CHAPTER 1

Vascular Access

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*Basic; **Advanced; ***Rare, exotic, or investigational
$, <100.00 $US extra; $$, >100.00 $US extra
⌛, <10 min extra; ⌛⌛, >10 min extra
💧, low risk of complications; 💧💧, high risk of complications

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CHALLENGES

Gaining vascular access without early or late bleeding at the access site is a major challenge for every operator carrying out diagnostic or interventional cardiovascular procedures.

FEMORAL APPROACH

GAMEPLAY

Ideal Location of Femoral Access

Usually the femoral artery is palpated below the inguinal ligament that runs from the anterior superior iliac spine to the pubic tubercle. The true position of the inguinal ligament is 1–2 cm below that line. An ideal "landing zone" is defined by vascular entry above the femoral bifurcation and below an upper margin conservatively defined as several centimeters below the inferior excursion of the inferior epigastric artery (IEA). The IEA descends to, but does not cross, distal to the inguinal ligament; thus, entry above the lowest point of the course of this vessel, which typically then turns cranial to supply circulation to the epigastrium, can be used to define an unequivocally high puncture [1] (Figure 1.1).

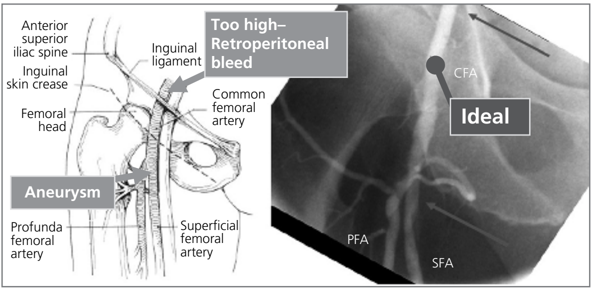

Figure 1.1 Ideal location for puncture of the femoral artery. Reproduced with permission of Wiley.

BEST PLAYERS

aka Standard of Technical Excellence in Femoral Approach

The technique employs visualization of the femoral head under fluoroscopy in a posterior–anterior projection. The skin puncture starts at the level of the lower border of the head of femur with the eventual goal of arterial cannulation at the mid-third of the head of femur. However, even with this technique, punctures below the bifurcation of the common femoral artery (CFA) cannot be completely avoided. This is due to variability in the site of the femoral artery bifurcation in reference to the femoral head. Although in a majority of cases (approximately 77%) the bifurcation is below the level of the femoral head, in approximately 23% of cases the femoral artery bifurcation site is higher. Ninety-seven percent of patients have the femoral artery lying on the medial third of the femoral head. Only 3% have the artery totally medial to the femoral head. Therefore the best way to perform a near-perfect femoral puncture is to use ultrasound guidance [1].

Real-time Actions

Ultrasound-guided puncture In this technique, a needle is initially positioned under fluoroscopy to locate on the skin the best location for puncture, the lower two-thirds of the femoral head (Figure 1.2a).

The equipment used is the Fujifilm SonoSite™, with the goal of locating the segment of the common femoral artery (CFA) proximal to the bifurcation. The femoral artery is recognized as a minimally pulsatile round structure next to another round structure, which is the femoral vein (Figure 1.2b). If the operator presses the vascular probe down, the size of the femoral artery stays the same, while the femoral vein is compressed (Figure 1.2c). The operator then tilts the probe up and down in order to locate the bifurcation with the superficial femoral artery (SFA) and the profunda femoral artery (PFA) (Figure 1.2d). Once the SFA and PFA are located, the puncture site would be proximal to the bifurcation (Figure 1.2b). The needle is positioned right at the middle of the probe and pointed tangentially towards the artery. The metal shadow of the needle can be traced and the tip of the needle makes a dent on the anterior wall of the CFA. Push forward and the tip is inside the lumen with strong blood flow back.

Tricks and Tips

*****Selection of the area for puncture under ultrasound** With ultrasound, the operator can recognize many areas with calcification on the anterior wall of the CFA. These are the areas to be avoided for puncture. The reason is that the needle could enter the wall of the artery but the following wire could not. At that time, manipulation of the needle could end up with vascular access. Another problem is that the wire could enter the

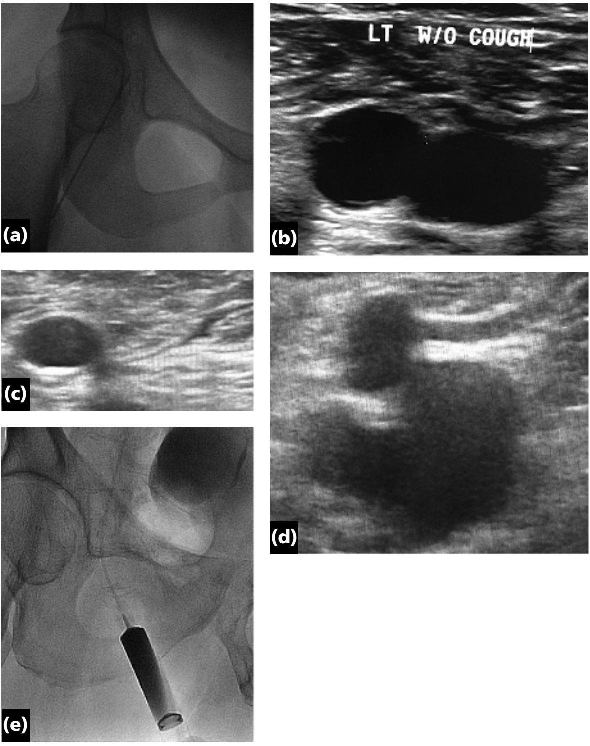

Figure 1.2 (a) A needle is positioned in the right groin area under fluoroscopy looking for the ideal location for puncture. The tip should be at the lower two-thirds of the femoral head. The reason for this is to locate the upper limit of the area of puncture so the tip of the needle does not end up too high as guided by ultrasound in a patient with a high bifurcation of the deep femoral artery. (b) The femoral artery is recognized as a minimally pulsatile round structure. Next to it should be an oblong structure, which is the femoral vein. (c) Press the vascular probe down: the femoral artery stays the same, while the femoral vein disappears because it is compressed. (d) The superficial femoral artery, profunda femoris artery and femoral vein at the bifurcation. (e) Before upsizing the micropuncture sheath, perform angiography of the arteriotomy site, in the ipsilateral 30–40° angle. Note vessel morphology. If the location is not "ideal", pull the sheath out, compress the groin area and re-access the artery.

