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CIRSE Standards of Practice on Arterial Access for Interventions

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Abstract This CIRSE Standards of Practice document is aimed at healthcare professionals (including interventional radiologists) performing endovascular procedures to provide best practices for performing arterial access for interventions. It has been developed by an expert writing group under the guidance of the CIRSE Standards of Practice Committee. This paper encompasses up-to-date clinical and technical aspects in performing safe and appropriate arterial access for interventions.

Keywords Clinical practice · Arterial intervention

Abbreviations

CTA	Computed tomographic angiography
MRA	Magnetic resonance angiography
GP	General practitioner
CFA	Common femoral artery
PAE	Prostatic artery embolisation
US	Ultrasound
ALARA	As low as reasonably achievable

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Introduction

The CIRSE Standards of Practice Committee established a writing group which was tasked with producing up-to-date recommendations on access for arterial interventions. Evidently, this is not a clinical practice guideline, nor is it a systematic review of the literature. CIRSE Standards of Practice documents are not intended to impose a standard of clinical patient care, but instead recommend a pragmatic and safe approach in performing access for arterial interventions.

Methods

The writing group, which was established by the CIRSE Standards of Practice Committee, consisted of six clinicians with internationally recognised expertise in arterial interventions. The writing group reviewed existing literature on arterial access using PubMed to search for relevant publications in the English language from 2002 to 2019.

Background

Due to a rise in obesity, diabetes, and an ageing population profile, the incidence of peripheral vascular disease (PVD) is increasing [1, 2]. Although arterial access is used for a vast number of procedures (prostate & fibroid interventions, tumour embolisation, emergency embolisation and stenting, to name a few), the presence of background atherosclerosis must still be considered for access purposes as well as management of PVD itself.

Compared to 1990, arterial intervention has become less invasive, and endovascular procedures outnumber open operations by approximately 4:1, and as a result, methods of diagnosis and treatment have altered considerably [3–6]. In addition, arterial access sites have also changed radically. At the start of some of the authors' careers, translumbar aortography was still carried out as a method of interrogating the aorta, visceral and peripheral vasculature. This has since been replaced by non-invasive imaging, and arterial access is predominantly used for therapeutic or pre-procedural planning. As well as this, in the last ten to fifteen years, other areas of access have been utilised such as the radial arteries. Imaging methods have also undergone a substantial change in practice with few interventionalists now undertaking any arterial intervention without some degree of pre-operative planning. Peri-operative imaging has also changed markedly, with proven lower rates of complication when ultrasound (US) guidance techniques have been employed to obtain arterial access [7]. An increase in day-cases means that access site complications, which were once 'part and parcel' of arterial access, are much less readily tolerated and can be avoided in many cases with appropriate work-up.

Patient Preparation and the Clinic Visit

A focused history detailing prior arterial and open procedures, prior groin interventions and significant events are more likely to aid management than an exhaustive history. Medications and allergies need to be detailed, particularly with respect to anticoagulation. The increasingly ageing population means that a greater number will be on either antiplatelet agents or anticoagulants. A detailed discussion of this is beyond the scope of this document, but reference to the CIRSE anticoagulation SOP is recommended [8].

Clinical examination, likewise, needs to be focused with the option of using an ultrasound (US) machine with colour and Doppler function to assess the access point; however, this does not substitute further imaging, but rather allows us to gain perspective on whether further imaging is required and which imaging would be best suited.

For radial access, the operator should be familiar with and proficient in performing Allen's and Barbeau's tests [9–11].

Pre-Procedural Blood Tests

Pre-procedural blood tests including a full blood count, coagulation and renal profile are routinely used in the authors' centres when considering further imaging, use of contrast and prior to intervention; however, their routine use is not mandated by international guidelines [8] and local protocols should be followed to ensure medicolegal compliance. For endovascular procedures, we do not routinely recommend 'group and save' or cross-matching of blood.

Pre-Procedural Imaging

The NICE guidelines provide a comprehensive summary of the entire peripheral arterial disease spectrum which can attain risk of transfemoral access [2]. First-line recommendations include performing a duplex US $\pm$ magnetic resonance angiography (MRA) or computed tomography angiography (CTA) [12–15]. This will allow for assessment of arterial disease proximal to the puncture site, tortuosity, aneurysms and stenoses.

