US monitor as an echogenic line with ring-down artefact and the cannulation process can be monitored completely by US (43). "Indirect" (or static) techniques (US-assistance) imply that US is used to locate the appropriate target vessel, to examine its topographical relations to surrounding structures and to assess its dimensions and depth from the skin. This is therefore a simplified technique, with the advantage that sterile covers are not necessary for the transducer and there is less equipment to manipulate during the sterile line insertion. Optionally, marking might be drawn or placed on the skin corresponding to the vessel's position just at the point where the center of the transducer overlies the center of the vessel (43). Another method which has proved to be beneficial, especially for inexperienced operators, is the mechanical US-guided approach. This implies the use of an attachment to the transducer which provides a fixed needle trajectory. The method has better success rate, improved venous access time, improved average number of attempts to success and was associated with fewer complications when compared to the traditional landmark approach (43,100). Doppler US can also be used to facilitate vessel visualization.

Comparison of access techniques

Review of the literature

US-assistance *vs.* landmark approach

Two randomized control trials (RCTs) have demonstrated that with US-assistance ("static ultrasound" for pre-procedural evaluation) IJV catheterisation can be performed quicker in comparison to the traditional landmark technique (101,102). Furthermore first attempt success rate was higher with US assistance (101). In one RCT comparing landmark and US-assisted techniques in ventilated patients with respiratory jugular venodilation, results of cannulation did not differ with respect to first attempt cannulation, overall success rate or the incidence of arterial puncture. However, in the patients without respiratory jugular venodilation, those outcome parameters were significantly improved in the US-assisted group (33).

A further RCT comparing complications and failures of SV catheterization using the standard landmark technique and US-assisted technique found no significant differences between the two methods (45). There are no data comparing US-assistance and landmark technique for femoral venous (FV) access (13).

US-guidance versus landmark approach

US-guidance versus landmark approach has been discussed in detail in the EFSUMB guidelines (13). There is convincing evidence from meta-analyses of RCTs that RTUS-guided access to the IJV and SV in adult patients is associated with a significantly lower failure rate both overall and on the first attempt, a shorter access time, and decreased rates of arterial puncture and hematoma formation compared to the traditional anatomical landmark approach (30,38,39,49-51,103,104). These advantages were shown for particular patient groups and clinical situations, e.g., for adults requiring emergent central venous catheter placement (51,52), ventilated patients (33), critical care patients (31,32), in oncological and haematological patients (34-36), in elective situations for parenteral nutrition (37), and for placement of hemodialysis catheters (13,38,39).

US-assistance versus US-guidance

The results of RCTs comparing US-assistance and RTUS-guidance for central venous access are conflicting (13,102,104,105). A prospective randomized study was conducted by Nadig, in order to assess if the rate of unsuccessful attempts in puncturing the IJV for the placement of dialysis catheters can be reduced with the use of RTUS-guidance. In 36 punctures with RTUS-guidance only 10 unsuccessful attempts occurred, as compared to 87 unsuccessful attempts in 37 punctures using only a skin mark determined by US. Also, a reduced time to successful puncture in favour of RTUS guidance (3.4±0.9 versus 4.8±2.2 min) has been registered (106).

Conclusions

Based on this evidence, RTUS-guidance for central venous catheter placement has been endorsed as a key safety measure by both the Agency for Healthcare Quality and Research in the United States and the National Institute for Health and Care Excellence (NICE) in the UK (8,13,107-114).

Real time US guidance, examination technique

The fundamental technique of InVUS (the puncture principle) is an alignment of two planes, namely the "scan plane" that shows the target vessel on the US screen and the "needle plane" containing the needle (or other InVUS device) approaching the target. Real-time visualization of the needle tip is possible using US due to the reflection from the metal in the needle (115). The intensity of the display of echoes from the "needle plane" will depend on the needle size, the scanning depth, angulation and the US system (116). The RTUS-guidance technique can be divided into three different approaches, the longitudinal, transverse and oblique techniques.