artery but in a subintimal fashion and dissect the artery. It is advisable to avoid all areas with calcification. Try to find an area without calcification and enter the vessel there.

****Difficulty in cannulating the arterial sheath** Sometimes there is slight difficulty in inserting a sheath into the artery. The reason for this is kinking of the wire at the entry site. Push the wire a little deeper and insert the sheath pointing downwards to get into the lumen, then slide the sheath up along the artery. This may need to be done under fluoroscopy to be sure that the dilator does not bend the wire (creating a pointed tip) and perforate the artery.

Real-time Actions

Fluoroscopically guided micropuncture access The micropuncture vascular access technique involves the use of needles and wires typically in the 21-gauge and 0.018-inch range. For femoral access, these needles are usually 7 cm in length. The outer diameter of this needle is 0.8 mm; in contrast, the 18-gauge needle used by most operators is 56% larger, resulting in as much as six times the blood flow rate through an inadvertent back wall puncture or from an arterial entry with failed sheath placement [2].

The CFA is punctured under fluoroscopic guidance using the mid-third of the femoral head to guide the needle to the anticipated puncture site, although restricting puncture to a point below the centerline of the femoral head may be the most prudent approach. After the initial localization of the bottom of the femoral head, repeat fluoroscopy is performed after the needle has been placed deep in the tissue track, but not yet into the femoral artery, to achieve an ideal location of puncture. The path of the needle can be adjusted several times, if necessary, as it traverses deep into the subcutaneous tissue [2]. Once the needle is in the vessel and there is blood return, some operators perform a limited femoral angiogram via the micropuncture needle using a 3-mL syringe (Figure 1,2e).

If an acceptable CFA access location is confirmed, a 0.018-inch wire is advanced through the needle. A 4-Fr micropuncture sheath is advanced over the wire and exchanged for a 0.035-inch wire to support passage of a larger sheath size. There are also larger, highly tapered sheaths designed to go directly over the micropuncture wire. This technique allows relatively safe removal of the micropuncture needle or sheath after unfavorable location entry, with manual pressure applied for 3–5 min before attempting a new puncture based on the angiogram [2].

Large sheath Newly developed inflatable vascular sheaths designed to minimize frictional forces caused by large-bore devices have been evaluated, and recent studies suggest that these sheaths may increase the availability of femoral access in patients with access-limiting peripheral artery disease (PAD). One of the large sheaths is the 19-Fr SoloPath™ balloon-expandable transfemoral access [3].

DEDICATED EQUIPMENT

E

The 19-Fr SoloPath Transfemoral Introducer (STFI) is a vascular access device that permits large-bore access with technology that enables entry into the femoral artery at a low insertion profile (13 Fr) and then radially expands to a larger profile (19 Fr). The STFI sheath is inserted in a folded state over an expansion balloon dilator. The SoloPath transfemoral system is advanced under fluoroscopic guidance over a stiff wire. It consists of a 25-cm flexible, reinforced polymer sheath pre-mounted over a central balloon dilatation catheter. The specially folded distal two-thirds of the sheath facilitates its passage through tortuous and calcified femoral arteries. Once the system is positioned in the abdominal aorta, the SoloPath balloon dilator is inflated for 60 s at 20 atm via injection of a 20-mL saline–contrast mix, deflated, and then removed, leaving a large 21-Fr central lumen vascular sheath (Figure 1.3) [3].

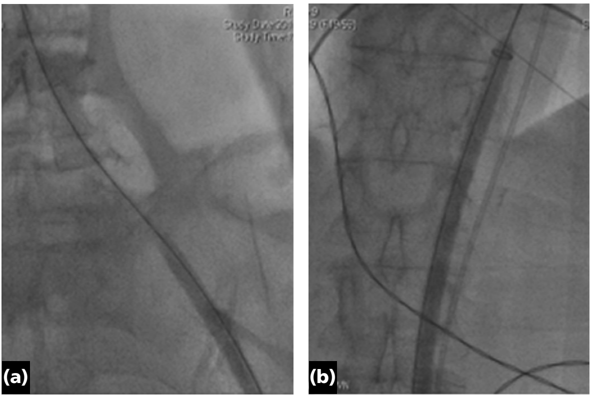

Figure 1.3 Fluoroscopic images of the (a) partially and (b) completely expanded SoloPath™ expandable sheath.

Tricks and Tips

****Angiography to check the location of femoral entry through a dilator** Some operators do not favor injecting through the micropuncture needle, a technique that incurs additional radiation for the operator and the potential risks of losing intraluminal positioning as well as vessel dissection. A modification, therefore, is to access the vessel with the micropuncture needle, advance the 0.018-inch wire, and place the small inner dilator of the micropuncture sheath over the 0.018-inch wire, using this small dilator for angiography rather than injecting directly through the micropuncture needle or the larger outer 4-Fr sheath.