Utilising imaging this way allows for a tailored and accurate approach to patient access regarding laterality as well as femoral vs radial access.

The Day of the Procedure

Meet the patient and confirm their identity as well as ensuring the pre-procedural work-up is complete. Briefly explain the procedure again including the risks, benefits and alternatives. The majority of endovascular procedures are minimally invasive, therefore negating the need for regional or general anaesthesia; however, in a small number of cases anaesthesthetic input will be required. Some patients may need regional blocks prior to their interventions. This can be screened for prior to the day of the procedure.

As part of the consent, the post-procedure period is also explained to the patient. Mark the entry site with a marker; and then a separate arrow for the 'treatment side' [16–20], e.g. right CFA access for left SFA treatment.

The shift from a standard common femoral arterial approach to an alternative site such as brachial and radial can occur for a number of reasons. These include easier compression, decreased risk of groin and other complications, earlier mobilisation (patient can sit up immediately after upper limb puncture), and more recently, a realisation that it provides superior access to many of the mesenteric and pelvic vasculature. It seems very likely that radial (and brachial) access will continue to be used to a greater extent in the future.

Procedure

Access Needles and Techniques

Femoral Access

Access via the common femoral artery can be obtained either with a standard 19 G needle or with a 21 G micropuncture needle. A hollow needle is preferred to avoid a double-wall puncture. The use of a needle with lateral flaps (Seldinger and Cournand design) is an operator's preference [21]. As arterial blood will be immediately returned, a needle with a cap may also be used by less experienced operators. A needle with a needlestick-prevention mechanism may also be used for safety.

The wire inserted in most cases is an 0.035-inch Teflon-coated standard J-tip (150 cm long) with a stainless steel core, however, shorter wires which accompany the sheath may also be used. This type of wire is proven to offer safe access and minimise dissection risk. A straight floppy-tip Teflon-coated wire may also be used, but a J-tip is considered less traumatic and is easier to advance via tortuous vessels. A wire with hydrophilic coating should be used very cautiously through the access needle as shearing of the coating might occur [22].

Sheath size and length choice depend on the type of procedure. Most operators would start with a 4 Fr or 5 Fr 11-cm sheath if a diagnostic angiogram needs to be performed. For a retrograde approach large size access (14–24 Fr), an 0.035″ extra-stiff guidewire needs to advance to the aortic arch before insertion of the sheath.

However, for antegrade access, a micro-puncture set is considered a better option because the 0.021″ guidewire can be manipulated under ultrasound guidance in longitudinal view. In severe atherosclerosis or obese patients, a stiffened introducer may be used. A haemostatic valve adapter or a small three-way extension needs to be connected to the 4 Fr or 5 Fr introducer and an angiogram is obtained unless a side port is present. In case of a complex lesion that would potentially require stent insertion, a compatible French and length sheath should be considered. If the angle of the antegrade access is acute, a short, stiff guidewire needs to be used. The tip marker is required in order to be in position to delineate the level of insertion of the sheath to the vessel.

Pedal Access

For direct pedal access, a shorter (4 cm instead of 7 cm) needle is used. A dedicated pedal access kit is now available. For pedal access, minimal local anaesthesia needs to be used as these vessels usually have a very low perfusion pressure, and extrinsic compression by the local anaesthetic can interfere with accessing the vessel [23].

Brachial and Radial Access

The micro-puncture set is also very useful for brachial access. A 4-cm instead of 7-cm needle can be used. For radial access, a tapered 5 Fr or 6 Fr hydrophilic sheath with an 0.018″ introducer is used. Special radial sheaths are available for radial use which include higher size sheaths based on radial artery diameter.

A modified Allen test or an oximeter test should be performed to assess collateral circulation.

Although radial access has advantages over femoral access in terms of risk of bleeding and time to ambulation, radial access has its own disadvantages including vasospasm and occlusion. There remains a very small risk of stroke as the aortic arch will be crossed; however, this risk is related to the catheter access via the arch and not as a direct result of the radial access.