Using the longitudinal technique, the target vessel is delineated in a long-axis view (referring to the needle: in-plane approach). With the transverse technique the target vessel is approached in a short-axis (transverse) view (referring to the needle: out-of-plane approach). Both techniques may be combined (oblique technique) (43). There is conflicting evidence with regard to the particular US-guidance technique (short-axis view/out-of-plane approach *vs.* long-axis view/in-plane approach), which precludes recommendation in favour of either of the two approaches (14,15,74,117-122).

Longitudinal technique

In the longitudinal technique the transducer is placed parallel to the vessel and the needle at the greatest anterio-posterior diameter of the targeted vessel. The puncture of the skin has to be close to one end of the transducer under an angle of approximately 30° from the skin surface depending from the skin-vessel distance (43). The course of the target vessel and the complete process of insertion and

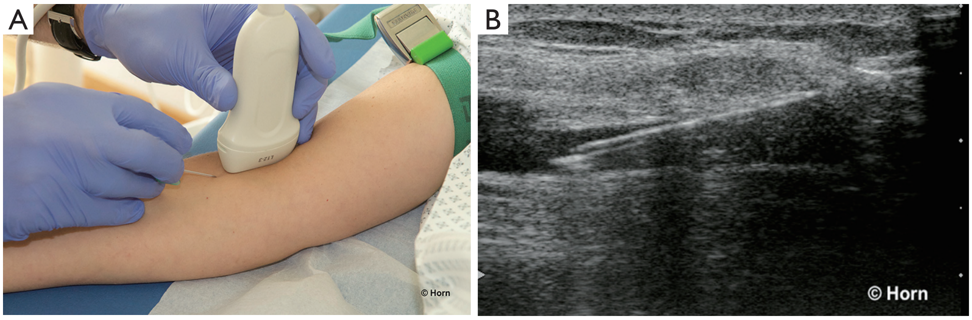

Figure 2 Longitudinal approach. (A) Insertion of the needle along the long axis of the US transducer; (B) RTUS visualization of the needle course. US, ultrasound; RTUS, real time US.

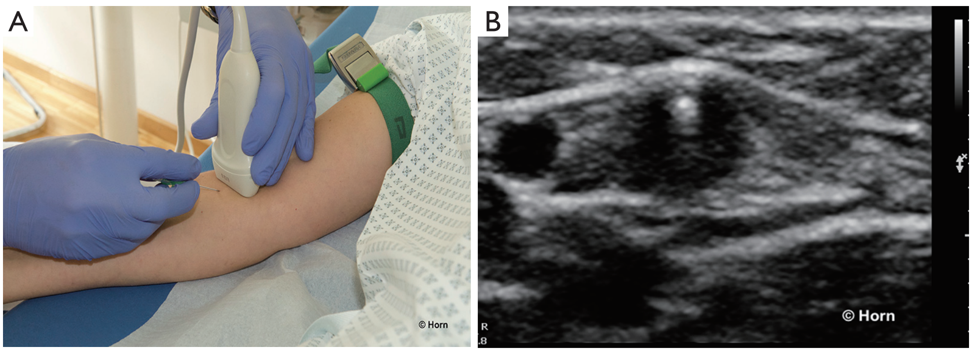

Figure 3 Transversal approach: the US transducer is placed transversally to the target vessel. (A) Needle insertion in the middle of the transducer; (B) RTUS-guidance of the course of the needle tip. US, ultrasound; RTUS, real time US.

advancement of the needle are visualized in real-time in the long axis of the transducer (*Figure 2*).

The advantage of this technique is the view of the whole needle which allows the operator to define the optimal insertion angle. By doing this the posterior wall of the vein will not be penetrated (123). However, in particular anatomical situations it may be difficult to show the course of the target vessel.