***Preparations in obese patients** The femoral pulse at the inguinal crease is not a reliable landmark for the CFA, particularly in obese or elderly patients whose crease tends to be much lower than the inguinal ligament. The protruding abdomen and panniculus should be retracted and taped to the chest with 3- to 4-inch tapes that are in turn secured to the sides of the catheterization table. Keep the tissue layer above the artery as thin and taut as possible, so the needle will not be deflected from the projected angle and selected pathway.

***Directing the needle** Once the needle tip is near the artery, it tends to pulsate except in those patients with severe local scarring (following many previous remote femoral artery cannulations, total hip replacement, or in severely calcified arteries in chronic renal failure etc.). If the hub inclines to the right, the needle should be withdrawn by 1 cm and the tip redirected to the right before advancing forward. If the hub inclines to the left side, the tip is redirected to the left before pushing in. If the needle pulsates on the vertical axis, it just needs to be pushed slowly deeper.

***If the wire cannot be inserted** Most often, this is because the needle has hit the contralateral wall. Just move the needle by pulling slightly or rotating it a little; the wire may then be able to be inserted. If there is a problem, it is better to withdraw the needle and re-puncture the artery rather than dissect the artery with a slippery wire. After the sheath has been inserted, where there is strong arterial backflow and the wire is not able to negotiate the tortuous iliac artery, pulling the sheath a little (to disengage it from under a plaque if that is what has happened) and a gentle injection of contrast may help to delineate the anatomy and determine the reason why the wire could not be advanced. If there is no strong backflow, then the sheath is not in the arterial lumen. In a very tortuous iliac artery, a diagnostic Judkins right (JR) catheter can be inserted with caution and advanced in order to help steer the wire tip. Injection through the JR may also help to find out why there is a problem advancing the wire.

***Sequential order for arterial and venous puncture** If there is a need for a right heart catheterization, the sequence of arterial and venous puncture is often a matter of personal preference. We prefer to puncture the vein first and insert a wire inside the vein to secure the access. Then, a few seconds later, after puncturing the artery, we insert the sheath into the artery and the vein. Because there is only a wire in the vein, there is minimal distortion of the arterial puncture site, which may be caused by the placement of the venous sheath. Less than 1 min without a sheath will not produce a hematoma at the venous site. If the artery is inadvertently punctured first, we cannulate the artery, then inject contrast in the arterial sheath. Puncture the vein under fluoroscopy, with the needle medial and parallel to the contrast-filled arterial sheath. Another way is to use ultrasound to guide the puncture.

The reason why we should not puncture the artery with a venous sheath in place is because, if the venous sheath is entered by mistake, we might not be able to stop by manual pressure the bleeding from the puncture hole in the extravascular segment of the venous sheath. Another way to avoid arteriovenous fistula is to perform the arterial and venous access in separate limbs (e.g. artery in the right and vein in the left groin).

****Kinked wire** It is not unusual for the wire to pass into the lumen easily but attempts to advance any dilator over the wire result in kinking of the wire at the point of vascular entry. Instead of exchanging the wire, if it is not too crooked, the first best maneuver is to advance the wire further so that the dilator can be advanced to dilate the entry site on a straight and stiffer segment of the wire. If the wire is too soft, then the second best maneuver is to exchange the softer wire with a stiffer wire over the smallest size 4-Fr dilator. Be sure to advance the dilator under fluoroscopy to check that the dilator does not bend the wire (making a pointed tip) and perforate the artery.

****Puncture of pulseless femoral artery** As usual, the artery should be punctured over the middle of the medial third of the femoral head. Localize the skin puncture site by fluoroscopy just below the inferior border of the femoral head in order to prevent a puncture (above the lowest border of the inferior epigastric artery). However, these proportions are valid only in the anteroposterior (AP), neutral position. Internal or external rotation of the femur can considerably change the relationship of the femoral artery to the femoral head. Performing the procedure under fluoroscopy is better. The best technique is to locate the CFA by ultrasound.

Confronting the Challenges

*****Two catheters inserted with single puncture technique** This is used in situations such as angioplasty for chronic total occlusion (CTO) when there is a need for contralateral injection. Another puncture, higher or lower than the puncture site of the first site of vascular access, or in the contralateral artery, is suggested. However, if there is no need for another puncture, change the sheath to an 8-Fr introducer. The two 4-Fr diagnostic catheters can be inserted and attached to separate manifolds for diagnostic purposes [4].

*****Insertion of intra-aortic balloon pump (IABP) through a diseased iliac artery** When an IABP needs to be inserted and an iliac lesion is found, the lesion should be dilated first. Insert the balloon pump, then perform stenting of the lesion later after the IABP is removed. When a balloon pump is to be inserted through a previously stented iliac artery, do it under fluoroscopy to be sure the balloon does not get stuck on the stent struts. Chronic endothelialization of the stent struts should minimize this problem.

Puncture of femoral bypass graft The problems involving puncture of an old vascular graft in the femoral area include: uncontrollable bleeding and hematoma formation because of the non-vascular nature of the punctured graft; disruption of the anastomotic suture line with subsequent false aneurysm formation; infection of the graft site; and catheter damage, kinking, and separation due to scar tissue in the inguinal area and firmness of the healed graft material. Inadvertent entry to the native arterial system may lead to the dead-end stump in the common femoral or iliac artery.

Real-time Actions

Bypass graft puncture Because the exact location of the suture line is not known, to avoid puncture of the anastomotic site it is best to puncture the proximal end of the inguinal incision site or as close to the inguinal ligament as possible. To avoid kinking of the catheter at the puncture site, it is better to introduce the needle at an angle of approximately 30–45° to the estimated long axis of the graft. Best is to locate the artery by ultrasound. Sometimes, because of severe scarring, the entry site has to be prepped by sequential dilatation with small to progressively larger dilators up to 1 Fr size larger than the sheath selected for the procedure.

