US-guided peripheral vascular interventions, comments on the EFSUMB guidelines

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Abstract

Peripheral venous as well as arterial punctures have 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. This review comments on the evidence-based recommendations on ultrasound (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 US in Medicine and Biology (EFSUMB) from a clinical practice point of view. Part 1 of the review had its focus on general aspects of US-guidance and on central venous access, whereas part 2 refers to peripheral vascular access.

Keywords: Guidelines, recommendations, interventions, complications, guidance.

Introduction

This review comments on on the recently published European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) on interventional ultrasound (US), part VI, US-guided vascular interventions [1], and gives practical advice how to perform real-time ultrasound (RTUS)-guided access to peripheral veins and arteries.

Peripheral veins

Most punctures of peripheral veins will be performed successfully without any image-guidance based sim-

ply on anatomical landmarks, inspection and palpation. However, US-guidance may be helpful and should be considered if traditional placement of peripheral venous catheters has failed or in the case of apparently difficult access conditions [1].

Anatomy and diameter

In general, a larger vein is prefered for peripheral venous access (e.g. brachial vein). The pre-procedural sonographic evaluation allows a rational choice of the appropiate diameter of the catheter, which in the case of venous access particularly should not exceed 1/3 of the internal diameter of the target vein [1,2]. The peripheral vein should be larger than 3–4.5 millimetres for successful puncture and should be located between 3-15 mm under the skin [3]. Increasing vessel diameter is associated with increasing likelihood of success. Down to a depth of 16 mm, the larger of two vessels identified yields a greated likelihood of success, even if located comparatively deeper [3]. Witting et al reported higher success rates for veins with a diameter ≥4 mm versus those with a diameter <4 mm [4].

Technique and results

Before puncture, it is mandatory to clearly identify the vein and to rule out thrombosis. Three systematic reviews have demonstrated that US-guidance increases the success rate of peripheral venous cannulation [5-7]. Peripheral venous access under sonographic guidance is safe in adults and in pediatric patients as well [8-10], with an overall success rate of 91% and a successful first attempt in 73% of the cases [11]. Even in the study of Costantino et al [12], the use of US to guide placement of peripheral intravenous catheters in patients with difficult access resulted in a success rate of 97% as compared to the success rate of only 33% by using palpation and landmark guidance. Moreover, the US-guided approach required less time overall (13 min versus 30 min), less time from first percutaneous puncture (4 min versus 15 min), and fewer percutaneous punctures (1.7 versus 3.7), resulting in greater patient satisfaction [12]. Greater patient satisfaction was reported also by Schoenfeld et al [13]. The same results have also been obtained in pediatric patients, with an overall success rates of 80% versus 64% respectively, less overall time (6.3 versus 14.4 min), fewer attempts (median, 1 versus 3) and fewer needle redirections (median, 2 versus 10) [14].

In a prospective randomized study of patients with difficult venous access, defined as at least three failed attempts by nurses, US-guided peripheral line placement was superior to an external jugular vein approach, with initial success of 84% versus 50% respectively and an overall success of 89% versus 55% [15]. This method is a safe and effective alternative to central venous access in patients without visible or palpable peripheral veins requiring simple venous access, which is especially the case in many emergency department (ED) patients [11,16,17]. Over a period of five years, it was shown in 401,532 ED patients, that central venous catheter placement could be markedly reduced in non-critically ill patients by the use of US-guided peripheral intravenous access [18]. Also in intensive care unit patients, US-guided peripheral venous access helps to avoid central venous catheter placement and to reduce central line days [19].

Risks and complications

The only complications of US-guided peripheral venous access are arterial puncture and nerve contact [12]. Brachial artery puncture has been reported in 2% of cases of brachial and basilic vein cannulation under US-guidance in 100 emergency department patients with difficult intravenous access [11].

Femoral veins

Anatomy

Demonstrated with pelvic computed-tomography scans, in the saggital plane a portion of the FV is overlapped by the femoral artery in 65% of patients [20]. This finding was confirmed by US scans of 50 patients [21].

Technique and results

In a randomized trial of 20 patients undergoing cardio-pulmonary resuscitation in emergency departments, the RTUS-guided approach had a higher success rate when compared to the landmark approach (90% versus 65%), with a lower mean number of needle passes (2.3±3 versus 5.0±5), and a lower rate of arterial catheterization (0% versus 20%) [22]. In patients who needed acute hemodialysis access, the success rate was 100% under RTUS-guidance, with a higher rate of succesful first attempts as compared to the landmark approach (92.9% versus 55.3%), and a shorter mean total procedure time (45.1±18.8 versus 79.4±61.7 seconds) [23].

