

# EFSUMB Guidelines on Interventional Ultrasound (INVUS), Part VI

## Ultrasound-Guided Vascular Interventions

### EFSUMB Leitlinien Interventioneller Ultraschall (INVUS), Teil VI Ultraschall-geführte Gefäßinterventionen

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#### Key words

- guideline
- venous access
- arterial access
- endovascular interventions
- ultrasound guidance
- arterial pseudoaneurysm

#### Abstract



The sixth part of the Guidelines on Interventional Ultrasound produced under the auspices of the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) assesses the evidence for ultrasound guidance and assistance in vascular interventions. Based on convincing data, real-time sonographic guidance for central venous access is strongly recommended as a key safety measure. Systematic analysis of scientific literature shows that in difficult situations and special circumstances US guidance may also improve the efficacy and safety of peripheral venous and arterial access and endovascular interventions. Moreover, the recommendations of this guideline endorse the use of ultrasound to detect complications of vascular access and US-guided interventional treatment of arterial pseudoaneurysms.

#### Zusammenfassung



Der sechste Teil der unter Federführung der European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) entstandenen Leitlinien zur interventionellen Sonografie bewertet die Evidenz für sonografisch gestützte und assistierte vaskuläre Interventionen. Auf der Grundlage überzeugender Daten wird die sonografisch gestützte Anlage zentralvenöser Zugänge als wesentlicher Sicherheitsstandard empfohlen. Die systematische Literaturanalyse zeigt, dass in schwierigen Situationen auch die Effizienz und Sicherheit sowohl peripher-venöser und peripher-arterieller Gefäßzugänge als auch endovaskulärer Interventionen durch sonografische Führung verbessert werden können. Darüber hinaus befürworten die Empfehlungen dieser Leitlinie die Nutzung der Sonografie für die Detektion von Komplikationen vaskulärer Zugänge und die ultraschallgestützte interventionelle Therapie arterieller Pseudoaneurysmen.

#### Bibliography

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#### Introduction



Part VI of the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) Guidelines on Interventional Ultrasound is dedicated to indications, safety and clinical relevance of US-guided vascular access and interventions. Recommendations for the implementation of these techniques in clinical practice are derived from the available evidence at the time of manuscript preparation. The methods of guideline development are described in the introduction to the EFSUMB Guidelines on Interventional Ultrasound [1]. Levels of evidence (LoE) and Grades of Recommendations (GoR) have been assigned according to the Oxford Centre for Evidence-based Medicine criteria (March 2009 edition) [[http://](http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009)

[www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009](http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009)].

#### Ultrasonographic vessel screening and imaging before vascular access



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 internal jugular veins (IJV) [2–6]. Up to 36% of patients demonstrate anatomical variations in the IJV and surrounding tissue [7]. There is a higher occurrence of anatomical and pathological variations (e.g., thrombosis) in patients with hematological and oncological diseases [8, 9]. Patient

position has a major influence on the vein diameter, the relative position of target veins and large arteries (e. g., common carotid artery, femoral artery), and, therefore, on the needle access route [4, 9]. The pre-procedural sonographic evaluation allows appropriate selection of the appropriate catheter diameter which in the case of venous access should not exceed 1/3 of the internal diameter of the target vein [10].

### Recommendation 1

Ultrasound vessel screening and imaging of target vessels should be performed to determine the most appropriate anatomical site and the optimal patient position for central vascular access (LoE 5, GoR D). Strong consensus (100%)

## Central venous access



### Ultrasound assistance

Two randomized controlled trials (RCT) have demonstrated that with ultrasound assistance ("static ultrasound", pre-procedural evaluation) internal jugular vein catheterization can be performed more quickly in comparison with the traditional landmark technique [11, 12]. Furthermore, the first-attempt success rate was higher with ultrasound assistance [11]. In one RCT comparing landmark and ultrasound-assisted techniques, the results of cannulation did not differ with respect to first-attempt cannulation, overall success rate, and the incidence of arterial puncture in ventilated patients with respiratory jugular venodilation. In the group of patients without respiratory jugular venodilation, the first-attempt cannulation rate, overall success rate and frequency of arterial puncture were significantly better in the ultrasound group [13].