Confronting the Challenges

*****Parallel technique** If the native artery is punctured and the wire cannot be advanced because the artery ends in a dead-end pouch, then leave the small 4-Fr sheath inside as a landmark. Palpate the femoral artery again and try to feel the two pulsations there: the first one is the native artery with the 4-Fr sheath, and the second, stronger one is the bypass graft if the graft is superficial (or it may not be easily palpable because of the thick wall of the bypass graft). Puncture the second pulsatile artery while avoiding the one with the sheath in it. This can be done under fluoroscope guidance to avoid any puncture near the first sheath.

ANTEGRADE PUNCTURE

Antegrade femoral puncture can be greatly simplified and is more successful if the tissue between the skin surface and the artery is as thin as possible. In obese patients, fatty panniculus may have to be retracted away from the puncture site manually and taped in position before the puncture is attempted [5]. The technique of antegrade puncture of the femoral artery is discussed in detail in Chapter 24.

Real-time Actions

Common femoral artery antegrade puncture The first step is to localize the CFA and its bifurcation under fluoroscopy. The CFA usually overlies the medial third of the femoral head, and the bifurcation occurs below the lower border of the femoral head. Once the landmark is located, to make the puncture, the needle may be directed toward the superior aspect of the femoral head, under fluoroscopy. The purpose of this maneuver is to prevent the inadvertent puncture of either or both the SFA or the PFA. It is important to puncture the femoral artery as high above the bifurcation as possible so that there will be enough space between the puncture site and the bifurcation for catheter exchanges and manipulation of catheters into the SFA. Using fluoroscopy, the site of the intended arterial puncture is identified (upper or middle third of the femoral head). The femoral pulse is palpated against the femoral head. Local anesthetic is infiltrated 2–3 cm cranial to the intended site of puncture. An 18-gauge needle is advanced at 45–60° directed caudally, aiming at the intended site of arterial puncture. Once pulsatile flow is obtained, a soft-tip wire is inserted toward the SFA. The wire should follow a straight caudal course into the SFA. Lateral deviation indicates entry into the PFA. The wire can be withdrawn and the needle tip deflected laterally to redirect the wire into the SFA [5]. Best is to puncture under ultrasound guidance.

Tricks and Tips

****Manipulation of the wire** If the wire was inserted into the PFA, it can be withdrawn and redirected by angling the tip of the needle medially toward the SFA. The other option is to have a wire with a curved tip and manipulate it so the tip points toward the SFA. The needle may be exchanged for a short dilator with a gently curved tip, which can be directed toward the SFA. This dilator can be withdrawn slowly from the PFA while injecting the contrast agent. Once the orifice of the SFA is seen under fluoroscopy, it can be selectively catheterized or it can be used to direct a wire into the SFA [5].

****Puncture of CFA with high bifurcation** In patients with a high bifurcation, one single puncture can result in entries of both the SFA and PFA. When this occurs, the first spurt of blood may indicate that the PFA is punctured. Do not remove the needle completely. Instead, withdraw it slowly and watch for a second spurt of blood. At this point, the contrast injection may show that the needle is in the SFA. In rare cases of high bifurcation, it may not be possible to puncture the CFA, which is excessively high in the pelvic area [5]. When the bifurcation is located more proximally, puncture of the CFA is more challenging, especially in obese patients. In these cases, it may be acceptable to selectively puncture and cannulate the SFA, if it appears not to have significant atherosclerotic disease and is of adequate size [5].

****Puncture with abduction and external rotation of the thigh** Another option to cannulate the SFA is with the thigh in abduction and external rotation. The goal of this maneuver is to facilitate a more mediolateral puncture site in the CFA. In the usual antegrade puncture, the needle is seen to point more toward the PFA, which is lateral to the SFA. In the abduction and external rotation position, the needle points more toward the SFA, and the PFA is seen medial to the SFA. This relationship is important when observing the course of the wire during its intended selective entry into the SFA. If the patient is punctured in this position, local compression of the artery after the procedure should take place with abduction and external rotation of the thigh because the puncture site is more mediolateral than usual [5].

BRACHIAL APPROACH

Even though the radial artery is the most common location used in the upper extremity, the brachial artery is still the access site of choice for procedures requiring a large sheath: subclavian artery stenting, renal stenting, or aortic aneurysm exclusion. It is best to puncture the brachial artery under ultrasound guidance. Radial access is discussed in Chapter 8.

AXILLARY PUNCTURE

Anatomically, the distal third of the axillary artery has three branches: the subscapular artery, anterior humeral circumflex artery, and posterior humeral circumflex artery. The location between the origin of the subscapular artery and the origins of the anterior and posterior humeral circumflex arteries is ideal for percutaneous access to this vessel (Figure 1.4). The axillary artery was chosen over the subclavian artery due to its accessibility outside the chest wall, which allows manual compression should closure procedures fail, and was chosen over the brachial artery due to its larger diameter and presence of collateral circulation, which decreases the likelihood of limb ischemia during the procedure [6].

It is important to note the structures that bound the axillary artery in this region in order to be aware of complications that may occur with this approach. In front of the artery are the medial head of the median nerve and the medial antebrachial cutaneous nerve. Medial to the axillary artery is the axillary vein. In between the axillary artery and vein is the ulnar nerve. The medial brachial cutaneous nerve is medial to the axillary vein. Laterally, there is the lateral branch of the median nerve and the musculocutaneous nerve. Behind the axillary artery are the axillary and radial nerves [6].