Transverse technique

In the transverse technique, also called the short-axis view, the position of the transducer is transversally placed to the vessel and the needle. The puncture of the skin should be performed exactly in the middle of the probe with an angle of approximately 45° to the skin. By tilting the probe during insertion, the tip of the needle is followed (*Figure 3*). The advantage of this technique is the reliable positioning of the needle tip according to the course of the vessel, preventing a deviation from the vessel's axis to the right or left. The transverse technique is useful in anatomical areas with limited access space and for cannulation of smaller vessels. It offers more confidence for inexperienced users. In the case of unsuccessful puncture, visualisation of needle tip deviation is easy. Disadvantages are possible loss of control over the needle tip with the risk of posterior wall penetration. Posterior vessel wall penetration is a frequent event in short-axis approach to IJV cannulation (72). Moreover, it is difficult to determine the most appropriate angle for insertion.

Oblique technique

In particular anatomical conditions, like puncture of the SV, the oblique technique may be helpful. It combines advantages of the short- and long-axis approaches, respectively better visualisation of the anatomical structures provided by the short-axis view and better needle tip visualization provided by the long-axis view (124).

In this approach, the position of the probe is parallel to the needle and oblique to the vessel. The view of the whole needle is maintained, while the vessel is only partially visible.

Comparison of long-axis versus short-axis vascular access

The prospective trial of Stone *et al.* (74) proved that the long-axis access allows improved visualization of the needle tip at the time of puncture, a result which is consistent with standard approaches of other procedures done under US-guidance (e.g., regional nerve anesthesia under US-guidance) (125,126). In this study no statistically significant differences of the time to vessel access were observed between inexperienced and experienced interventionalists (74). A recent RCT demonstrated that the long-axis access approach to the IJV and SV was more time efficient than the short-axis access. The long-axis approach to SV catheterization was also associated with fewer posterior wall penetrations (118). Disconcordantly, Blaivas *et al.* reported that emergency medicine residents without previous experience in US-guidance in an inanimate model were able to complete the procedure faster using the short-axis approach as compared to the long-axis approach (123).

US imaging techniques

B-mode

In preparation of an US-guided procedure, it is important to choose the appropriate transducer, imaging program (presetting/application) and the correct interventional apparatus (14,15). Before puncture, it is mandatory to clearly identify the vein and to rule out thrombosis, which is often done by the compressibility test using B-mode. However, in patients with very low blood pressure the artery may also be compressible. The threshold for arterial compressibility is assumed to be <60 mmHg. In patients with a very low blood flow, blood stasis may look like thrombosis using B-mode. The compressibility test may be helpful but sometimes colour Doppler imaging (CDI) and rarely CEUS are necessary to prove or rule out thrombosis (*Figures 4-6*). Surgical emphysema, for example in thoracic trauma, reduces the visibility of vessels. Other artifacts

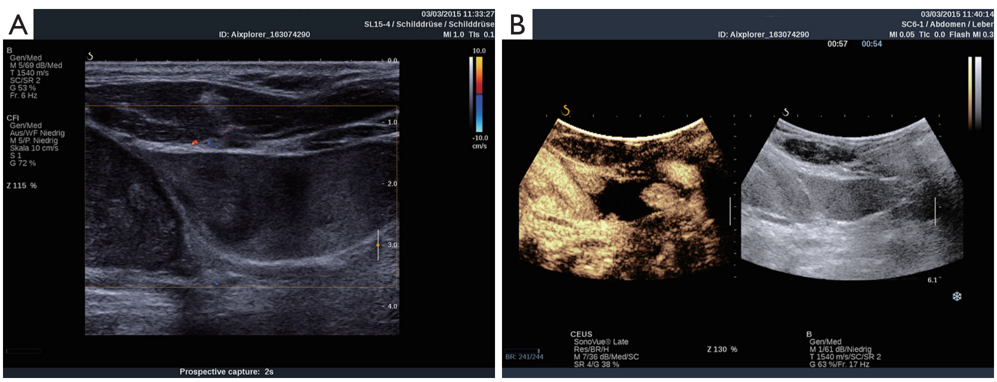

Figure 4 Difficult venous access due to a hypoechoic tumor (Schwannoma). (A) B-mode US; (B) delineation of the tumor and the target vessel using CEUS. US, ultrasound; CEUS, contrast-enhanced US.