An RCT compared the complications and failures of subclavian vein (SV) catheterization using the standard landmark technique and the ultrasound-assisted technique. No significant differences between the two methods were observed [14]. There are no data comparing US assistance and the landmark technique for femoral venous (FV) access.

### Ultrasound guidance

The results of RCTs comparing ultrasound assistance and real-time ultrasound guidance for central venous access are conflicting. In one RCT the ultrasound-assisted technique was found to be as effective and safe as the real-time ultrasound-guided technique for the cannulation of the right IJV [12]. Another RCT performed in neonates and infants found significant advantages of ultrasound guidance over ultrasound assistance with regard to procedure time and number of puncture attempts [17]. A systematic review of the data supports real-time guidance of central line insertion into the IJV as compared to the use of US before IJV puncture [16].

There is convincing evidence from meta-analyses of RCTs that real-time ultrasound-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 [15, 16, 18–23]. In particular, a Cochrane review showed significant risk reductions by using two-dimensional US guidance of IJV catheterization for total complication rates (71%), inadvertent arterial

puncture (72%) and hematoma formation (73%). First-attempt access increased by 57% (two-dimensional US) or 58% (Doppler US) and the overall success by 12% [16]. There is limited data on US guidance of FV catheterization. A Cochrane review did not show any advantage of US guidance with regard to inadvertent arterial puncture or adverse events. However, the overall and first-attempt success rates increased with US guidance [15]. Meta-analyses also show a significant reduction in subsequent complications of central venous access for real-time ultrasound guidance compared to the landmark technique, in particular for pneumothorax and hemothorax [20–22]. These advantages were shown for particular patient groups and clinical situations, e. g. for adults requiring emergent central venous catheter placement [23, 24], ventilated patients [13], critical care patients [25, 26], oncological and hematological patients [27–29], in elective situations for parenteral nutrition [30], and for placement of hemodialysis catheters [20, 21]. Importantly, one RCT showed that US guidance reduces the incidence of complications when central catheter placement is performed by inexperienced operators [31]. Furthermore ultrasound guidance of central venous cannulation was shown to be cost-effective [19, 32].

Data are limited and inconsistent in pediatric patients. Two meta-analyses were not able to show a significant advantage of the ultrasound-guided over the traditional landmark approach [22, 33]. However, two subsequent RCTs found that real-time ultrasound guidance improved some outcome parameters [17, 34]. Based on this evidence, real-time ultrasound 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 [35–37]. Guidelines from various professional societies and expert groups endorse ultrasound guidance for the facilitation of central venous catheter placement, particularly when an internal jugular approach is used [10, 38–42].

### Recommendation 2

Real-time ultrasound guidance rather than ultrasound assistance should be routinely used for both short-term and long-term central venous access (LoE 1a, GoR A). Strong consensus (100%)

## Venous access – transjugular or transhepatic intravascular interventions of the portal venous system and/or of the hepatic veins



Beyond access to central veins, ultrasound guidance may be used to facilitate percutaneous transhepatic or transjugular placement of catheters and devices into the portal venous system or into the liver veins as a prerequisite of diagnostic interventions, in particular transjugular liver biopsy [43, 44], or of therapeutic interventions like thrombolysis and stent placement [45, 46], application of tissue seals or islet cell transplantation [47, 48]. The feasibility of endoscopic ultrasound-guided diagnostic and therapeutic interventions of the portal venous system has been described in experimental studies [49–52].

## Peripheral venous access

Two systematic reviews have shown that in adult and pediatric patients with difficult access, ultrasound guidance for peripheral venous catheter insertion increases the likelihood of successful cannulation [53, 54]. However, there is substantial variation in the definition of difficult venous access, procedure time, and success rate. In a study of more than 400 000 patients in an emergency department, it was shown that systematic training of residents and technicians in ultrasound-guided peripheral venous access was associated with reductions in the need for central venous catheter placement, particularly in noncritically ill patients [55]. Therefore, ultrasound guidance should be considered in selected patients, particularly if the traditional placement of peripheral venous catheters has failed or in the case of apparently difficult access conditions.