Figure 1.4 Normal subclavian and axillary artery angiogram. Subscapular artery (A) and anterior and posterior humeral circumflex arteries (B and C) are labeled in the third part of the axillary artery [6]. Reproduced with permission of Wiley.

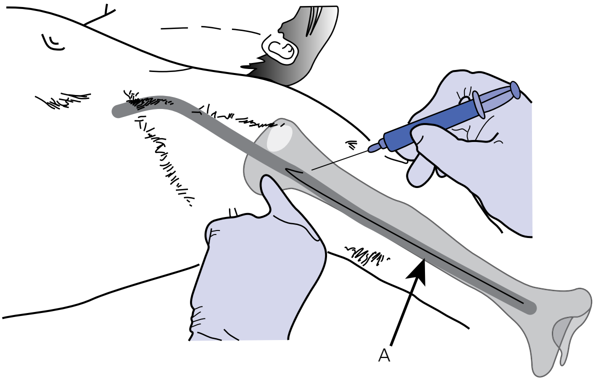

Figure 1.5 Patient in supine position with left arm abducted. A J-wire (A) inserted via a 7-Fr left radial sheath is visualized under fluoroscopy and marks the ideal location for needle insertion between the origin of the subscapular and humeral circumflex arteries [6]. Reproduced with permission of Wiley.

Prior to obtaining access in the left axillary artery, a 7-Fr sheath is inserted into both the right and left radial artery. An angiogram of the right radial artery is obtained to ensure that there are no contraindications for using this approach for percutaneous coronary intervention (PCI). An angiogram of the left upper extremity is then obtained to establish the patency of the axillary artery and identify the optimal location for cannulation of the third part of the vessel proximal to the origin of the anterior and posterior humeral circumflex arteries and distal to the subscapular artery. A 0.038-inch J wire is then inserted through the left radial artery sheath extending to the axillary artery. A micropuncture needle is used to gain access to the axillary artery using the J wire as a fluoroscopic guide, and a 6-Fr sheath is placed via the modified Seldinger technique (Figure 1.5).

RIGHT HEART CATHETERIZATION IN PATIENTS UNDERGOING PROCEDURE WITH RADIAL APPROACH

The upper and lower arm are prepped and draped in sterile fashion, using brachial drapes over the wrist and antecubital fossa. Arterial access is obtained via the radial artery and the sheath inserted. Swing the table over so that the antecubital fossa is positioned under the image and then inject 5–7 mL of a 50/50 contrast–saline mix into the radial artery under fluoroscopy via the side port of the sheath (the "arterial phase"). After approximately 5–10 s, the basilic vein of the upper arm should be visible (the "venous phase").

This is a good time to anesthetize an area over the basilic vein. Obtain access with the same micropuncture needle used for the radial access, place a 5-Fr radial sheath in the basilic vein, and then perform the right heart catheterization through the sheath [7].

CLOSURE DEVICES

A closure device can be used after any procedure such as PCI, valvuloplasty, IABP or when an artery is inadvertently punctured, such as after cannulation of a subclavian artery. The choice between collagen plugs and suture closure is largely a matter of personal preference and experience. Kaolin patches are currently available in case collagen plugs or a suture-mediated device cannot be used because of massive calcification or severe kinking enabling the insertion of such devices.

Collagen Plug Device: MYNX®

The MYNX vascular closure device features a polyethylene glycol sealant ("hydrogel") that deploys outside the artery while a balloon occludes the arteriotomy site within the artery. The MYNX device is inserted through the existing procedural sheath and a small semicompliant balloon is inflated within the artery and pulled back to the arterial wall, serving as an anchor to ensure proper placement. The sealant is then delivered just outside the arterial wall where it expands to achieve hemostasis. Finally, the balloon is deflated and removed through the tract, leaving behind only the expanded, conformable sealant. One problem with the MYNX is that the balloon can be punctured when there is a sharp calcium ledge in the CFA (Figure 1.6). If there is concern about calcified plaque in the CFA, or if the operator does not want to use a closure device which leaves an intravascular component, then the operator can use a VASCADE®. The reason is that the VASCADE uses a collapsible disk as anchor.

Another problem with the MYNX closure device is the presence of a lesion in the mid external iliac artery. There is concern that the balloon could be inflated at the site of an iliac artery plaque. The trick here is to inject the balloon of the MYNX device with

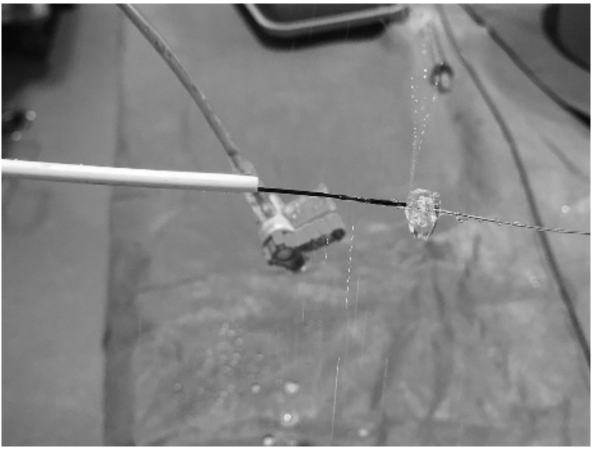

Figure 1.6 The MYNX balloon was punctured when there was a sharp calcium ledge in the common femoral artery.