Risks and complications

In patients requiring acute hemodialysis access, femoral artery puncture occurred in 7.1% of the cases when using US-guided access, and in 15.8% of the cases when using the landmark approach [23].

Arteries

Overall, arterial line placement is considered a safe procedure, with a rate of major complications that is below 1% [24]. Arterial lines can be placed in various arteries, including the radial, ulnar, brachial, axillary, posterior tibial, femoral, and dorsalis pedis arteries. In both adults and children, the most common site of cannulation is the radial artery, primarily because of the superficial nature of the vessel. Additional advantages of radial artery cannulation include the consistency of the anatomy and the low rate of complications [25]. After the radial artery, the femoral artery is the second most common site for arterial cannulation. One advantage of femoral artery cannulation is that the vessel is larger than the radial artery and has stronger pulsation. Additional advantages include decreased risks of thrombosis and accidental catheter removal, though the overall complication rate remains comparable [26]. For percutaneous transarterial diagnostic and therapeutic interventions, preferably radial and femoral access routes are used.

General remarks

Generally, arteries are round, their wall is thicker than the veins wall, and normally a pulsation is visible. Colour Doppler Imaging (CDI) may be helpful to differentiate between arteries and veins, to measure the diameter and to identify pathologies like calcification, dissection, occlusion or anatomical variants.

Arterial RTUS-guided access techniques must be performed under sterile conditions. The transducer is placed in a sterile cover. The target vessel is examined using B-mode and colour Doppler US in a longitudinal and cross-sectional view. After local anesthesia, the arte-

rial puncture is performed usually in the long-axis view showing the full needle path and facilitating wire-insertion [27]. Going beyond arterial access, US guidance may be used also to facilitate endovascular interventions of femoropopliteal, crural, aortoiliac, forearm, carotid and renovascular vascular occlusions in selected patients or in particular with severe renal insufficiency or iodine allergy. The results of RTUS-guided peripheral vascular interventions are comparable to fluoroscopy-guided endovascular treatment [27].

Indications and contraindications

The indications for arterial line placement are as follows: continuous direct blood pressure monitoring: arteriel catheter mean artery pressure measurements are more accurate than sphygmomanometric blood pressure readings – escpecially in obese or very thin patients [28]; inability to use indirect BP monitoring (eg, in patients with severe burns or very low blood pressure); frequent arterial blood sampling.

Transarterial access is indicated for cardiac catheterization, diagnostic angiography and for various endovascular interventions.

Contraindications for arterial line placement and transarterial access include [29]: absent pulse; thromboangiitis obliterans (Buerger disease); full-thickness burns over the cannulation site; inadequate circulation to the extremity e.g. Raynaud syndrome; inadequate collateral flow; infection at the cannulation site; previous surgery in the area; synthetic vascular graft.

Risks and complications

Immediate adverse events of arterial puncture may include wall hematoma, dissection and acute thrombotic occlusion. The rate of these complications is related to the lumen diameter of the artery, the age of the patient, the presence of peripheral vascular disease, peri-interventional use of heparin, the number of puncture attempts and the size of the indwelling catheter or sheath [30,31].

Catheter site infections are uncommon but the incidence increases with the length of time the catheter is in place [32]. The risk of arterial catheter-related bloodstream infection (CRBSI) was found to be higher with the femoral site than with the radial site [33]. Common complications of arterial line placement are temporary radial artery occlusion, bleeding and hematoma [26]. Rare complications include permament ischemic damage, pseudoaneurysm formation, thrombosis, arteriovenous fistula, air embolism and nerve injury. Femoral artery dissection is a very rare event.

Tips and tricks (how to avoid risks and complications)

The tips, tricks and technique are similar as for the veins. In addition, for arterial access the following rules should be kept in mind: identify the artery by its pulsatile arterial flow pattern; to reduce the complication rate of arterial line placement, the catheter should be removed as soon as possible; the extremity with the catheter in place as well as the puncture site should be inspected daily for signs of ischemia, swelling and local infection; the catheter must be removed immediately at the fist sign of circulatory compromise, clot formation or infection. In this situation, flushing or manipulating the catheter must be avoided.