To avoid the potential disadvantages, a combination of medicines is administered in combination with the patient's blood; some refer to this as a "radial-access cocktail". Several different types of radial-access cocktails have been used for this purpose [24]. A cocktail of 2000 IU heparin, 200 μg nitroglycerine and 2-5 mg verapamil has been proposed for transradial access for interventional radiology in single-centre experience [25]. Diluting the cocktail with 20 ml blood and injecting it over 30 s to 1 min can prevent discomfort in the hand that is predominantly caused by verapamil.

Peri-Procedural Medication

Prior to the procedure any required medication should be prescribed, including radial cocktail (see above) if needed.

Use of antibiotics when puncturing or for interventions with in-situ stents remains controversial; referral to international and local antibiotics guidelines is recommended [26].

Image Guidance

Femoral Access

Traditionally arterial access is obtained by locating the common femoral artery (CFA) and the inguinal ligament by palpation. Fluoroscopy over the femoral head may be used to prevent high or low arterial entry. However, routine US guidance has demonstrated a decreased frequency of access site-related complications in large patient series and should be the first approach for all cases [7]. US permits delineation of the arterial anatomy, the level of the bifurcation, and the presence of arterial plaques and allows a single-pass puncture. The superiority of US guidance has also been demonstrated for antegrade punctures [27].

Brachial Access

US guidance should always be used as it assesses the proximity of the artery with bony structures as well as the larger nerves. For pedal access, a retrograde approach may be performed under fluoroscopic guidance if the vessels are heavily calcified, but there is significant radiation exposure to the hands of the operator. The puncture is much easier with ultrasound guidance both in transverse and longitudinal view. Assessing vessel patency is achieved by using a linear transducer probe with an appropriate frequency (higher) and using colour flow to assess vessel patency at the level of access. For pedal access, the foot should be in plantar flexion when accessing the dorsalis pedis and anterior tibial artery, inverted for the distal peroneal artery and in eversion and dorsiflexion for the distal posterior tibial artery.

Radial Access

Both arms may be accessed, but most operators would prefer the right arm. In addition, before puncturing a radial artery, it is recommended that the operator gathers information about potential previous or future coronary interventions. Distal puncture sites close to the wrist skin creases are less favourable as the radial artery is smaller, more tortuous and lies partially below the flexor retinaculum. However, very proximal punctures should also be avoided if possible as the artery lies in a deeper position which is less favourable for punctures and haemostasis. Blind puncture may also be performed; however, ultrasound guidance has shown better outcomes and is thus recommended [28].

A relatively novel approach that appears promising is distal radial access, as the artery is punctured in a position where not all collaterals are blocked, avoiding complete occlusion [29]. This is now increasingly utilised (Table 1 Summary of advantages, disadvantages and complication risks for arterial access sites).

A blind puncture at that site may lead to damage of the tendon's structures and the double-wall technique can irritate the underlying periosteum and increase the risk of haematoma formation. The use of the US allows identification of anatomical landmarks and enables accurate vessel access, especially in impalpable distal radial arteries. Accurate scanning can identify the superficial branch of the radial nerve, thus avoiding potential injury.

Procedural Steps

1. Groin vs wrist vs arm access and patient positioning
   As a general rule, patient positioning on the angiographic table should provide the easiest and most

Table 1 Summary of advantages, disadvantages and complication risks for arterial access sites [44]

Access point	Advantages	Disadvantages	Complication risk/rate
Femoral	Majority allows for prompt access and haemostasis Large sheath access possible and low risk	Can be challenging and increase procedure time when iliacs are occluded Increased bed rest post-procedure	Infection risk < 1% [25]; groin complications: 0.7% with closure device, 0.4% without [25]
Brachial	Suitable as an alternative when CFA access not possible Access from tip allows access to angulated branches Patient can sit up immediately post-procedure	End artery, limited maximal sheath size Higher complication rate Crosses the vertebral artery	Infection risk 1%; Embolic stroke < 1%
Radial	Easy access and easy haemostasis Patient can sit up earlier Easier access for coronary, supra-aortic vessels as well as angles viscerals and iliacs	Distance between access and target lesion can be limiting factor, especially in tall patients If not worked up properly, hand ischaemia can occur Limited upper sheath size	Infection risk 1%; Arterial occlusion < 0.3% [33]; Haematoma 0.3%
Axillary/subclavian	Larger vessel access compared to brachial	Manual compression extremely challenging/not possible Use of closure device mandated Can result in significant bleed during closure failure Larger sheath sizes may need cut-down	Haematoma 1–5% [43]; Nerve injury 1–5%; Stroke < 1%
Crural vessels [45]	If proximal lower limb vessels are occluded or severely diseased	Small calibre	Damage to the pedal arteries