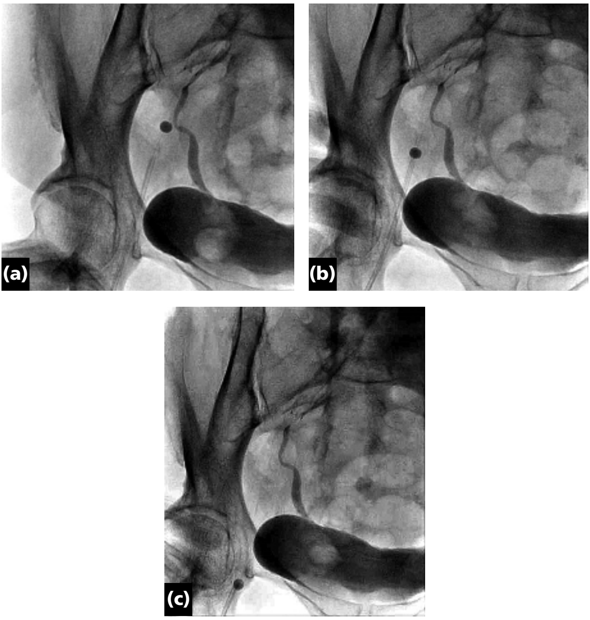

Figure 1.7 (a) The balloon was injected with contrast, positioned, and inflated under fluoroscopic guidance below the lesion in the iliac artery. (b) The balloon and the sheath were pulled down under fluoroscopy. (c) The balloon is at the wall and the protein plug is ready to be deployed.

contrast and position the balloon distal to the iliac lesion under fluoroscopy. Inflate the balloon under fluoroscopy (Figure 1.7a). Pull the balloon down under fluoroscopy (Figure 1.7b) and deploy the protein plug (Figure 1.7c).

Clip Device: StarClose®

The StarClose® device achieves hemostasis with a 4-mm nitinol clip implant. The device is inserted into the arterial lumen then "wings" are deployed such that when the device is withdrawn the wings are pulled against the arterial wall, indicating correct positioning. The clip is then deployed just outside the arterial wall. The clip grasps the edges of the arteriotomy, drawing them together for closure. The StarClose® device is labeled for diagnostic and interventional procedures and for closure of 5- to 6-Fr arteriotomies, but has been used with 7- to 8-Fr arteriotomies.

Real-time Actions

The Perclose

Preclosure of large arterial access In cases where use of a large-sized sheath is intended (e.g. for aortic valvuloplasty), prior to deployment of the sheath untied sutures can be pre-placed using the Perclose percutaneous suture delivery system. A 5- to 6-Fr sheath may be used for arterial angiography to identify appropriate anatomy for suture delivery in the CFA (no calcification, not close to a lesion), and then a suture device is used to place untied sutures. At the end of the procedure, the existing "purse string" is closed around the arteriotomy [8].

Preclosure of large venous access The technique of "preclosure" involves preloading a 6-Fr Perclose suture closure device into the femoral vein after access with a 6-Fr or 8-Fr dilator, prior to insertion of a 14-Fr venous introducer sheath used for antegrade aortic valvuloplasty. Intravenous placement of the Perclose device within the venous system is then verified by either back-bleeding from the marker port or contrast injection through the marker port. Then the needles are pulled and the sutures clipped; after the sutures are deployed, a wire is placed into the femoral vein through the Perclose device. An exchange is made over the wire for a 14-Fr sheath while the sutures are laid alongside of the puncture and covered with gauze soaked with povidone–iodine. Upon completion of the valvuloplasty procedure, a wire is passed through the 14-Fr sheath to secure the vessel in case the suture closure fails. Heparin is not reversed. The sheath is then removed through the existing sutures, and the sutures are tied around the wire. If hemostasis is successfully achieved with the suture, the wire is gently removed and the knot pushed further to complete the closure [8].

Tricks and Tips

*****Differences in technical details for preclosure of venous access** As the veins are comparatively thin-walled, the amount of tension applied when pulling back the Perclose device is necessarily **less** than for arterial closure. It is possible to securely contact the vessel wall with the foot of the device while applying steady pressure, with **less** force than needed for arterial closure. Back-bleeding through the marker port occurs in the vast majority of cases. Due to the lower pressure in the venous system, this is of course less prominent than in arterial closure. Usually, a slow dribbling of blood from the marker port can be noted. There is a delay in the appearance of back-bleeding, due also to the low venous pressure, and this may be accentuated by having the patient take a deep breath or by employing the Valsalva maneuver [8].

*****Double Angio-Seal™ closure for a 10-F vascular access** Although Angio-Seal labeling indicates compatibility with 8-Fr or smaller procedural sheaths, the Angio-Seal has been used successfully to close 10-Fr arteriotomies utilizing a "double wire" technique. With this technique, at the conclusion of the procedure, the Angio-Seal wire and a second, additional, wire is placed through the sheath. The Angio-Seal is deployed in standard fashion using the Angio-Seal wire, leaving the second adjacent wire in place. If hemostasis is achieved, the second wire is carefully removed while maintaining pressure on the collagen plug. If hemostasis is not achieved, the second wire serves as a "backup/safety" to allow deployment of a second Angio-Seal device next to the first [9].

*****Double MYNX closure for a 14-Fr arterial access** Two MYNX closure devices were simultaneously passed through the 14-Fr arterial sheath and both distal semicompliant balloons were inflated with a 3:1 saline:contrast mixture to allow balloon visualization. Under fluoroscopic guidance, the MYNX balloons were withdrawn to the distal end of the 14-Fr sheath, and then both balloons and the sheath tip were drawn back to the previously visualized arteriotomy. The polyethylene glycol sealant from each MYNX device was advanced into the 14-Fr sheath in a sequential fashion, and the sheath was then withdrawn allowing hydration and expansion of the sealant in an extra-arterial position over the arteriotomy site. After 2 min, the balloons were deflated, the MYNX delivery catheters removed, and manual compression held for an additional 2 min. Closure of the 14-Fr arteriotomy was confirmed to be complete with no bleeding or vascular compromise nor hematoma on inspection [10].