Several approaches have been validated to prevent complications of transradial and transfemoral access for percutaneous transarterial interventions: pre-interventional US vessel mapping and risk stratification, RTUS-guidance, appropriate anti-coagulation, intra-arterial application of nitroglycerin in the case of transradial approach, and reduction of sheath size [1]. Summarizing the available evidence, RTUS-guidance helps to reduce the complication rate of arterial access for cardiac and vascular interventions [34-43]. Technical failures are related to difficult US visualization of the interventional anatomy, especially in the presence of significant calcification [35,39,44].

Radial artery

Anatomy

The radial artery originates in the cubital fossa from the brachial artery. It traverses the lateral aspect of the forearm and gives rise to the palmar arches that provide vascular flow for the hand. At the wrist, the radial artery is proximal and medial to the radial styloid process located and just lateral to the flexor carpi radialis tendon.

Technique and results

Before puncturing the radial artery, adequate palpable collateral flow (ulnar blood flow) to the hand has to be confirmed. The initial puncture site should be as distal as possible. A common location is over the radial pulse, at the proximal flexor crease of the wrist. In any case, the puncture site should be at least 1 cm proximal to the styloid process so as to avoid puncturing the retinaculum flexorum and the small superficial branch of the radial artery.

Five meta-analyses of US guidance for radial artery catheterization in children and in adults reported a significant reduction of first-attempt failure, procedural time, and local hematoma rate compared to the standard landmark and palpation-based approach [45-49]. Regarding transradial access for cardiac catheterisation, a significant improvement of first-pass access rates, number of attempts and time to access in comparison to the traditional palpation-guided approach was shown in a prospective multicentre randomized control trial (RCT) [50]. Another RCT did not find substantial differences between both approaches in terms of success rate, time to

access, or safety however. Only in the case of failure of palpation-guided radial access, an additional US-guided attempt was associated with a shorter overall time to access [51]. Among experienced cardiac anesthesiologists, the use of US guidance had no impact on procedure success or complications [52].

Femoral artery
Anatomy

The femoral artery originates at the inguinal ligament from the external iliac artery. It passes under the inguinal ligament at approximately the midpoint between the anterior superior iliac spine and the pubic tubercle. It lies normally medial to the femoral nerve and lateral to the femoral vein and lymphatics.

Technique and results

To facilitate control of periprocedural bleeding and to prevent bleeding into the pelvis, the common femoral artery should always be accessed approximately 2.5 cm below the inguinal ligament, where it can be easily compressed. Problems may arise in the case of a high bifurcation of the common femoral artery. Normally, the femoral arterial pulsation can be palpated midway between the anterior superior iliac spine and the pubic symphysis.

Femoral artery access for percutaneous transarterial angiographic interventions usually is performed based on palpation and guided by fluoroscopy. However, in very obese patients, in patients with nonpalpable arterial pulse and in patients with extensive scarring in the groin region, in particular after vascular surgery (the "hostile groin"), femoral artery cannulation may prove difficult. The first report on Doppler US-guided femoral artery access was published in 1980 [53]. A RCT showed that US-guided puncture of the femoral arteries in comparison with traditional palpation-guided access, significantly decreased the number of attempts needed, as well as time to successful arterial puncture, in patients with weak arterial pulse and those with a leg circumference of ≥60 cm. In this study however, US-guidance was more time-consuming in those patients with a strong femoral artery pulse [54]. A multicentre RCT found RTUS-guidance for retrograde femoral artery access to be more successful than fluoroscopic guidance, but only in patients with a high bifurcation of the common femoral artery. In all patients RTUS-guidance improved first-pass access rate and speed of the procedure and resulted in a lower rate of venous puncture [44,55,56]. If traditional common femoral artery access is hampered by morbid obesity or by a "hostile groin", RTUS-guided superficial artery access seems to be technically easier, safer and faster compared with RTUS-guided common femoral artery access [55]. Summarizing the results of the randomized studies, a recent meta-analysis found RTUS-guided catheterization

of the femoral artery resulted in a 49% reduction in overall complications (hematoma, accidental venipuncture) and increased the likelihood of first-attempt cannulation success by 42% [57].In patients with large-bore catheter (≥20 French) cannulation of the femoral artery for the endovascular placement of aortic stent grafts, RTUS-guidance reduced vascular complications, improved the success rate of percutaneous access closure and reduced total intervention time [58].

Pedal arteries

A recent study showed feasibility and high success rate for US-guided transpedal artery access for treatment of peripheral artery disease [59].