direct access to the puncture site. The operator should be able to easily manipulate the catheter, observe the puncture site and use the angiographic table during the procedure. Patient positioning should also provide the best patient comfort during the procedure [30]. If there is a plan to use cone-beam CT during the procedure, arms should be out of the working area when possible. The patient is placed head-first supine for the retrograde femoral access and feet-first supine for the antegrade femoral access. For groin access, the patient arms are positioned at the side of the patient. If the patient is obese, the abdominal pannus should be retracted with tape to have clear access to the groin.
For arm and wrist access, the patient is placed supine and the index arm is abducted to 45 degrees and slightly hyperextended and externally rotated. For axillary or high brachial access, the patient arm is abducted 90 degrees with the elbow flexed and hand placed under the back of the head [30]. For pedal access, the patient is mostly placed in a feet-first supine position at the angiography table, the foot should be stabilised and knee slightly flexed, hip slightly externally rotated and supported with towels [31]. US is to be placed in such a position as not to cause significant neck torque for the operator during arterial access. Alternatively, utilising modern angiosystems which display the US image on the monitors can avoid the aforementioned issues. The working area should be clear of radiopaque external medical devices like cardiac/vitals monitorisation lines.

2. Sterilisation/patient draping
Sterile technique is used to prevent contamination and infection of the wound and procedure site. Arterial access procedures are considered clean procedures; therefore, absolute sterile technique measures should be applied. The most common source of pathogens for contamination and infections is endogenous flora of the patient's skin, mucous membranes, or hollow viscera. Possible exogenous sources for contamination are the operating team, the operating room environment, and all instruments and materials that are within the sterile field [31].

The procedure site and surrounding area should be prepared with an antimicrobial agent. The most commonly used antimicrobial agents are 2–4% chlorhexidine gluconate, 60–70% alcohol preparations and povidone-iodine [31]. After skin preparation, patient draping is performed with sterile sheets and towels. Draping creates a barrier between the non-sterile and sterile field. Sterile sheets and towels are placed in a specific manner that provides a sterile field where sterile instruments and gloved hands can be placed. Careful hand disinfection is paramount in preventing spread of infections. All personnel that participate in the procedure must sanitise their hands meticulously.

3. Local Anaesthesia
Lidocaine (maximum dosage of 5 mg/kg without epinephrine, 7 mg/kg with epinephrine) or prilocaine (maximum dosage of 8 mg/kg) should be applied to the skin and subcutaneous deep tissue in order to achieve local anaesthesia, and thus minimise the patient's discomfort during the arterial access. Although prilocaine has the lowest neurological and cardiac toxicity in amide local anaesthetics, it is associated with methemoglobinemia when exceeding a dosage of 400 mg [32]. Lidocaine is acidic and thus causes pain during injection. This pain could be eliminated if acidic lidocaine is buffered with 1 ml of 8.4% sodium bicarbonate per 10 ml anaesthetic [30]. Aspiration before the injection of local anaesthetic prevents inadvertent intravascular injection.