### Recommendation 3

Real-time ultrasound guidance should be considered for peripheral venous access in cases with difficult conditions for cannulation (LoE 1a, GoR A). Strong consensus (100%)

## Arterial access – radial artery catheterization

There is less published evidence on ultrasound-guided arterial access, when compared to central venous cannulation. Four meta-analyses of ultrasound guidance for radial artery catheterization in children and in adults reported a significant improvement of the first-attempt success rate, a time saving, and a reduced incidence of local hematoma compared to the standard landmark and palpation-based cannulation [56–59].

### Recommendation 4

Real-time ultrasound guidance should be considered for the catheterization of the radial artery (LoE 1a, GoR A). Strong consensus (100%)

## Arterial access – percutaneous transarterial angiography and interventions

Femoral artery access for percutaneous transarterial angiographic interventions may be difficult, particularly in obese patients, in patients with poorly palpable arterial pulse and in patients with scarring of the groin (“hostile groin”). An RCT showed that ultrasound-guided cannulation of the femoral arteries significantly decreased the number of attempts needed as well as the time for successful arterial puncture but only in patients with a weak arterial pulse and those with a leg circumference of  $\geq 60$  cm [60]. A recent multicenter RCT showed that ultrasound-guided retrograde femoral artery access was significantly superior to fluoroscopy with regard to the first-attempt success rate, number of cannulation attempts, speed of the access procedure and safety [61]. When a large-bore catheter or sheath ( $\geq 20$  French) is required for the endovascular placement of aortic stent grafts, real-time ultrasound guidance was found to reduce vascular complications, significantly shorten the procedure time and improve the success of percutaneous access closure [62]. In cases in which antegrade puncture of the common femoral artery was

not possible due to obesity or scarring, puncture of the superficial femoral artery guided by color Doppler imaging (CDI) was found to be technically easier and quicker, was associated with less radiation exposure and generated fewer complications than CDI-guided common femoral artery puncture [63]. However, beyond arterial access, CDI guidance of percutaneous transluminal angioplasty and stenting of femoropopliteal, crural, carotid and renal arteries has been shown in large series of patients to be technically feasible, safe and effective. Both the arterial puncture and the crossing of vascular lesions with a wire can be performed under ultrasound guidance. The selection of balloon length and diameter and positioning and inflation of balloons and stents may be performed with ultrasound assistance and guidance, respectively. The intraprocedural efficacy of the angioplasty can be assessed without contrast injection. The advantages of CDI-guided vascular interventions are decreased radiation exposure, both to patients and operators, no risk of iodinated contrast agent nephrotoxicity or allergies, quicker and safer arterial access, improved access to proximal occlusions of the superficial femoral artery, real-time detection of complications or failed recanalization (dissection, recoiling, embolism) and improved arterial access [64–73]. However, the technical success rate of CDI-guided femoropopliteal angioplasties in one prospective study was significantly lower than that of fluoroscopically guided angioplasties although the 12-month patency rates were similar. Technical failures are related to difficult ultrasound visualization of the interventional apparatus, especially in the presence of vascular calcification [64]. Further disadvantages of CDI guidance include incomplete visualization of the overall anatomy of the crural arteries, limited visualization of the pelvic and retroperitoneal vessels and relatively poor guidance for “crossover” procedures. As a consequence, up to 10% of cases require the additional use of fluoroscopy or the use of minimal iodinated contrast agents [61, 65, 69].

### Recommendation 5

Ultrasound can be used to facilitate arterial access (LoE 1b, GoR A) and to guide endovascular interventions (LoE 3b, GoR B). Broad agreement (80%)

## Technique of US guidance of vascular access

Despite US guidance, posterior vessel wall puncture may occur as a complication of venous catheterization [74, 75]. Various techniques are described for US-guided vascular access. Vascular access may be guided by target vessel delineation in a short-axis view (out-of-plane approach), in a long-axis view (in-plane approach), or both techniques may be combined. 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 favor of either of the two approaches [76–82].