Complications of vascular access

Arterial pseudoaneurysm
Definition

Arterial pseudoaneurysm (PSAN, false aneurysm) is a complete rupture of the arterial wall contained by the surrounding tissues. At present, most PSANs result from percutaneous transarterial cardiac and peripheral vascular interventions. Trauma, infection or surgical (vascular) interventions are rare causes. Due to the risk of concomitant complications, PSAN formation implies further treatment [60].

Frequency

Femoral PSANs are reported to occur with a frequency of 0.05 - 2 % after diagnostic angiography and 2 - 8 % after transarterial vascular interventions using a transfemoral approach [27]. After transradial catheterisation, PSAN is a very rare event [61,62].

Risk factors and complications

Risk factors are large-size sheaths, long and complex interventions, inadequate compression after sheath removal, and puncture site above the inguinal ligament. Patient-specific risk factors are arterial hypertension, diabetes mellitus, coronary artery disease, high body mass index, coagulation disorders and anticoagulation treatment, in particular combined antiplatelet and anticoagulant therapy. Symptoms include inguinal pain, swelling, bruit and rarely peripheral malperfusion. Potential complications are rupture and overt bleeding, compression of nerves, and infection. Combination of PSAN with an arteriovenous fistula may occur [60,63-65].

Diagnosis

Clinical presentation of peripheral PSNAs is painful swelling accompanied by a bruit. On B-mode US, a hypoechoic mass adjacent to the artery can be visualized, closely located to the puncture site. Sometimes, arterial pulsations are visible. PSAN may consist of several connecting chambers (loculated PSAN). Colour Doppler

US shows a typical pulsatile, bidirectional swirling flow pattern with rapid systolic inflow and decelerated diastolic outflow. The connecting tract ("aneurysm neck") between the PSAN and the feeding artery varies in diameteter and length (fig 1). The size of the PSAN, its morphology, thrombosed portions, length and diameter of the connecting tract, and anatomical relation of PSAN and vein accompanying the affected artery should be evaluated [27,66,67].

Treatment

Small PSANs (≤20 mm) will resolve spontaneously in approximately 50 % of cases depending on coagulation status [65]. Close follow-up is required. If treatment is necessary, options include "blind" compression, US-assisted or RTUS-guided compression [68,69], RTUS-guided para-aneurysmal saline-injection [70-73], RTUS-guided intralesional thrombin injection [60,68,74-77], percutaneous transarterial closure of the arterial defect using a covered metal stent or surgical repair [78].

Compression

A recent Cochrane analysis showed that compression treatment is effective in achieving PSAN thrombosis. There is no proof from comparative studies that

RTUS-guidance confers any benefit over manual compression or compression using a mechanical device (FemoStop) [68]. RTUS-guided compression treatment is time consuming and often painful. Average compression time to occlusion in one retrospective study was 33 (10-120) minutes [69]. Consequently, sufficient analgesic treatment is mandatory. In one large case series (n=281 patients), the overall success rate was only 72%. Anticoagulant treatment (further reducing the success rate to approximately 30% of cases), and large PSAN size negatively affect outcome of compression treatment [79,80].

Saline injection

Combining manual compression with prior large-volume US-guided saline injection around the PSAN neck shortens compression time and increases success rate to approximately 90% [70-72]. One RCT compared RTUS-guided compression and RTUS-guided para-aneurysmal saline injection and found similar final success rates of approximately 90% for both techniques. However, saline injection treatment was less likely to cause vasovagal reactions and reduced duration of the procedure compared to compression [73]. With this technique, under RTUS-guidance, 20-80 ml of isotonic saline solution is injected using a 22-gauge injection needle close to the PSAN neck until blood flow within the PSAN is markedly reduced or disappears. If necessary, a short period of RTUS-guided compression is added to achieve complete flow cessation [70-72].

Thrombin injection

Percutaneous thrombin injection for the obliteration of PSAN was introduced in 1986 [81]. In short, a 22-gauge injection needle is advanced into the inflow tract of the PSAN under sterile conditions and RTUS-guidance, followed by injection of small amounts of thrombine solution until complete cessation of blood flow is achieved (fig 2).
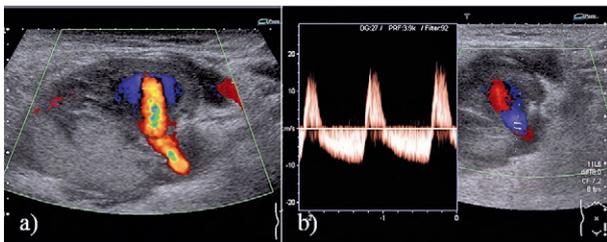