Post-Treatment and Follow-Up Care

Immediately After the Procedure

- Haemostatic control (manual compression or vascular closure device)
  Haemostasis following arterial puncture is traditionally obtained using direct manual compression at the puncture site for a variable length of time, depending on the size of the sheath introduced and the coagulation status of the patient. Manual compression of the vessel should be performed against a bony structure (i.e. femoral head, carpal bones, tarsal bones, the proximal or distal humerus). Subclavian and distal axillary arteries may be difficult to compress, and many operators prefer the use of a closure device. In situations where there is failure of haemostasis, either surgical cut-down or balloon tamponade from a second access site can be used to achieve haemostasis.
  Manual compression can be time-consuming and personnel intensive (10–30 min or more), requires prolonged bed rest on completion (up to 4–8 h) and can be uncomfortable for both patient and the provider [24]. Difficulties in achieving haemostasis with manual compression can also occur in obese patients, uncooperative patients, prolonged procedural time, patients on anticoagulant/antiplatelet therapy, or after removing large-bore sheaths.
- Closure Device Choices
  For radial puncture haemostasis, specifically designed pressure cuffs can be used to provide non-occlusive

haemostasis. The deflation rate is variable. Some of the authors remove 1-2mls every 5 min; others have a rule of thumb of half a minute per French. No standard deflation has been declared, but the general consensus remains to remove the balloon haemostat by 30 min [29].

Vascular closure devices are strongly recommended in same-day procedures, as they allow faster haemostasis, ambulation, and discharge, as well as decrease costs [25, 33]. Closure devices are categorised by their mechanism of action and fall into two main groups: active approximators and passive approximators. Active approximators are devices that physically close the arteriotomy site with use of either a nitinol clip or a suture. An example of this includes the Perclose closure device. Passive approximators are devices that deploy a plug, sealant, or gel at the arteriotomy site without physically closing the arteriotomy. Other types of device exist which provide haemostasis without direct action on the artery wall, such as clamps for assisted compression, assisted coagulant patches and sealants. The choice of device is mostly left to the discretion of the practitioner; however, for large vascular access, suture-based devices are mostly used, with newer technology emerging [34]. Antegrade femoral approach is not an absolute contraindication in the use of closure devices if used appropriately. Elasto-compressive dressing can be used following haemostasis [35].

- Bed rest with immobilisation of involved extremity
  For arterial access with sheath introducers up to 7 Fr diameter, a day-case setting is often performed. Patients must be instructed to bed rest for 4–6 h after the procedure while maintaining a flat, supine position for the first part of this period. Again, closure devices allow earlier mobilisation [36, 37]. Larger access or complicated access may require an overnight stay.
- Vital parameter monitoring
  After the procedure, pulse and blood pressure of all patients are regularly observed, either in a hospital ward or in the recovery room if in a day-care setting.
- Evaluation soon after the procedures
  Visual and palpatory inspection of the access site is performed immediately after closure, before bandaging or medication.
  Duplex sonography/hand-held Doppler in obese patients or in cases of antegrade puncture ± haematoma. Distal run-off should always be assessed with duplex/hand-held Doppler pre- and post-procedure.

In-Hospital Management

Clinical inspection is recommended 4 h after the procedure where the elasto-compressive dressing can be removed, and patient mobilisation is allowed.

If any significant bruising, haematoma or bleeding from the vascular access is noted during routine inspection, a colour Doppler US examination should be performed. If positive for a haematoma or pseudoaneurysm, US-guided manual compression ± use of thrombin injection may be required. CTA is recommended in those with clinical and physiological suggestions of active bleeding.

Provide patients with contact details of the vascular team, in case of any discomfort or swelling at the access site. Day-case patients should be contacted the next day to ensure they are appropriately recovering with no ongoing puncture-site issues.

Outpatient appointment can be offered based on local guidance and patient's clinical requirements. In most cases of percutaneous revascularisation, regular outpatient visits at 2–6 weeks include a US colour Doppler sonography during which the vascular access site should be inspected.

