Vascular Access

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Introduction

Over the past decade, the use of a transradial approach (TRA) to obtain arterial access for cardiac catheterization procedures has gained popularity and surpassed the use of a femoral artery approach (FA) [1, 2]. The brachial artery, axillary artery, ulnar artery, and femoral artery cut down for access are rarely used.

Femoral Access

Obtaining femoral artery access is crucial for procedural and clinical success, and remains one of the key technical challenges for an interventional cardiologist. Access site complications are an important cause of cardiac catheterization morbidity and mortality.

- A "high" sheath insertion above the inguinal ligament increases the risk of retroperitoneal bleeding.
- A "low" sheath insertion into the profunda femoris or the superficial femoral artery (SFA) may result in an arteriovenous fistula, pseudoaneurysm, or limb ischemia.

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Contraindications for Femoral Artery Access

- Recommend not to perform if INR ≥2.0.
- If a patient is taking warfarin (INR ≥2.0) and a percutaneous procedure needs to be performed urgently or emergently via a FA, 1–2 units of fresh frozen plasma should be given to correct the coagulopathy. Patients who are considered high-risk for thromboembolic events should be bridged with unfractionated heparin or low molecular weight heparin.
- Avoid in patients taking a factor Xa inhibitor (rivaroxaban, apixaban) or a direct thrombin inhibitor (dabigatran), unless these medications have been held for >24–48 hr [3].
- Avoid in patients with morbid obesity, severe peripheral vascular disease, or aortic dissection.

Sheath Selection

- A 5 French (Fr) sheath will suffice for most diagnostic cardiac procedures.
  - If the pretest probability of disease is low, consider using a 4 Fr sheath.
  - Common femoral artery (CFA) diameter in women and diabetics tends to be smaller; consider using a 4 Fr sheath [4].
- The sheath can be upsized as needed for interventions (Table 2.1).

Table 2.1 Femoral sheath size by the procedure

Procedure		Sheath size
Diagnostic cardiac catheterization		5 Fr
PCI— most PCIs, two-stent strategy for bifurcation lesions [DK Crush technique, Culotte technique], bailout stent technique [TAP technique, Reverse Crush (internal) technique], orbital atherectomy or rotational atherectomy burr <2 mm		6 Fr
PCI with a planned two-stent strategy for bifurcation lesions [Mini Crush technique, modified T technique, SKS technique, V technique] or rotational atherectomy burr of 2 mm		7 Fr
Rotational atherectomy burr of 2.15 mm or 2.25 mm		8 Fr
Balloon aortic valvuloplasty	Tyshak 16–20 mm balloon	8 Fr
	Vida 16–20 mm balloon	8 Fr
	Z-MED 20 mm balloon	10 Fr
	True 20 mm balloon	12 Fr
Impella	2.5	13 Fr
	CP	14 Fr
Transcatheter aortic valve replacement	SAPIEN 3 (23 mm, 26 mm)	14 Fr
	SAPIEN 3 (29 mm)	16 Fr
	Evolute Pro Plus (23 mm, 26 mm, 29 mm)	18 Fr
	Evolute Pro Plus (34 mm)	22 Fr

> **Pearls**
> - In obese patients, stretch the skin tightly over the femoral head by moving the pannus out of the way and taping it across the body.
> - Use long sheaths (25 cm or 45 cm) in patients with tortuous iliac arteries or when the CFA is located deep below the subcutaneous tissue.

Needle Used

- High-risk patients may require the use of a micropuncture needle for more controlled access into the CFA, so a vascular closure device may be employed to close the access site after the procedure. These patients include:
  - Extremely obese patients with deep vasculature.
  - Patients who are anticoagulated or have a coagulopathy.
  - Patients with known or suspected peripheral arterial disease (arterial access should be obtained in a relatively non-diseased segment of the vessel).

Ideal Access Location

- The segment of the common femoral artery below the inguinal ligament (1–2 cm below the line traced from the anterior superior iliac spine to the pubic tubercle) is the ideal location for arterial access.
- This correlates roughly to an area that is at the mid-third of the femoral head, which is usually above the femoral bifurcation and below the lowest point of the course of the inferior epigastric artery (Fig. 2.1).

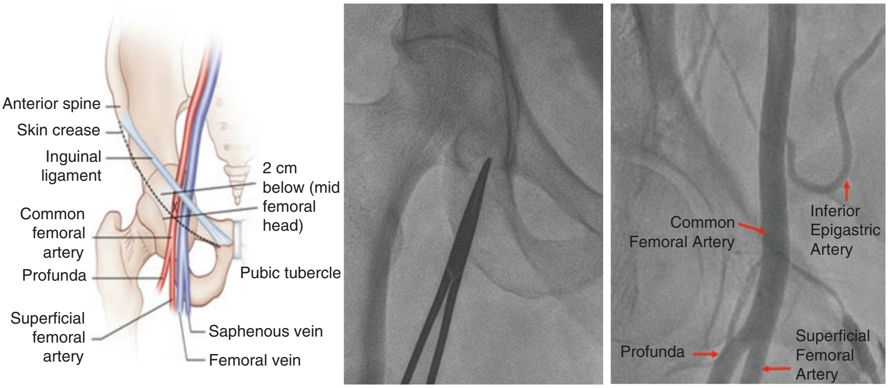

Fig. 2.1 Location and anatomy for femoral access

- The ultrasound (US) guided approach is safe and effective. US use to cannulate the CFA reduces the number of attempts, the time required to achieve successful access, and the rate of vascular complications [5].
- Femoral artery bifurcation is below the inferior border of the femoral head in 80% of cases, and below the inguinal ligament and middle of the femoral head in all patients [1].
- The femoral artery lies on the medial third of the femoral head in 92% of patients, and is completely medial to the femoral head in 8% of patients [6–8].