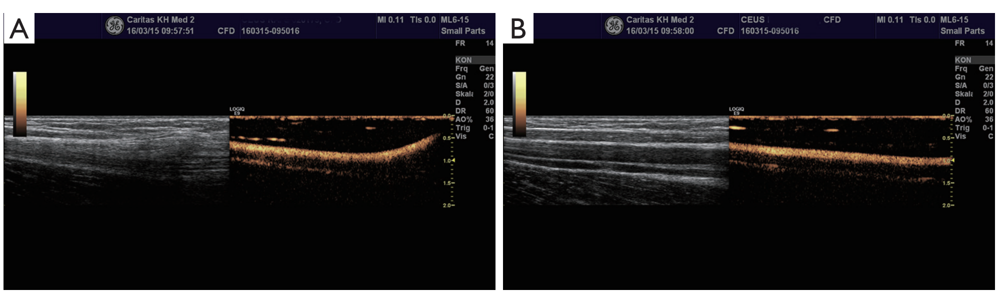

Figure 5 Proof of intravasal position of a venous catheter using contrast-enhanced ultrasound. (A) Site of catheter insertion; (B) delineation of the vessel lumen by the injected contrast agent.

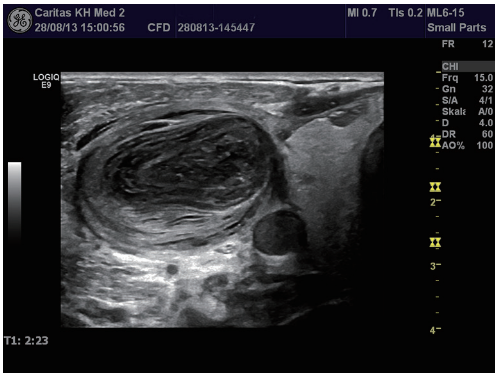

Figure 6 Ultrasound image of thrombosis of the right internal jugular vein.

may be caused by circumscribed sclerosis of the arterial walls.

CDI

CDI may be helpful to differentiate arteries and veins and might help to identify anatomical variants and pathological findings. Compared with the landmark technique, Doppler-guidance increases the first-attempt success rate of central venous catheter placement by 58% (103). The meta-analysis of Rabindranath *et al.* (39) included RCTs in patients requiring hemodialysis catheter insertion. Compared to the landmark approach, RTUS Doppler-guidance significantly decreased catheter placement failure, first-attempt failure rate, time to canulation, and number of attempts per catheter insertion. Associated complications such as arterial puncture or hematoma formation were also significantly decreased. They concluded that RTUS-guidance using Doppler US should be strongly recommended for hemodialysis catheter placement.

CEUS

With the use of RTUS-guidance for catheter placement, the canulation of a thrombosed or of a small vein can be prevented (49).

CEUS is helpful:

- To diagnose thrombosis;
- To exclude thrombosis;
- For catheter tip position control;
- For detection of catheter obstruction;
- To detect pericatheter leakage.

Additional imaging

All available imaging results should be used to reduce the associated risk of vascular access. Mainly in oncological patients computed tomography and easily available US findings (21,127-129) but also the endoscopic US reports should be known (130-135).

Central venous access

General remarks

The most common used central veins for vascular access are the IJV, the femoral vein (FV) and the SV. The most appropriate central venous access site depends on the particular circumstances of the patient. As a first step, thrombosis should be ruled out. Especially for access through the IJV, it is mandatory to examine the contralateral veins since thrombosis is a contraindication to catheterisation. The IJV is the easiest central vein to puncture. On the other hand, SV access is associated with the lowest infection rate. For intravascular temperature management the FV is also a good choice. A traditional 'blind' approach reported failure rates of 30% or higher in emergent or cardiopulmonary arrest cases (44,136-138). In 2001, RTUS-guidance for central venous access was listed in guidelines published by the American College of Emergency Physicians as one of the primary applications for emergency US (139). Skin disinfection should be performed according to local hospital guidelines for surgical disinfection. For normal central lines, chlorhexidine is often recommended. We refer to the EFSUMB guidelines (14,15).