Complications

Complications after arterial access procedures have been significantly reduced with the use of minimally invasive access, US guidance and closure devices. However, the number of procedures continues to grow and the indications for minimally invasive treatments of complex patients expand with new techniques (i.e. distal radial access) being introduced. As a result, novel and pre-existing complications need continued consideration. Bleeding is the most common and the most severe complication. For retrograde CFA access, this may occur in the form of a haematoma (between 2–3% of cases), particularly in obese patients, and there is 0.5% risk of retroperitoneal bleeding in these cases [38–41]. In the latter case, patients will become haemodynamically unstable very soon after the procedure and a computed tomography contrast scan is immediately required to assess the extent of the bleeding followed either by endovascular treatment with the use of a stent graft or by surgical repair. Main risk factors for severe retroperitoneal bleed include using larger size sheaths, the number of attempts performed for femoral access, the erroneous location of puncture (i.e. above the inguinal ligament), the presence of anticoagulant and antiplatelet agents and erroneous haemostasis technique either because of inappropriate manual compression or because of failure of a closure device [42]. The majority of the above-mentioned risk factors may be limited prior to any arterial intervention. In case of antegrade puncture the likelihood of a high puncture is very low given also that most antegrade punctures are performed under ultrasound guidance.

In pedal access, haemostasis is usually performed with the use of a balloon from the antegrade approach, and the micro-puncture sheath is then removed safely. For brachial access, haemostasis should always be performed under US guidance, confirming the compression of the artery over the bony structures given the elevated mobility of the artery that might deceive the operator when performing manual compression. For the radial artery, there are specific haemostatic bands that are applied.

If a haematoma occurs in any arterial territory, this is usually self-limiting after one to two weeks. If there is persistence of haematoma, then the presence of a pseudoaneurysm needs to be excluded with a Doppler ultrasound scan. In case of pseudoaneurysm formation, percutaneous thrombin injection may follow in most cases; surgical repair may be considered in complex or refractory cases.

Other potential complications may be related to the catheterised artery and include arterial dissection, thrombosis, arteriovenous fistula (AVF) formation, arterial spasm, and distal embolisation. Prevention of such complications may again be related to the use of appropriate access guidewires, imaging guidance and appropriate pharmacological approach. Death is a complication that may occur in 0.03% of femoral access cases and 0.09% of the axillary access cases, both usually due to retroperitoneal bleeding, aortic dissection or severe allergic reactions. This is nowadays even more rare and with the use of all preventive measures this risk can be even further minimised.

Summary

Arterial access is the main access point for all arterial procedures, including vascular, oncology, trauma and emergency procedures. Careful planning of the access point, use of US-guided puncture and appropriate peri-procedural planning can minimise any complication and allow good outcomes for patients.

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Declarations

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References

1. Lu JT, Creager MA. The relationship of cigarette smoking to peripheral arterial disease. Rev Cardiovasc Med. 2004;5(4):189–93.
2. Peripheral arterial disease: diagnosis and management clinical guideline. (2012). [online]. Available at: https://www.nice.org.uk/guidance/cg147/resources/peripheral-arterial-disease-diagnosis-and-management-pdf-35109575873989.
3. Vartanian SM, Conte MS. Surgical intervention for peripheral arterial disease. Circ Res. 2015;116(9):1614–28.
4. Thukkani AK, Kinlay S. Endovascular intervention for peripheral artery disease. Circ Res. 2015;116(9):1599–613.
5. Spiliopoulos S, et al. Day-case treatment of peripheral arterial disease: results from a multi-center European study. Cardiovasc Intervent Radiol. 2016;39(12):1684–91.
6. Guez D, et al. Recent trends in endovascular and surgical treatment of peripheral arterial disease in the medicare population. AJR Am J Roentgenol. 2020;214(5):962–6.
7. Seto AH, Abu-Fadel MS, Sparling JM, et al. Real-time ultrasound guidance facilitates femoral arterial access and reduces vascular complications: FAUST (femoral arterial access with ultrasound trial). JACC Cardiovasc Interv. 2010;3(7):751–8.
8. Hadi M, Walker C, Desborough M, et al. CIRSE standards of practice on peri-operative anticoagulation management during interventional radiology procedures. Cardiovasc Intervent Radiol. 2021;44:523–36.
9. Cable DG, et al. The allen test. Ann Thorac Surg. 1999;67(3):876–7.
10. Jarvis MA, et al. Reliability of allen's test in selection of patients for radial artery harvest. Ann Thorac Surg. 2000;70(4):1362–5.
11. Barbeau GR, Arsenault F, Dugas L, Simard S, Larivière MM. Evaluation of the ulnopalmar arterial arches with pulse oximetry and plethysmography: Comparison with the allen's test in 1010 patients. Am Heart J. 2004;147(3):489–93.
12. Dhanoa D, et al. Position statement on noninvasive imaging of peripheral arterial disease by the society of interventional radiology and the Canadian interventional radiology association. J Vasc Interv Radiol. 2016;27(7):947–51.
13. Christie A, Roditi G. Vascular imaging: the evolving role of the multidisciplinary team meeting in peripheral vascular disease. Semin Intervent Radiol. 2014;31(4):320–9.
14. Layden J, Michaels J, Bermingham S, Higgins B; Guideline Development Group. Diagnosis and management of lower limb peripheral arterial disease: summary of NICE guidance. BMJ. 2012;345:e4947.
15. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, Hiratzka LF, Murphy WR, Olin JW, Puschett JB, Rosenfield KA, Sacks D, Stanley JC, Taylor LM Jr, White CJ, White J, White RA, Antman EM, Smith SC Jr, Adams CD, Anderson JL, Faxon DP, Fuster V, Gibbons RJ, Hunt SA, Jacobs AK, Nishimura R, Ornato JP, Page RL, Riegel B; American association for vascular surgery/society for vascular surgery; society for cardiovascular angiography and interventions; society for vascular medicine and biology; society of interventional radiology; ACC/AHA task force on practice guidelines. ACC/AHA guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and