Pearls
- The inguinal crease is not a reliable landmark; however, we find it safer to puncture below it [9].

Common Steps for Micropuncture and Regular Access Needle

- Fluoro the femoral head with an overlying hemostat to mark the inferior border of the femoral head and palpate the point of maximal pulsation at this level.
- Give lidocaine 1–2% subcutaneously. Create a subcutaneous wheal at the entry site with 5 cc of lidocaine and then gradually deliver an additional 10–15 cc of local anesthetic to the deeper subcutaneous tissue, covering the anticipated needle path from the skin to the arterial wall.
- The needle entry point at the skin level should be at the lower border of the femoral head. Aim for an area between the inferior border of the femoral head to the mid femoral head (Fig. 2.1).
  - Monitor the patient for any vagal reaction, and the ECG for bradycardia.
- In rare cases, a small skin nick followed by the opening of the subcutaneous space gently with blunt forceps is required.
  - This provides a pathway for blood to ooze out of the skin in case of bleeding and allows for early identification of complications.
  - This step should be considered when there is difficulty inserting a sheath or when Perclose™ technique of closure is planned, especially for the closure of large sheaths.
- Enter the anterior wall of the femoral artery by advancing either the 18-gauge needle or the 21-gauge micropuncture needle at a 45° angle until there is backflow of arterial blood at the needle hub (Fig. 2.2. Step Ia).
  - Advancing the needle at a more vertical angle can result in kinking of the sheath and a more horizontal angle can result in a high stick.

- The backflow of blood when an 18-gauge needle is used should be brisk and pulsatile.
- The flow through a micropuncture needle is six times less compared with blood flow through an 18-gauge needle. The backflow may not appear pulsatile, but should be steady.

18-gauge Needle Steps

- The 0.035″ guidewire is threaded through the needle. There should be no resistance as the guidewire is advanced. If resistance is encountered, fluoroscopy should be used to ensure guidewire advancement is correct (Fig. 2.2. Step II a, b, and c).