Anatomy

RTUS allows determination of anatomical variants, such as small diameter, medial or lateral displacement. Valsalva maneuver response, or lack thereof, needs to be correctly assessed and evaluated in order to avoid further complications.

Ultrasonographic vessel screening and imaging before vascular access

US vessel screening and imaging of the target vessels should be performed to determine the most appropriate anatomical site and the optimal patient position for central vascular access (13). In order to successfully cannulate a vessel, understanding of the technical issues is necessary. A decision upon the best approach for US-guidance (direct, indirect, free-hand, mechanical guide, Doppler) should be made by

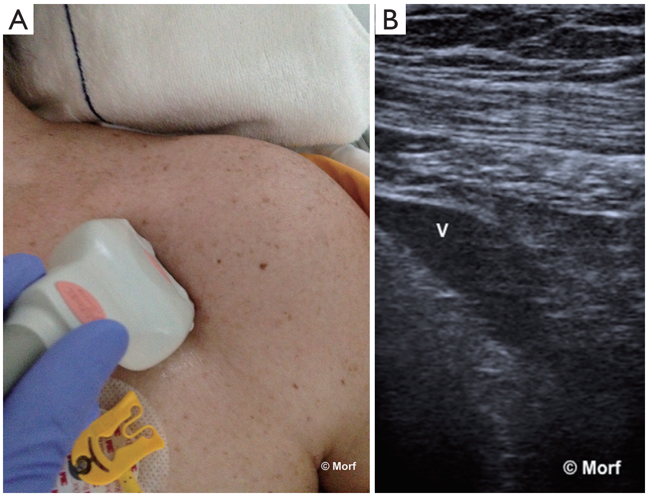

Figure 7 Sonographic visualization of the subclavian vein: transducer position (A), corresponding US image (B). US, ultrasound.

the operator, according to patient's characteristics, equipment used and operator expertise (43). Changes in head position may influence the vein diameter and the relative position of surrounding vessels (3,140), so care must be taken (141).

Procedure

As central line insertion is painful, local anesthesia is recommended. The Seldinger procedure is normally performed. In brief, for the initial puncture a needle with attached syringe, half filled with sterile fluid, is used. After blood aspiration a guide wire is advanced under RTUS control. For the beginner, we recommend learning this procedure with another interventionalist present to aid. The second step is to perform it alone, as good coordination is required to perform the puncture with just one hand whilst manipulating the US probe with the other.

Jugular vein

Central venous access through the IJV is preferred in many cases. Due to its larger diameter it is easily accessed with wider catheters, as for hemodialysis or plasmapheresis. The rate of delayed complications, such as stenosis, is lower than for other central veins (11).

Anatomy

The IJV usually lies anterior and slightly lateral to the carotid artery, being usually larger (3), however variants are common.

Review of the literature

Denys *et al.* found IJV anatomical variants in 8% of the 200 patients assessed (2). Of 1,009 patients assessed by Troianos *et al.*, in 54% of cases the IJV overlaid the carotid artery, predisposing to arterial puncture (5). Docktor *et al.* found the same anatomical variant in 25% of 150 patients (141). Benter *et al.* investigated 113 patients with haematological or oncological diseases, examining sonographically potential target regions for placement of a central catheter via the IJV and found anatomical variations of the IJV location and surrounding tissues in 36% of the patients (*Figure 7*). They concluded that the use of US-guided techniques for central venous catheters placement, particularly in haematological and oncological patients, is of particular importance in order to avoid arterial puncture (11). Particular attention must be payed to this group of patients because they may present a partially or completely thrombosed IJV, in up to 6% of cases according to the study of Benter *et al.* (11), whilst 4.4% of those investigated by Denys *et al.* had either thrombosed or absent IJV (2). A small IJV diameters ≤7 mm has been reported in 12–15% of the cases (142,143) and is associated with a catheterization failure rate of 14.9% (as compared to 3.9%, if IJV diameter is >7–10 mm) and a complication rate of 8.5% (as compared to 3.8%, if the IJV diameter is >7–10 mm) (143). The right IJV is as big, or bigger than the left IJV in about 74% of the patients, and offers a straighter and more direct path to the superior vena cava and the right atrium. Its cannulation is associated with a lower risk of pneumothorax, since the right lung apex is lower than the left one (142). It is worth noting that the diameter of the IJV expands during the Valsalva maneuver (144).