Discriminating Differences

Which vascular closure devices for which patients? Vascular closure devices (VCD) are not suitable for all patients, and caution is required when considering the use of these devices in patients with peripheral vascular disease, extremely obese patients, those with small femoral arteries (diameters <4–5 mm), or those with arterial cannulation at or below the bifurcation. Apart from these patient- and artery-specific factors, factors related to the mechanism of action of VCDs should also be taken into consideration, i.e. presence of an intravascular component of the closure device.

Use of devices with a significant intravascular component, such as the Angio-Seal™ device, is not recommended for bifurcation punctures, as there is a risk of obstruction of the smaller branches by the intravascular portion of the device. Moreover, accurate alignment of the intravascular part might be difficult due to the complex angles at the site of bifurcation. In addition, there is a risk of intravascular deployment of the collagen plug. Thus, access-site closure in patients with bifurcation punctures continues to be a challenge. Devices that do not have any significant intravascular component (e.g. StarClose or MYNX) are especially attractive in this group of patients.

Do not use VCDs in high arterial punctures because they have been associated with an odds ratio as high as 17:1 for retroperitoneal hemorrhage [11].

Confronting the Challenges

Suspecting intra-arterial deployment of collagen plug During deployment of an Angio-Seal device, intra-arterial deployment of the collagen plug can be caused by inadequate tension on the suture, vigorous tamping, too deep insertion of device into the artery so that the anchor is caught in the posterior wall, etc. Suspicion of a problem is aroused when there is a long travel distance of the tamper tube or continued bleeding [12].

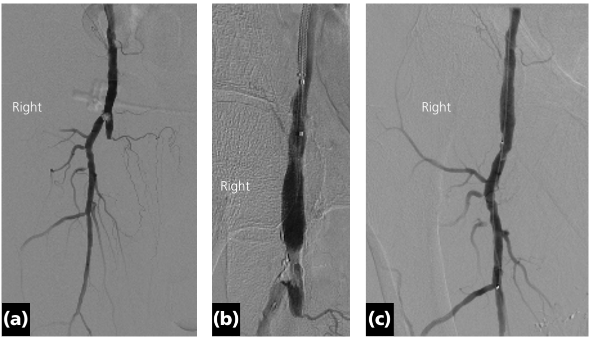

Figure 1.8 (a) The patient underwent diagnostic catheterization of the carotid artery. The right femoral angiogram was not performed at the end of the case because of a high creatinine level = 1.2 mg/dL. An Angio-Seal™ device was deployed. One hour later the patient had severe right leg pain. The femoral angiogram showed acute occlusion of the superficial femoral artery at the bifurcation. (b and c) A snare was advanced to the bifurcation area and successfully removed the embolized plug.

*****Management of intra-arterial deployment of collagen plug** In a case report of possible intra-arterial deployment of the collagen plug by the Angio-Seal, while inserting the tamper tube it was observed that the tube was inserted much deeper than usual. The patient continued to bleed, so a tension spring was placed as usual. At the same time, a hemostat was used to secure the end of the suture, and a FemoStop™ compression device was applied above the Angio-Seal to stop bleeding. After 4 h, the anchor, which is composed of an absorbable polymer material, became softened and therefore pliable. A hemostat was placed on the suture at the level of the skin. If the suture were to break during traction, the hemostat would prevent the anchor and the collagen plug from embolizing. Then steady traction was applied to the suture, perpendicular to the femoral artery. The pressure should not be excessive. After 20 min, the plug was removed. The FemoStop was reapplied and hemostasis was achieved [12]. Another way to remove the embolized plug is to use a snare to pull it out (Figure 1.8a–c). Management is summarized in Box 1.1.

BOX 1.1 WHAT TO DO IF COLLAGEN IS INSERTED INTRA-ARTERIALLY [11]

1. Prevent the problem: always maintain tension on the suture and avoid tamping with excessive force
2. Recognize the problem: absence of resistance during tamping and inadequate hemostasis are clues
3. Duplex ultrasound can document intra-arterial collagen
4. Apply tension on the string in the usual fashion; secure the suture with a hemostat at skin level to add security
5. **Do not cut the suture:** embolization of the anchor and plug may occur

6 If there are signs of embolism and thrombosis, obtain a vascular surgery consultation
7 Wait at least 4 h to allow softening of the anchor
8 Exert steady vertical traction on the suture with approximately 10 lb of force
9 If removal of the device is achieved, maintain manual compression to achieve hemostasis
10 A FemoStop device should be ready for rapid deployment after the device is removed
11 Remove the collagen plug using an atherectomy device (if needed)

COMPLICATIONS

Hematoma

The frequency of hematoma increases with increasing size of the sheath, level of anticoagulation, and obesity of the patient. Surgical evacuation is not required, even for large hematomas, unless there is undue tension on adjacent structures or in the case of a truly huge hematoma. Surgical evacuation and arterial repair are required when the hematoma is pulsatile and expanding, an indication of communication between the hematoma and the femoral artery and the presence of a false aneurysm.

Arteriovenous Fistula (AVF)

This happens rarely (>0.4%) when the puncture is made where the artery overlies the vein. Most small AVFs are asymptomatic and usually close spontaneously. A large AVF with symptoms of high-output failure needs to be corrected surgically.

Acute Arterial Thrombosis

Occlusion of the femoral artery may occur due to thrombosis or local arterial injury. It happens mostly in women with small femoral arteries that are completely blocked by the catheter during the procedure and in patients whose SFA is catheterized rather than the CFA.