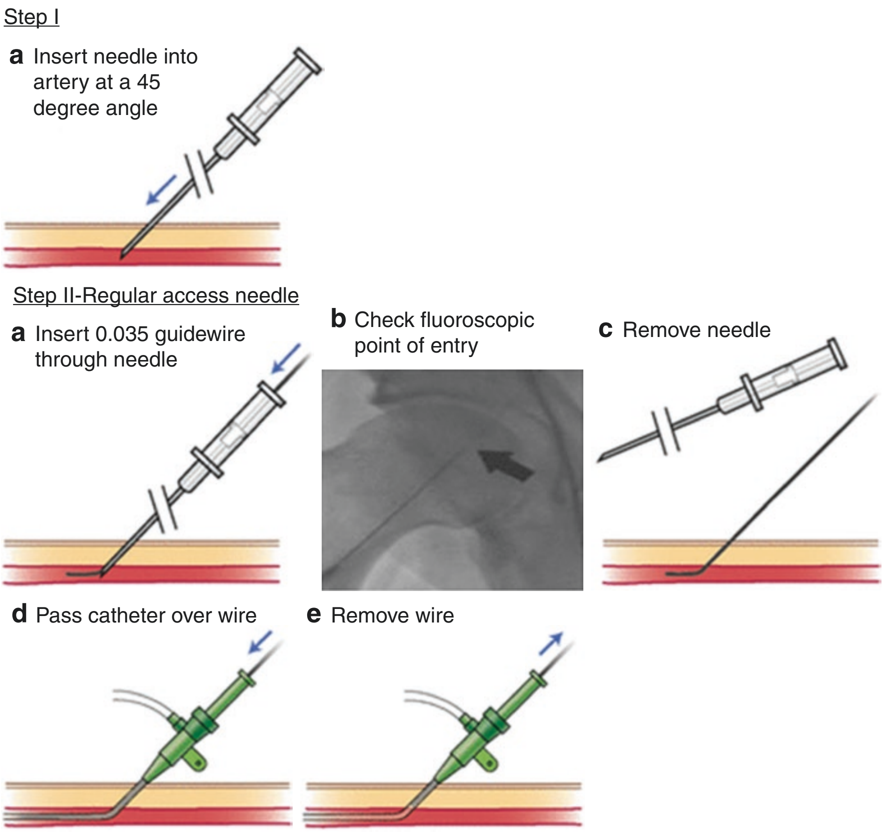

Fig. 2.2 Steps of femoral access

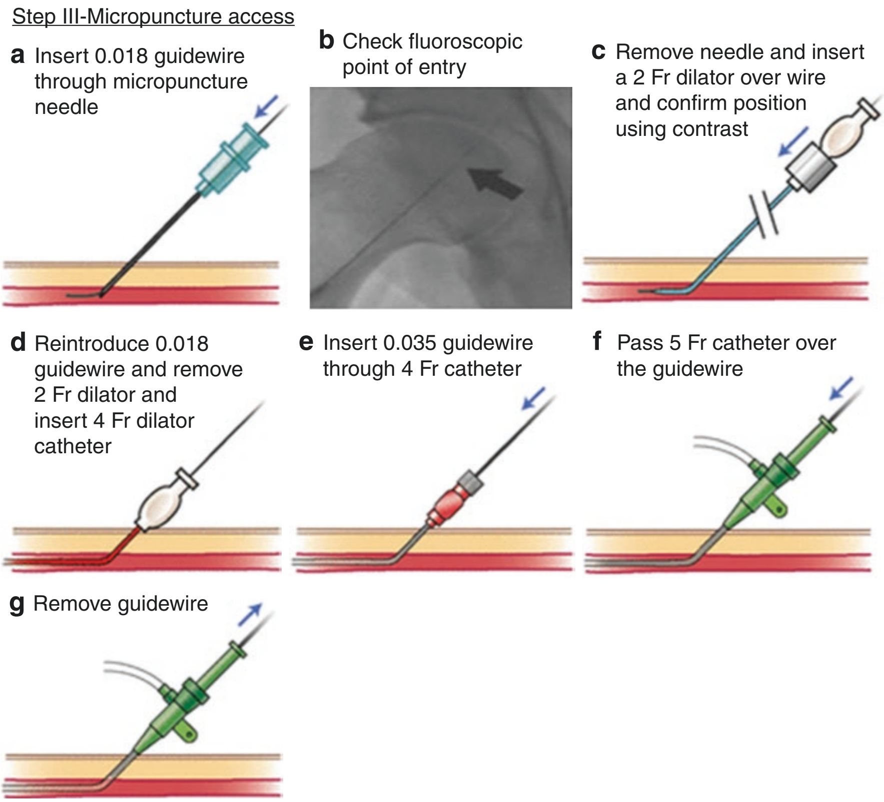

Fig. 2.2 (continued)

- Next, the needle is removed, the sheath/dilator system is advanced over the guidewire until the unit is well within the lumen of the vessel, and the guidewire and dilator are removed, leaving the sheath within the artery. (Fig. 2.2. Step II d and e).
- Once arterial access is obtained, a femoral arteriogram should be obtained by injecting dye through the sheath.

Micropuncture Steps

- Access the artery as described above using the needle from the micropuncture access kit.
- Once arterial access is obtained, the accompanying 0.018″ guidewire is advanced through the needle (Fig. 2.2. Step III a). Because the wire is straight (not J-tipped),

it is essential to check by fluoroscopy that the wire tip is in the iliac artery and has not advanced into a small branch (Fig. 2.2. Step III b).

- Remove the needle, thread the 2 Fr dilator accompanying the 4 Fr sheath/dilator system over the guidewire into the artery (Fig. 2.2. Step III c), and remove the guidewire. Alternatively, the 4 Fr micropuncture sheath/dilator system can be inserted directly over the guidewire. The 2 Fr dilator and guidewire is removed, leaving the 4 Fr micropuncture sheath within the artery.
- Perform an arteriogram with a 3–5 cc injection of contrast through the 2 Fr dilator to confirm the site of entry. If the arterial puncture site is not optimal, remove the catheter, hold pressure for 3–5 min to achieve hemostasis, and re-access the artery with the micropuncture needle. If the 4 Fr microcatheter was used to inject contrast and access is acceptable, insert the 0.035" guidewire and follow the steps as detailed below.
- Reinsert the 0.018" guidewire, remove the 2 Fr dilator and re-assemble the 4 Fr micropuncture sheath/dilator system, advance the system over the guidewire until the unit is well within the lumen of the vessel, remove the guidewire and dilator, and leave the sheath within the artery (Fig. 2.2. Step III d).
- Exchange the 0.018″ wire with a 0.035″ guidewire, remove the 4 Fr sheath, advance the 5 Fr or 6 Fr sheath/dilator system over the 0.035" guidewire, remove the guidewire and dilator, and leave the sheath within the artery (Fig. 2.2. Step III e, f, and g).

Angiographic Views

- The common femoral artery bifurcation is usually best visualized in the ipsilateral view 30°.
- In some cases, a contralateral view with a slight caudal projection may allow better visualization of the bifurcation.
- The angiogram should be evaluated carefully to see the level of puncture and the presence of arterial dissection or extravasation of dye due to peri-sheath leak, perforation, or back wall puncture.

Complications

- Clinical features, prevention, and treatment of various femoral artery complications are listed in Table 2.2 [2].

Table 2.2 Complications of femoral access: clinical features, prevention, and treatment

Type	Clinical features	Prevention	Treatment
Hematoma	Incidence: 5–23% Pain, swelling, or hardened area under the skin at the site If severe can cause tachycardia, hypotension, and fall in Hct Most resolve in a few weeks	Adequate compression after sheath removal Avoid arterial puncture below the femoral bifurcation	Manual pressure Mark the area to monitor change in size Obtain a vascular ultrasound to evaluate for pseudoaneurysm Other steps same as for retroperitoneal hematoma
Pseudoaneurysm	Incidence: 0.5–9% Swelling at the insertion site Large, painful pulsatile mass Bruit and/or thrill in the groin area A pseudoaneurysm can rupture or cause nerve compression resulting in limb weakness Diagnosed by ultrasound	Adequate compression after sheath removal and good hemostasis Avoid arterial puncture below the femoral bifurcation	Bed rest Small: Monitor as they spontaneously resolve after cessation of anticoagulation Large: manual or ultrasound-guided compression/thrombin injection or surgery
Arteriovenous fistula	Incidence: 0.2–2.1% Bruit ± thrill at the access site Extremity swelling, tenderness Diagnosed by ultrasound	Adequate compression after sheath removal and good hemostasis Avoid arterial puncture below the femoral bifurcation or above the inguinal ligament	Some resolve spontaneously Ultrasound-guided compression Surgical repair
Infection	Incidence ~ 0.4% 80% are diabetics with a mortality rate of 6% 50% ~ mycotic aneurysm, 50% result in mycotic aneurysm with S. aureus in 75% of cases *S. aureus* in 75% of cases The incubation period is 1 week to 1 month. Have a high degree of suspicion for any pain, erythema, swelling, drainage from the puncture site, or systemic signs of infection up to 1-month post-procedure, especially in diabetics	*VCD/manual sheath removal protocol* Clean area with an antiseptic solution. Place sterile towels and change gloves. Pull out in one fluid movement and let it bleed back and hold pressure just above the puncture site. Do not rub into the wound Avoid VCD in patients with significant PVD, CFA <5 mm, >3 prior procedures at the same site, or if the puncture is below the femoral bifurcation. Give 1 g of IV Cefazolin or 1 g of IV vancomycin (PCN allergic patients) in DM or morbidly obese patients receiving VCD	Long-term IV antibiotics or antifungals Surgical debridement and removal