There might be differences in neonates and infants (105). Using variable degrees of head rotation, Lorchirachoonkul *et al.* proved that at 30° head rotation there is a potential for difficult catheterisation in 15%, with more difficulty on the left as compared to the right IJV (20% versus 10%). Head rotation did not significantly influence neither the risk of difficult catheterization, neither the size of the IJV nor the average distance between mid IJV and the skin. However, the degree of head rotation influences the position of the IJV relative to the carotid artery on both sides, with an increased overlap as the head is rotated further from the midline (142). These results have been recently confirmed by Maecken *et al.* only for the left IJV. These authors did not observe a significant impact of head position on the position of the right IJV (3). Therefore because anatomical variations

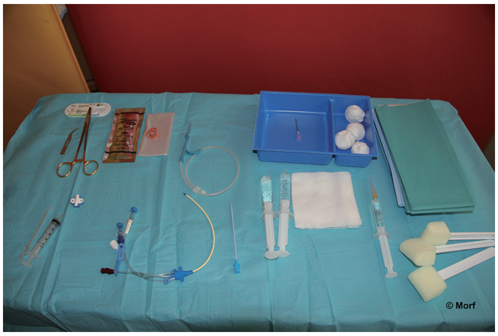

Figure 8 Equipment preparation for sterile vessel puncture.

Figure 9 Position of the interventionalist for RTUS-guided IJV access. RTUS, real time ultrasound; IJV, internal jugular vein.

Figure 10 RTUS-guided central venous access technique. (A) Puncture; (B) aspiration of blood; (C) sonographic visualization of the needle tip with the vessel lumen (V: internal jugular vein; A: common carotid artery). RTUS, real time ultrasound.

impact on the success of IJV catheterization, as well as the incidence of associated complications, the use of RTUS-guidance is also recommended in patients with seemingly normal neck anatomy (142).

Technique and results

IJV catheterisation with RTUS-guidance can be performed faster, with a higher success rate (101,102) and fewer complications (33) than the traditional landmark technique (*Figures 8-10*).

Risks and complications

Adverse events can occur even under RTUS-guidance in about 20% of the cases of IJV central line attempts (53). Complications can be classified in three categories: mechanical (with anatomical variations an important risk factor), infectious and thromboembolic (142). The most frequently encountered complication is placement of the catheter tip within the right atrium, which occurs in about 6–14% of the cases. Cardiac malposition is associated with a mortality risk due to possible cardiac perforation and subsequent tamponade (54). Pneumothorax and hemothorax are very rare if RTUS-guidance is used for central venous access (50,51). Puncture of the carotid artery is a common complication as well (*Figure 11*).

Tips and tricks (how to avoid risks and complications)

Where the IJV overlays the carotid artery, arterial puncture may occur due to the so-called "double wall puncture" phenomenon. This occurs in cases of low IJV pressure, allowing the anterior wall to be pushed against the posterior wall and the IJV to be completely compressed before the needle punctures it (100,141). A common solution is to advance the needle a little deeper and then slightly retract, until the tip lies within the IJV lumen. Exclusion of an underlying carotid artery however, is of utmost importance with this technique (100).

SV

The size of the SV allows placement of central access catheters.