abdominal aortic): a collaborative report from the American associations for vascular surgery/society for vascular surgery, society for cardiovascular angiography and interventions, society for vascular medicine and biology, society of interventional radiology, and the ACC/AHA task force on practice guidelines (writing committee to develop guidelines for the management of patients with peripheral arterial disease)–summary of recommendations. J Vasc Interv Radiol. 2006;17(9):1383–97.
16. Lee MJ, Fanelli F, Haage P, Hausegger K, Van Lienden KP. Patient safety in interventional radiology: a CIRSE IR checklist. Cardiovasc Intervent Radiol. 2012;35(2):244–6.
17. Golfieri R, Pescarini L, Fileni A, Silverio R, Saccavini C, Visconti D, Morana G, Centonze M. Clinical risk management in radiology. Part I: general background and types of error and their prevention. Radiol Med. 2010;115(7):1121–46.
18. Corso R, Vacirca F, Patelli C, Leni D. Use of "time-out" checklist in interventional radiology procedures as a tool to enhance patient safety. Radiol Med. 2014;119(11):828–34.
19. Dankelman J, Grimbergen CA. Systems approach to reduce errors in surgery. Surg Endosc. 2005;19(8):1017–21.
20. Koetser IC, de Vries EN, van Delden OM, Smorenburg SM, Boermeester MA, van Lienden KP. A checklist to improve patient safety in interventional radiology. Cardiovasc Intervent Radiol. 2013;36(2):312–9.
21. Seldinger SI. Catheter replacement of the needle in percutaneous arteriography; a new technique. Acta radiol. 1953;39(5):368–76.
22. Kemper FJ, Tielbeek AV, el Biltagiu S, el Gamal MI, van Gelder LM. Shearing of the plastic coating of a hydrophilic guide wire in a right femoropopliteal bypass graft: removal from the contralateral side. Cathet Cardiovasc Diagn. 1992;27(3):209–11.
23. Rogers RK, Dattilo PB, Garcia JA, Tsai T, Casserly IP. Retrograde approach to recanalization of complex tibial disease. Catheter Cardiovasc Interv. 2011;77(6):915–25.
24. Goldsweig AM, Secemsky EA. Vascular Access and Closure for Peripheral Arterial Intervention. Interv Cardiol Clin. 2020;9(2):117–24.
25. Robertson L, Andras A, Colgan F, Jackson R. Vascular closure devices for femoral arterial puncture site haemostasis. Cochrane Database Syst Rev. 2016;3:CD009541.
26. Chehab MA, Thakor AS, Tulin-Silver S, Connolly BL, Cahill AM, Ward TJ, Padia SA, Kohi MP, Midia M, Chaudry G, Gemmete JJ, Mitchell JW, Brody L, Crowley JJ, Heran MKS, Weinstein JL, Nikolic B, Dariushnia SR, Tam AL, Venkatesan AM. Adult and pediatric antibiotic prophylaxis during vascular and IR procedures: a society of interventional radiology practice parameter update endorsed by the cardiovascular and interventional radiological society of Europe and the canadian association for interventional radiology. J Vasc Interv Radiol. 2018;29(11):1483-1501.e2.
27. Slattery MM, Goh GS, Power S, Given MF, McGrath FP, Lee MJ. Comparison of ultrasound-guided and fluoroscopy-assisted antegrade common femoral artery puncture techniques. Cardiovasc Intervent Radiol. 2015;38(3):579–82.