Retroperitoneal hematoma	Incidence: 0.15–0.4% Moderate to severe abdominal, back, or ipsilateral flank pain Groin/hip pain with radiation to back if close to the iliopsoas muscle especially during extension of the hip Hypotension and tachycardia. Ecchymosis and decrease in hematocrit are late signs Diagnosed by CT Potentially fatal if not recognized early	Avoid puncture above the inguinal ligament Use micropuncture access in obese patients or difficult access and confirm site before sheath insertion Adequate compression after sheath removal and good hemostasis	Do not delay treatment if suspicion is high IVF/bed rest Interrupt anticoagulants and antiplatelets with blood transfusion if required May need surgical evacuation/ percutaneous balloon tamponade
Arterial occlusion by thrombo-embolism (TE)	Incidence: <0.8% 5 Ps: pain, paralysis, pallor, paresthesias, pulselessness Doppler studies/angiogram	Anticoagulation Vasodilators Careful monitoring during sheath removal and injection	Small TE may undergo spontaneous lysis Larger TE may need surgical or percutaneous thromboembolectomy or thrombolytic agents
	Percutaneous thrombectomy:		
	Access from the contralateral side and give 5000 units of heparin if no Anticoagulated		
	Cross TE with a 0.014″ or 0.018″ wire		
	Thrombectomy device is then introduced over the wire to remove any thrombi ± PTA/stent		
Iliac dissection	Usually painless and retrograde		Bed rest with follow-up clinical exams and imaging if nonflow limiting If flow limiting, PTCA + stent is the treatment of choice
Femoral neuropathy	Incidence: ~0.2% Pain ± tingling at the access site Numbness ± weakness at access site or down the leg Decreased patellar tendon reflex	Avoid injection or insertion lateral to the arterial pulsation	Physical therapy Local anesthetic injections

Radial Access

Performing cardiac procedures via a TRA compared with a FA is associated with a reduction in bleeding events and vascular complications. This is largely driven by lower rates of minor bleeding [10]. A shift to a "radial-first" strategy in the United States has improved acute coronary syndrome related outcomes, quality of life metrics, and reduced healthcare costs [10]. The failure rate for cardiac procedures using a TRA is higher than the FA and ranges from 1–5% [11].

TRA Failure

- TRA failure is usually seen in patients who are:
  - Short.
  - Elderly.
  - Female.
  - Post-CABG.
- TRA failure is usually attributed to [11]:
  - The steeper learning curve for obtaining radial access.
  - The smaller caliber of the radial artery.
  - Anatomical variations in radial artery distribution.

Advantages and Limitations of TRA for Cardiac Procedures

- Advantages [11]:
  - Reduced duration of post-procedure bed rest and length of stay.
  - Lower incidence of access site complications (bleeding, pseudoaneurysm, and arteriovenous fistulas).
  - Lower in-hospital mortality.
  - Patient comfort.
  - Reduction in overall costs.
- Limitations [11]:
  - Inability to use larger sheaths (largest recommended is 6–7 Fr sheath).
  - Increased radiation exposure (exposure is greater with the right TRA compared with a left TRA; overall exposure decreases with experience).
  - Potential for radial spasm, radial artery occlusion, other vascular complications (refer to radial complication section below).
  - Potential need for crossover to a FA.

Vascular Anatomy of the Hand

- The ulnar artery and the radial artery provide a dual blood supply to the hand (Fig. 2.3).
- The superficial palmar arch lies below the palmar fascia. It is supplied predominantly by the ulnar artery and to a lesser degree by the superficial branch of the radial artery.
- The deep palmar arch lies beneath the flexor tendons and proximal to the superficial arch. It is supplied predominantly by the deep branch of the radial artery and to a lesser degree by the deep branch of the ulnar artery.
- Patients may have variations in anatomy limiting or precluding dual blood supply to the hand. If this is the case, a TRA should be avoided.
- Allen's test or Barbeau's test can help evaluate the presence of adequate blood supply to the hand before performing a procedure via the TRA.

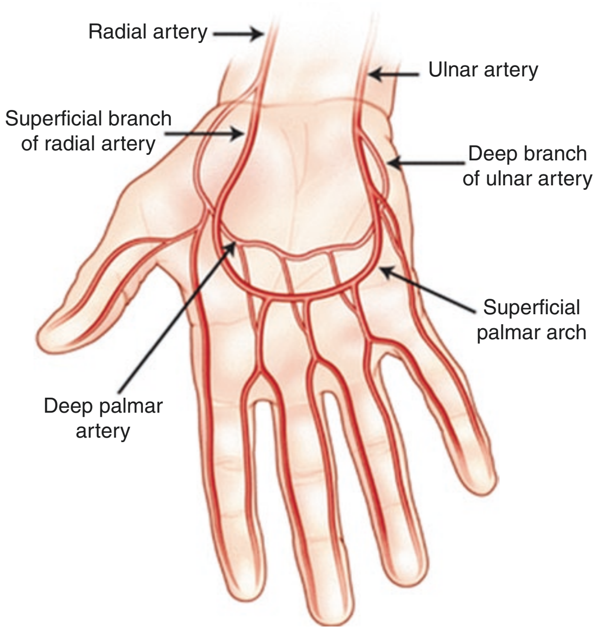

Fig. 2.3 Arterial supply of the hand

Patient Screening and Selection

- TRA is preferred in patients who are at high risk for femoral vascular access complications. These patients include:
  - Morbid obesity (>125 kg).
  - Severe lower extremity peripheral vascular disease.
  - Abdominal aortic aneurysm with thrombus.
  - Anticoagulated patients.
  - Patients who cannot lie flat.
  - Patients with bleeding diathesis.