## Detection of complications of central venous and arterial cannulation

Despite US guidance, immediate adverse events occur in approximately one-fifth of IJV central line insertion attempts [83]. Improper placement of the tip of the catheter in the right atrium is ob-

served in approximately 6% to 14% of cases and carries the risk of cardiac perforation and subsequent tamponade [84]. Pneumothorax and hemothorax are rare events if central venous puncture is performed under real-time US guidance [22, 23]. Ultrasound is effective in detecting central venous catheter misplacement [85–91] and is proven in the assessment of the presence or absence of a pneumothorax and other immediate complications of central venous access particularly in critically ill patients [84–87, 92, 93].

Ultrasound is also a valuable tool for the detection of mid-term and long-term complications of central venous catheter placement, in particular of thrombosis of the target vessel [94, 95], arterial pseudoaneurysm and arteriovenous fistula [96–100].

#### Recommendation 6

Ultrasound should be used to detect complications of vascular access (LoE 2b, GoR B). Strong consensus (100%)

### Treatment of arterial pseudoaneurysm

Arterial pseudoaneurysm (PSAN) is a contained rupture of all three layers of the arterial wall resulting from percutaneous transarterial interventions, trauma, infection or surgical vascular intervention. PSANs are reported to occur with a frequency of 0.05% to 2% after diagnostic angiography and 2% to 8% after transarterial interventions. Risk factors are the use of large introducer systems, complex interventions, inadequate compression after sheath removal, combined treatment with antiplatelet drugs and anticoagulants and other patient-specific factors [98, 101–103]. Small PSANs ( $\leq 20$  mm) in patients without antiplatelet and/or anticoagulant treatment will resolve spontaneously in approximately 50% of cases [104, 105].

Treatment options include US-guided compression, US-guided perifocal injection of saline solution, US-guided intralesional injection of thrombin or tissue adhesives, endovascular stent graft placement and surgical repair. A Cochrane analysis showed that compression treatment is effective in achieving PSAN thrombosis, regardless of whether US guidance was used [106]. However, compression treatment is time-consuming [107], often painful, and has a reported success rate of only 72%. Predictors of failure of compression therapy are anticoagulation and PSAN diameter [108, 109]. Preliminary studies suggested that combining manual compression with prior US-guided saline injection around the PSAN neck facilitates treatment and shortens compression time [110–112]. One RCT indicated US-guided para-aneurysmal saline injection treatment to be as effective, significantly faster and less likely to cause vasovagal reactions compared to US-guided compression treatment [113]. US-guided percutaneous thrombin injection into the PSAN proved to be more effective than a single session of US-guided compression in achieving primary pseudoaneurysm thrombosis within individual comparative studies. However, meta-analysis of pooled prospective data failed to demonstrate a statistically significant advantage of intralesional thrombin injection treatment [106]. A treatment algorithm assigning patients with small ( $\leq 20$  mm) PSANs and PSANs with a high complication risk for thrombin injection (lack of clearly definable neck, concomitant arteriovenous fistula) to US-guided compression treatment and all other pseudoaneurysms to US-guided intralesional thrombin injection was successful in 97% of 432 cases [114]. Further large case series reported comparable

success rates with thrombin injection therapy [98, 115–117]. The effect of thrombin injection therapy can be observed immediately and seems to be independent from medication with antiplatelet and anticoagulant drugs and PSAN diameter [98, 116, 117].

#### Recommendation 7

Compression treatments or para-aneurysmal US-guided saline injection or US-guided intrapseudoaneurysmal thrombin injection are effective treatments of femoral artery pseudoaneurysms after transarterial interventional procedures (LoE 1a, GoR A). Broad agreement (86%)

#### Recommendation 8

When deciding on the particular mode of treatment, the size of the pseudoaneurysm, antiplatelet drug and anticoagulation treatment, patient symptoms and specific features of the pseudoaneurysms should be taken into account (LoE 2b, GoR B). Strong consensus (100%)

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