Fig 1. Large femoral PSAN with partial thrombosis 14 days after percutaneous transarterial coronary intervention in a patient with double antiplatelet treatment: reversal of blood flow direction at the apex of the PSAN (a; red: inflow; blue: outflow); Colour Doppler with typical "to and fro" waveform (b; Doppler sample within the connecting tract to the common femoral artery).
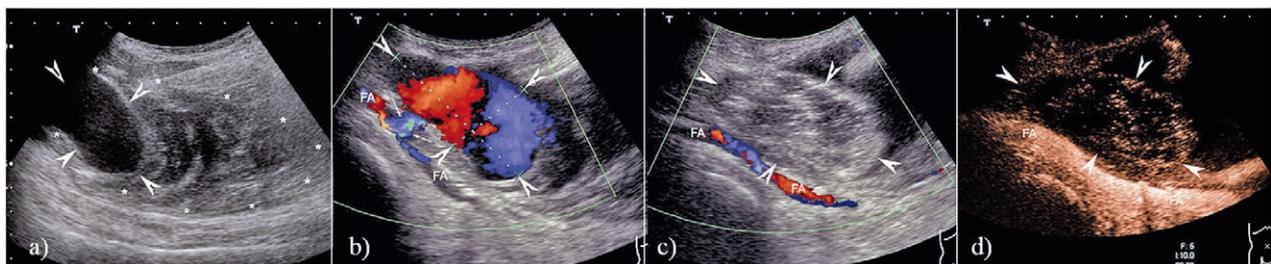

Fig 2. Thrombin injection of a huge femoral PSAN 28 days after percutaneous transarterial coronary intervention in a patient on dual antiplatelet treatment: partial thrombosis of the very large PSAN (a, b: the PSAN is marked by asterixis; the "open" part measuring 64 x 35 mm is marked by arrowheads); only 1 minute after injection thrombosis develops within the formerly "open" part (arrowheads) causing multiple hyperechoic reflexes, no flow within the PSAN in colour Doppler (c; femoral artery (FA) with flow using colour Doppler); complete thrombosis of the PSAN as well as unimpaired flow in the femoral artery are documented by CEUS (d; femoral artery (FA) is enhancing, the formerly "open part" of the PSAN (arrowheads) is not enhancing).

Several RCT have shown higher treatment efficacy of US-guided thrombin injection than a single session of US-guided compression. However, meta-analysis of these data failed to demonstrate a statistical significance of this advantage [68]. Overall success rates of thrombin injection treatment were reported between 94 and 100% [60,75-77]. The effect of thrombin injection therapy can be observed immediately and seems to be independent of antiplatelet or anticoagulant therapy and PSAN diameter [60,76,77]. Complications are rare, occurring in 1.3% of cases. Clinically, relevant arterial embiolisation was observed in 0.5% of cases [60].

Cyanacrylat injection

Single case reports have described the successful use of n-butyl cyanoacrylate combined with temporary trans-arterial balloon-occlusion of the feeding artery to prevent peripheral embolization of the sealant [82,83].

Treatment algorithm and contra-indications of RTUS-guided treatment

The decision on the particular treatment technique should be made considering size and anatomy of the PSAN, antiplatelet drug and anticoagulation treatment, symptoms and specific features of the pseudoaneurysms (e.g. lobulation or association with arteriovenous fistula) [1]. The presence of arterio-venous fistula is considered a contra-indication of intralesional thrombin injection due to a high risk of thrombin migration into the deep veins causing thrombosis. Infection, skin necrosis and local compression syndromes necessitate surgical repair [27].

A treatment algorithm assigning patients with small (≤ 20 mm) PSANs and PSANs with a high risk for adverse events of thrombin injection (lack of clearly definable neck, concomitant arteriovenous fistula) to US-guided compression treatment and all other PSANs to RTUS-guided thrombin injection was successful in 97 % of 432 cases. Implantation of a covered stent-graft was successful in two PSANs (0.5%), whereas surgical intervention was necessary in 10 patients (2.3%) [74].

Conclusion

The recently published EFSUMB guidelines on interventional ultrasound (part VI, US-guided vascular interventions) give evidence-based recommendations on the indications of ultrasound-guided access to peripheral veins and arteries including arterial pseudoaneurysms. This review comments these recommendations from a practical point of view and gives practical advice on how to perform ultrasound-guided peripheral vascular interventions.

Conflict of interest: none

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