Pearl

- Left TRA is preferred in patients of short stature, older age, with a high probability of tortuosity in the right subclavian artery, and those requiring LIMA angiography.

Contraindications for Radial Access

- Non-palpable radial artery pulse.
- INR > 2.5 for elective procedures.
- Patients with existent AV fistula for dialysis or those at risk for starting dialysis [10].
- Severe vaso-occlusive disease (i.e. Raynaud disease, Takayasu arteritis, thromboangiitis obliterans) [10].
- Documented small radial artery size or known complex radial/brachiocephalic anatomy [10].

Preprocedural Testing

- Adequate collateral circulation to the hand can be assessed by performing Allen's test or the Barbeau's test (more objective) [2].
  - Neither test has been shown to predict clinically significant periprocedural complications and performing these tests is not mandatory.
- The most reliable method to assess collateral circulation is by using Doppler ultrasonography [2].
  - Allows for evaluation of the blood flow in the arteries and collaterals.
  - Allows for a better understanding of vascular anatomy.

Allen's Test

- The patient is asked to make a fist.
- The operator simultaneously compresses the radial and ulnar arteries, occluding both arteries (Fig. 2.4).

- The patient opens and closes their hand five times. The final opened palm should appear blanched.
- Pressure on the ulnar artery is released while maintaining occlusive pressure on the radial artery. The hand is observed for color changes.
  - Return of the hand color to pink within 8–10 s is a "positive" Allen's test and suggests that the ulnar blood supply in that hand will be sufficient if the radial artery is occluded (Fig. 2.5).
  - If the release of the ulnar artery occlusive pressure does not result in a return of pink hand color within 8–10 s then it is a 'negative' Allen's test. This suggests that the ulnar blood supply to the hand will be insufficient if the radial artery is occluded. TRA on that hand should be avoided, and alternative access should be obtained.

Fig. 2.4 Allen's test, compress the radial and ulnar arteries simultaneously

Fig. 2.5 Release the ulnar artery

Barbeau's Test (Allen's Oximetry Test)

- Attach a pulse oximeter to the access site hand and observe the pulse waveform on plethysmography.
- Apply occlusive pressure to both the radial and ulnar arteries simultaneously so the waveform on plethysmography is absent.
- Release pressure from the ulnar artery while maintaining occlusive pressure on the radial artery, monitor the pulse waveform on plethysmography, and compare findings with baseline pulse waveform on plethysmography (Fig. 2.6).
- Changes of the tracing are classified by the Barbeau classification into four categories (Fig. 2.7).

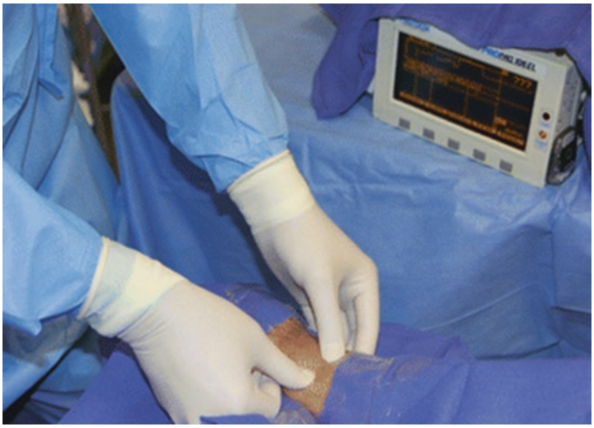

Fig. 2.6 Compress the radial artery and ulnar artery to occlude both vessels until the waveform on plethysmography is absent, release the ulnar artery, and observe the pulse waveform of the ulnar artery

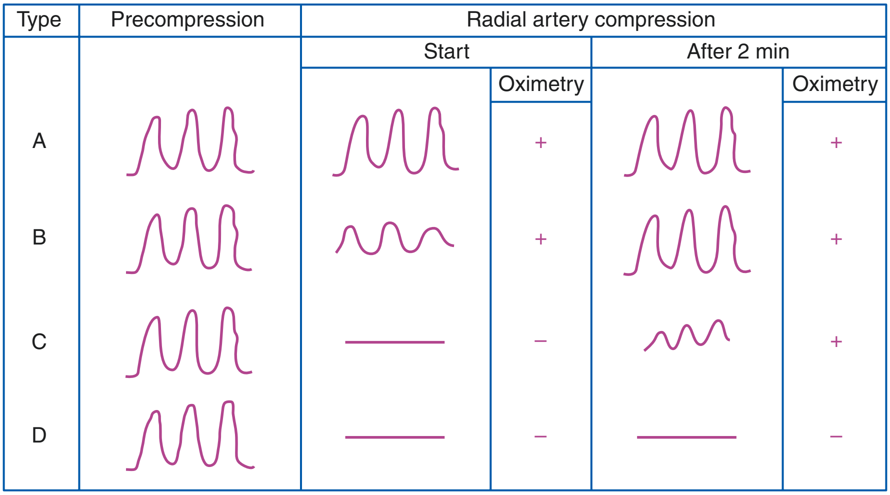

Fig. 2.7 Barbeau test

- Type A: no change in pulse wave.
- Type B: damped but distinct pulse waveform.
- Type C: loss of phasic pulse waveform, followed by recovery in 2 min.
- Type D: no recovery of pulse tracing within 2 min.

- Interpretation of the Barbeau's test findings.
  - Normal test:
    Return of a waveform (Type A waveform).
  - Abnormal test if any of the following:
    Oximetry readings are different after the release of ulnar artery occlusive pressure (Type B or C waveform).
    Continued absence of a waveform (Type D waveform) (Do not cannulate the radial artery if a type D waveform is present).