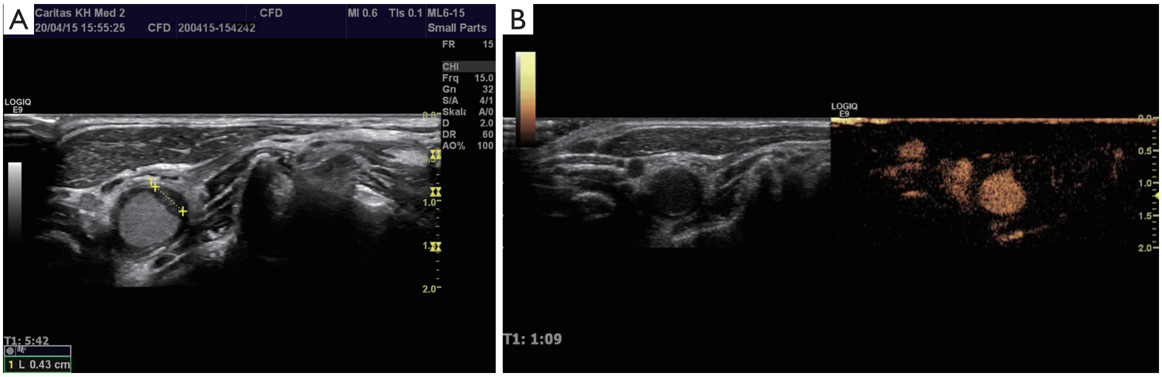

Figure 11 Small hematoma of the vessel wall following inadvertent puncture of the common carotid artery. (A) B-mode; (B) CEUS: the vessel lumen is not occluded. CEUS, contrast-enhanced ultrasound.

Anatomy

The SV is deeply located and partially hidden under the clavicle bone. This hinders access to some of its portions. Its mid-portion can be cannulated using US guidance, however, it is difficult to obtain short-axis images at this level. Additionally, the lung apex is closely located, less than 1 cm (145), as is the subclavian artery and brachial plexus (43) with the risk of associated complications and morbidity.

Technique and results

RTUS-guidance is challenging due to the limited space available for both placement of the transducer and needle insertion. Two alternatives can be used with RTUS-guidance. One is the "low-IJV approach", with a safer and direct route to the superior vena cava and right atrium (146). The other alternative is to access the SV further laterally on the shoulder by cannulating the axillary vein, offering a better approach under RTUS-guidance and a lower complication rate (147,148). This "axillary approach" is possible also in patients with a cervical collar or neck trauma (43). The axillary landmark approach has been proven to be safe and efficient in adults (149) and in critically ill pediatric patients (150). Using the axillary vein approach under RTUS-guidance, Gualtieri *et al.* obtained a higher success rate and less complications as compared to the landmark technique (92% versus 44% and 4% versus 41%, respectively), with lower mean numbers of attempts and insertion kits used (1.4 versus 2.5 and 1.0 versus 1.4, respectively) (151). In patients with relative contraindications to SV catheter placement using the landmark approach, Fry *et al.* (152) reported 100% success rate with RTUS-guidance.

Risks and complications

No complications were been reported by Silberzweig *et al.* (146) using the low-IJV approach in 116 patients. The average number of attempts needed for success was 1.2. These results have been confirmed also by the study of Milone *et al.*, who reported no complications for the RTUS-guided cannulation of the SV, while 13% of the patients cannulated using the landmark approach developed mechanical complications (e.g., pneumothorax or arterial puncture) (153). The knowledge of surrounding structures is of main importance (154).

Detection of complications of venous access

As the EFSUMB INVUS guidelines (13) state, central venous catheter misplacement into the right heart may be detected by transabdominal US using a subxiphoidal approach or by echocardiography (55-61). Moreover, transthoracic US may be used to detect or to rule out pneumothorax related to central venous access in the critically ill patient. Therefore, routine chest radiography is dispensable after central venous line placement (54-57,62,63). Moreover, US has a very high accuracy for the detection of vascular complications of venous and arterial access, in particular of thrombosis of the target vessel (64,65), arterial pseudoaneurysm and arteriovenous fistula (66-70). Therefore, US should not only used to guide central venous access, but also to check correct placement of the line and to rule out the most common complications in the intensive care unit (13,155-157). The role of endoscopic US for catheter placement has not been examined so far (130,131,158).

Conclusions

According to the available evidence in literature it is strongly recommended to use real-time US guidance for central venous access.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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