28. Moussa Pacha H, Alahdab F, Al-Khadra Y, Idris A, Rabbat F, Darmoch F, Soud M, Zaitoun A, Kaki A, Rao SV, Kwok CS, Mamas MA, Alraies MC. Ultrasound-guided versus palpation-guided radial artery catheterization in adult population: a systematic review and meta-analysis of randomized controlled trials. Am Heart J. 2018;204:1–8.
29. Nairoukh Z, Jahangir S, Adjepong D, Malik BH. Distal radial artery access: the future of cardiovascular intervention. Cureus. 2020;12(3): e7201.
30. Kaufman JA, Lee MJ. Vascular and interventional radiology: the requisites E-Book: Elsevier Health Sciences; 2013.
31. Schmidt A, Scheinert D. Transpedal access. Catheter-Based Cardiovascular Interventions: Springer; 2013. p. 413–22.
32. Schug SA, Fuller C, Lau JH. Local anesthetics. Side effects of drugs annual. 31: Elsevier; 2009. p. 231–45.
33. Pate G, Broderick B. Variations in the usage and composition of a radial cocktail during radial access coronary angiography procedures. Ir Med J. 2011;104(9):280–1.
34. Noori VJ, Eldrup-Jørgensen J. A systematic review of vascular closure devices for femoral artery puncture sites. J Vasc Surg. 2018;68(3):887–99.
35. Van Wiechen MP, Ligthart JM, Van Mieghem NM. Large-bore vascular closure: new devices and techniques. Interv Cardiol. 2019;14(1):17–21.
36. Tagliaferro FB, Orgera G, Mascagni L, Laurino F, Tipaldi MA, Cariati M, Rossi M. FemoSeal® vascular closure device for antegrade common femoral artery access: Safety and technical notes. J Vasc Access. 2020;21(1):79–85.
37. Spiliopoulos S, Karnabatidis D, Katsanos K, et al. Day-case treatment of peripheral arterial disease: results from a multicenter european study. Cardiovasc Intervent Radiol. 2016;39(12):1684–91.
38. Upponi SS, Ganeshan AG, Warakaulle DR, et al. Angioseal versus manual compression for haemostasis following peripheral vascular diagnostic and interventional procedures—a randomized controlled trial. Eur J Radiol. 2007;61(2):332–4.
39. Samal AK, White CJ. Percutaneous management of access site complications. Catheter Cardiovasc Interv. 2002;57:12–23.
40. Kuchulakanti PK, Satler LF, Suddath WO, et al. Vascular complications following coronary intervention correlate with long-term cardiac events. Catheter Cardiovasc Interv. 2004;62:181–5.
41. Tsetis D. Endovascular treatment of complications of femoral arterial access. Cardiovasc Intervent Radiol. 2010;33:457–68.
42. Tavris DR, Wang Y, Jacobs S, et al. Bleeding and vascular complications at the femoral access site following percutaneous coronary intervention (PCI): an evaluation of hemostasis strategies. J Invasive Cardiol. 2012;24:328–34.
43. Tsetis DK, Perdikakis E, Kehagias E. Percutaneous treatment of iatrogenic femoral artery access complications. Hell J Radiol. 2017;2(2):51–65.
44. Harris E, Warner CJ, Hnath JC, Sternbach Y, Clement Darling III, R. Percutaneous axillary artery access for endovascular interventions. Journal of Vascular Surg. 2018;68:555–9.
45. Radaideh Q, Shammas NW. When pedal access is the only way to save a limb! Int J Angiol. 2020;29(3):205–9.