Prepping the Arm

- The arm is immobilized on the radial arm board with the palm facing upward and obliquely.
- The wrist is hyperextended with a wrist brace or towels. In this position, the radial artery is more superficial, making it easier to palpate (Fig. 2.8a).
- A pulse oximeter is placed on the index finger for continuous monitoring during the procedure.
- Sterilizing solution is applied to the area from the flexor crease to the mid-forearm. Also, prepare and sterilize the right and left groin because of the possibility of cross-over from the TRA, or the need for mechanical support.
- Drape the arm and hand so only the area from the styloid process of the radius to approximately 5 cm proximal is exposed.

Radial Artery Puncture and Sheath Insertion

- Pre-procedure planning is crucial for TRA success. It helps avoid multiple arterial punctures, reduces the risk of radial artery spasm, and vascular complications.
- Ultrasound can be used to visually identify radial artery location, depth, course, and patency.
- Palpate the radial artery, stabilize it with the tip of your finger, and apply local skin anesthesia with 0.5–1 ml 1% lidocaine.
- The radial artery puncture site should be 2 cm proximal to the styloid process (Fig. 2.8b).
- Use one of two techniques to gain successful radial artery access.
  - *Seldinger technique with back wall puncture (Double-wall 'Through-and-Through' approach).*

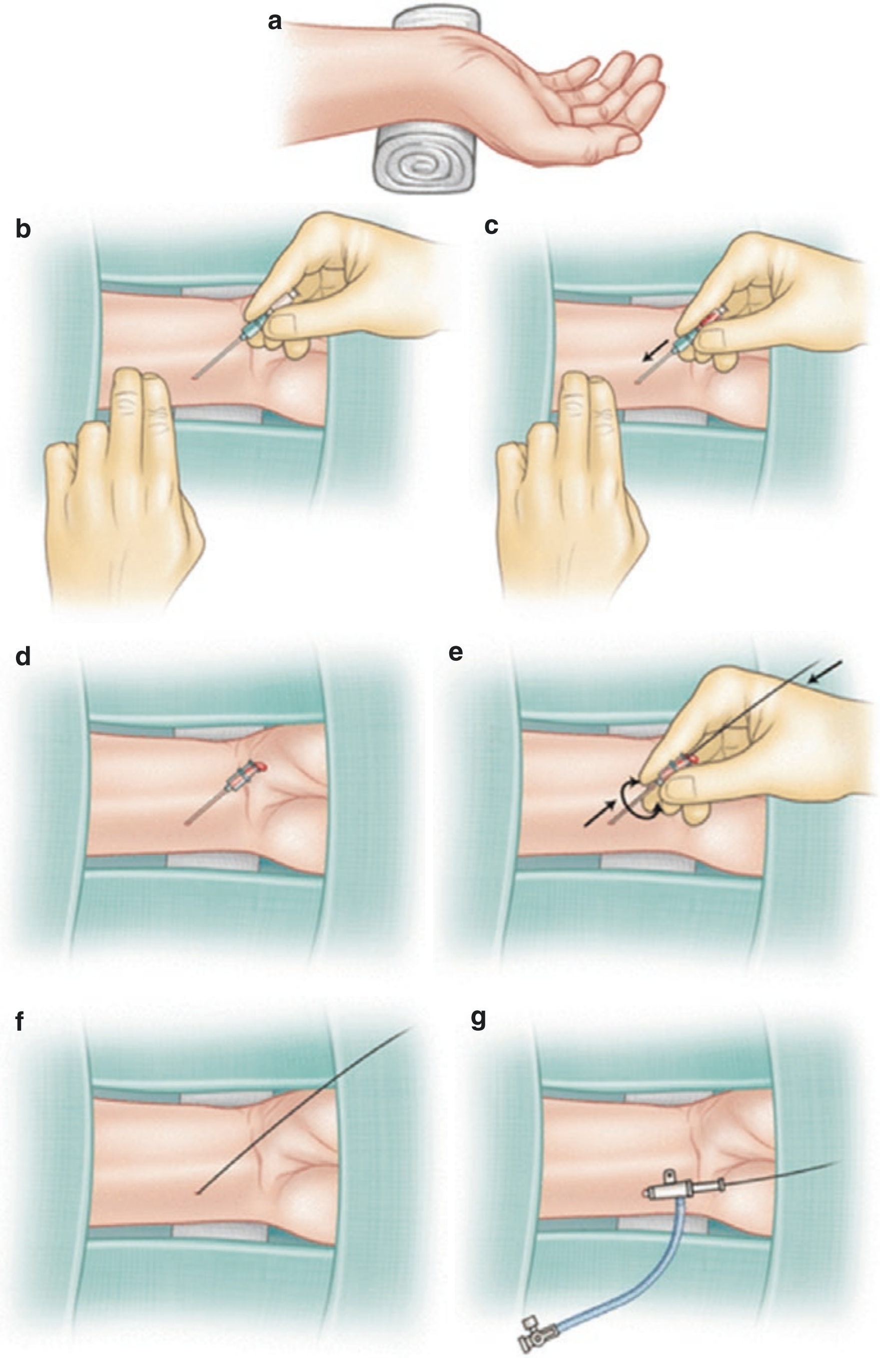

Fig. 2.8 Steps of radial access. (**a**) Hyper-extend the wrist. (**b**) Puncture 2 cm above the styloid process. (**c**) Pulsatile blood flow is seen. (**d**) Advance needle a few millimeters. (**e**) Thread the 0.018" guidewire through the needle. (**f**) Remove the needle. (**g**) Insert the Terumo sheath

When blood appears in the hub of the IV catheter (Fig. 2.8c), the needle and catheter system is advanced a few millimeters through the back wall of the artery to transfix the artery.
Subsequently, the needle is withdrawn leaving the catheter in place (Fig. 2.8d).
The catheter is gently drawn back until pulsatile backflow appears.
Once pulsatile blood flow is observed, advance a 0.018″ nitinol floppy guidewire (30–50 cm in length, with a floppy tip and more rigid shaft) through the cannula of the catheter (Fig. 2.8e).
Once the wire is passed to the desired level through the cannula, the catheter is removed leaving the wire in place (Fig. 2.8f).

– *Single-wall anterior puncture technique.*

This approach uses a 21-gauge micropuncture needle that is 2–5 cm in length.
You may or may not feel a tactile "pop" as the needle passes through the anterior wall of the radial artery.
When the needle is in the lumen, you will have immediate brisk blood flow, which may not necessarily be pulsatile.
Once you have steady blood flow insert a 0.018″ nitinol floppy guidewire, remove the needle, and leave the guidewire in place.

- Advance a 10 cm hydrophilic sheath over the 0.018″ nitinol floppy guidewire (Fig. 2.8g).
  - Sheath size is selected based on the minimum inner diameter needed to accommodate the equipment to be used for the procedure.
  - To reduce radial artery occlusion, try to maintain a radial artery inner diameter to sheath outer diameter ratio of <1.10.
  - For most patients, a 6 Fr sheath is generally safe to use and preferred (should intervention be required, the sheath does not necessarily need to be exchanged).
- Remove the guidewire and dilator, and leave the sheath within the artery.
- Next, a cocktail consisting of an antithrombotic agent (unfractionated heparin, enoxaparin, or bivalirudin), and one or more vasodilators (nitroglycerin, verapamil, and nicardipine) is prepared in a single 50 cc syringe and given through the sheath sidearm to prevent thrombosis and vasospasm.
  - When giving the cocktail aspirate 20–30 cc of blood to dilute the mixture before injection and deliver the cocktail slowly over 30–60 s, as this helps reduce patient discomfort.
- After delivery of the cocktail, flush the sheath with 10 cc of heparinized saline.
- Secure the sheath in place with a transparent adhesive dressing.

Antithrombotic Agents

- The recommended doses of antithrombotic agents are as follows [2]:

– Unfractionated heparin 50 IU/kg, up to 5000 IU total.
– Enoxaparin 60 mg.
– Bivalirudin 0.75 mg/kg bolus intravenously for diagnostic procedures, followed by infusion at 1.75 mg/kg/h if PCI is indicated.

Vasodilators Agents

- The recommended doses of vasodilator agents are as follows [1]:
  – Verapamil 2.5 mg; Verapamil is to be used cautiously (or avoided entirely) if the patient has severely reduced systolic left ventricular function or bradycardia.
  – Nitroglycerin 200μg; Nitroglycerin is to be avoided in hypotensive patients or those with severe aortic stenosis.

Pearls

- When using the Seldinger technique with back wall puncture, ascertaining pulsatile flow from the IV catheter is essential before proceeding. Pulsatile flow may not be seen when using a micropuncture needle.
- Quickly recognize problems by tactile feedback from a floppy tipped guidewire. If you feel resistance while advancing the 0.018″ nitinol floppy guidewire, stop, and perform the following steps to delineate the level and type of impedance encountered [12].
  – Fix the guidewire and remove the IV catheter.
  – Partially insert a 5 Fr or 6 Fr sheath dilator into the artery over the guidewire to a distance of 5–10 cm and remove the guidewire.
  – Perform angiography using 3–5 cc of contrast.

Radial Complications

Radial Artery Spasm

- Most common reason for TRA failure (~40% of cases) [13].
- Risk factors predisposing for spasm:
  – Younger age.
  – Women.
  – Lower body weight.
  – Small radial artery diameter.
  – Large sheath size.
  – Multiple access attempts.
  – Number of catheters used.
  – Procedure duration.

- Suspect spasm if the patient reports pain in the arm or if there is resistance to catheter advancement.
- Angiographically the vessel will appear narrowed with smooth arterial contours.
- Differential diagnosis must include inadvertent recurrent radial artery access, anomalous radial origin (high origin) and course, medial calcific sclerosis (Mönckeberg disease).
- Prevention and Treatment [12]:
  - Gaining radial access on the first attempt is imperative because the vessel is prone to spasm with repeated attempts.
  - Medications:
    - Give additional sedation.
    - Direct administration of vasodilatory/antispasmodic agents through the sidearm of the introducing sheath (nitroglycerin, verapamil, diltiazem, adenosine, nitroprusside, or nitric oxide).
  - Repeat angiography after several minutes to assess if the spasm has resolved

    If spasm resolves, use a 0.035″ wire to traverse the area of spasm. If the wire passes, then load and advance the catheter over the wire.

    If spasm does not resolve, consider using alternative access.

Radial Artery Occlusion

- Most common complication following TRA (typically subclinical).
- Occurs usually shortly after the procedure (~1–10% of cases) [2]:
- Concerning because [2]:
  - Increased risk of developing hand ischemia.
  - Unable to use a TRA for future procedures.
  - Radial artery is no longer a suitable conduit for:
    - Coronary artery bypass grafting.
    - Arteriovenous fistula formation for patients requiring dialysis access.
    - Intra-arterial pressure monitoring.
- Risk factors predisposing for RAO [2]:
  - Older age.
  - Women.
  - Lower body weight.
  - Elevated creatinine.
  - Peripheral artery disease.
  - Diabetes.
  - Smoking.

- Procedural factors associated with RAO [2]:
  - Sheath size relative to the radial artery diameter.
    - Larger sheaths increase the risk of vascular trauma and create a prothrombotic state.
    - It is important to maintain a sheath-to-artery diameter ratio < 1.10.
  - Inadequate anticoagulation.

  – Inadequate patent hemostasis.
- Majority of patients are asymptomatic because of dual blood supply and extensive collateral circulation involving the hand.
- Suspect RAO if the radial pulse is absent.
  – However, the presence of a radial pulse does not exclude the diagnosis of RAO because there may be collateral blood supply to the area around the RAO.
- Patency is best assessed clinically using the reverse Barbeau's test or Doppler US [2].
  – Reverse Barbeau's test: pulse oximeter is placed on the thumb or 1st digit of the ipsilateral hand, and then the ulnar artery is occluded. If the plethysmography waveform is absent, this highly suggests RAO.
  – Doppler US: allows for direct imaging of the artery and assessment of blood flow within the vessel. If visible obstruction or absent blood flow, it is diagnostic of RAO.
- Prevention and treatment [2]:
  – Spontaneous recanalization occurs within 1–3 months in 50% of patients.
  – Smaller and appropriately sized sheaths should be used, and upgraded to a larger sheath when required.
  – Consider using sheath-less guide catheters. These catheters reduce the outer diameter of the vascular access system by 1–2 Fr compared with conventional sheaths and catheters.
  – Administer adequate anticoagulation as part of the initial cocktail.
  – Consider administration of unfractionated heparin 50 IU/kg, up to 5000 IU total at the end of the case [14].
  – Initial treatment is usually conservative:

    Begin with compression of the ipsilateral ulnar artery for an extended period (up to 60 min).

    If the above method fails, most cases of RAO can be managed with enoxaparin or fondaparinux for 4 weeks duration.

    If this fails, percutaneous recanalization can be considered.

    In rare cases, acute treatment and emergent vascular surgery consultation may be required (i.e. acute ischemia of the hand).

Access Site Hematoma

- Generally results from improper hemostatic device application or device failure.
- Usually, it is easily managed with compression of the radial artery by placing a vascular band in the correct position.
  – The radial artery should be compressed proximal and distal to the puncture site to control antegrade and retrograde flow.

Forearm Hematoma

- Occurs in <0.3% of cases [13].

- Early recognition of this complication is of critical importance because bleeding may already be significant before it even manifests with forearm swelling.
- Management and treatment [13]:
  - Crucial to rapidly assess and treat this complication.
  - If not controlled and managed appropriately, a trivial forearm hematoma can develop into a serious compartment syndrome.
  - Immediately palpate the forearm, compare findings of softness and size with the opposite arm.
  - Apply hemostatic compression along the length of the access artery to prevent further blood extravasation.
    - Application of an Ace bandage to the forearm.
    - Application of an Ace bandage with gauze balls placed along the course of the artery. Tightening the ace bandage over the gauze balls selectively compresses the artery.
    - Use a sphygmomanometer cuff to compress the brachial artery.
      - Inflate the cuff to a pressure > 10–20 mmHg more than systolic blood pressure, and then intermittently deflate it every 2–3 min for 10–15 s. Repeat this cycle until adequate hemostasis is achieved.
    - Sealing of the perforation with a long sheath (rarely necessary).
      - If a perforation occurs before angioplasty, one can continue to use a guiding catheter and complete the procedure, by which time the perforation usually seals off.
      - Sealing of the perforation with a covered stent (rarely necessary)
- If the patient develops pain, pallor, paresthesia, paralysis, or absent pulse suspect compartment syndrome.
  - Direct measurement of the compartment pressure is a useful confirmatory tool and helps guide treatment strategy (conservative vs. urgent surgical fasciotomy).

Pseudoaneurysm Formation

- Rarely occurs with TRA.
- Antecedent oral anticoagulation is the biggest risk factor.
- Usually managed with prolonged compression for 10–20 min.
- If pseudoaneurysm fails to occlude with compression, surgery may be required.
  - This can be performed using local anesthesia, and done as an outpatient.

Radial Artery Tortuosity or Loop

- Tortuosity occurs in <10% of cases [12].
- Loops occur in <1% of cases [12].
- Treatment:
  - Perform angiography to help define anatomy if there is difficulty advancing a 0.035″ guidewire.

Position the access sheath appropriately.
Perform arteriogram using 3–5 cc of contrast.

- Use an angle-tip hydrophilic-coated wire with catheter support, and advance it using fluoroscopy.
  Hydrophilic wires allow for smooth, rapid movement through a tortuous segment of a vessel. However, they are highly prone to navigate into small side branch vessels and should be advanced using fluoroscopy.
- If the above technique fails to navigate the loop, use a 0.014″ coronary wire.
  Occasionally, you might need to use two coronary wires to assist with the tracking of the catheter.
- If the above technique fails to navigate the loop, use a 2.0–2.5/12 mm balloon to perform balloon-assisted tracking of the catheter.
  Remember to position the balloon so half of its length protrudes outside the tip of the catheter and insufflate to low pressure (4 atm).
- If the catheter navigates the loop, exchange the wire to a stiff angle glidewire and reduce the loop with traction and counterclockwise rotation of the catheter and wire.

Pearl

- Patients should be well sedated before performing the procedure.
- If the catheter fails to advance despite the techniques described above, obtain alternative access.

Radial Artery Stenosis

- Very rare.
- If the stenosis is focal and equipment can easily traverse the lesion, then it is reasonable to continue with the procedure, otherwise, alternative access should be pursued [12].

Other Rare Complications

- List of other potential transradial access site complications [2, 13]:
  - Radial arteriovenous fistula formation.
  - Radial artery eversion during sheath removal.
  - Hand ischemia.
  - Compartment syndrome.
  - Radial artery avulsion due to intense spasm.
  - Sterile abscess formation at the radial artery access site.
  - Persistent post-procedural pain.
  - Upper extremity loss of strength.

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