Confronting the Challenges

Mechanical thrombectomy for acute thrombosis If thrombosis of the femoral artery is suspected, access is obtained from the contralateral side and 5000 units of heparin are given. A 6-Fr crossover sheath is placed in the external iliac artery over a 0.035-inch stiff Amplatz guidewire. The occluded/thrombosed/embolized segment or the artery is crossed with a 0.014-inch or 0.018-inch wire. Any thrombectomy device can then introduced over the wire and an attempt is made to remove thrombi. If normal distal flow is established without any residual stenosis, the procedure is terminated. If there is still residual thrombus, then the segment is dilated with a peripheral balloon, and if the post-percutaneous transluminal angioplasty (PTA) result is not optimal, a self-expanding stent may be deployed [13].

If heavy thrombotic burden still persists after mechanical thrombectomy, then tissue plasminogen activator (tPA) 0.05 mg/kg can be given along with heparin through a multi-hole delivery catheter (e.g. 5-Fr Mewissen). Four hours later, an angiogram can be carried out to check the progress and if there is still thrombus the patient can undergo longer infusion (12–18 h) [13].

Limb Ischemia

Patients who develop acute limb ischemia after femoral artery catheterization must be carefully and immediately evaluated by duplex ultrasound. Angiography is mandatory and should not be delayed. The purpose of angiography is to identify the location (aortoiliac inflow circulation, infrainguinal outflow circulation, or runoff circulation) and cause (dissection, thrombosis, distal embolization, sheath/vessel mismatch) of ischemia, since these factors will help determine the treatment strategy (e.g. vascular surgery, percutaneous revascularization, thrombectomy, intra-arterial thrombolytic infusion). In most cases, digital subtraction angiography is best, because cineangiography may not permit adequate visualization of the runoff circulation [14].

Confronting the Challenges

*****Temporary relief of iatrogenic ischemic limb: percutaneous technique for in vivo femoral artery bypass** During PTA of high-risk patients, if acute limb ischemia arises during femoral artery catheterization, the antegrade sheath in the femoral artery and the retrograde sheath in the contralateral CFA can be connected using standard 12-inch pressure tubing and a male-to-male adapter. This technique is considered a temporary method to restore blood flow, minimize the metabolic consequences of acidosis and muscle necrosis, permit more definitive percutaneous or surgical revascularization as indicated, and to allow the use of devices for invasive hemodynamic support when such devices cause limb ischemia and there are no other therapeutic alternatives [14].

Preventing limb ischemia Steps to prevent limb ischemia include: (1) careful examination of femoral pulses and bruits before catheterization; (2) angiography prior to insertion of any hemodynamic support device; (3) angioplasty and stenting of suitable aortoiliac stenoses before device insertion; and (4) use of a sheathless IABP, which might reduce the risk of ischemic complications in patients with diffuse aortoiliac disease or small vessels [14].

Retroperitoneal Hematoma

The clinical clues of retroperitoneal hematoma (RPH) include hypotension without apparent reason, blood loss without possible source, suprainguinal tenderness and fullness, and flank discomfort. A small hematoma is not able to cause any hemodynamic disturbances or any increase of the retroperitoneal cavity pressure to cause neurological symptoms (Figure 1.9a).

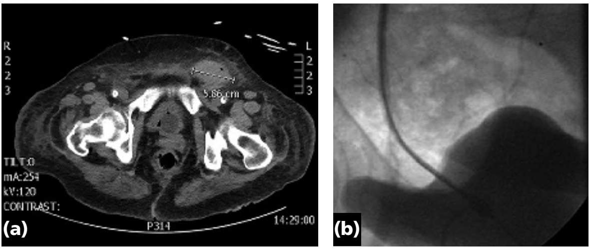

Figure 1.9 (a) A hematoma was seen in the left groin area (in the left upper corner of the CT scan of the abdomen). (b) A dented bladder due to retroperitoneal hematoma. It looks different from the normally round shape of the bladder.

An RPH in close proximity to the iliopsoas muscle will often present with severe muscle spasm, resulting in severe pain in the groin or hip area with radiation to the lower back and anterior thigh on any attempt to extend the hip. With an expanding hematoma, femoral nerve compression typically occurs along the iliopsoas gutter with a characteristic pain in the anteromedial thigh. Usually, bleeding into the retroperitoneal site is self-limiting unless the patient is anticoagulated.

Mechanism of clinical symptoms

The femoral nerve is formed by the second to fourth lumbar nerve roots and provides motor innervation to the quadriceps, sartorius, pectineus, and iliopsoas. It supplies sensory innervation to the anteromedial thigh and medial leg. The nerve lies in the groove between the iliacus and psoas muscles. Entrapment of the femoral nerve by an iliopsoas hematoma is the most likely cause of femoral nerve palsy. Weakness of the quadriceps muscle and decreased patellar reflex are the most striking findings on physical examination [15].

Management of RPH includes stopping heparin and reversing anticoagulation with protamine, then rapid fluid resuscitation to reverse hypovolemia. Transfusion may be needed. The decision of when to intervene with evidence of persistent hemorrhage remains controversial and a vascular surgical consultant should be involved at an early stage. The RPH will often have a tamponade effect on the site of persistent hemorrhage. Surgery could potentially reduce the effect of the tamponade with catastrophic consequences. With this in mind, there is a trend toward such techniques as stent grafts or intra-arterial embolization to halt the persistent hemorrhage. Open surgery should be considered if the patient remains hemodynamically unstable and the previously mentioned measures have been unsuccessful [16].

Discriminating Differences

Medical and surgical management of retroperitoneal hemorrhage After PCI, the presence of RPH was associated not only with a higher frequency of post-procedure cardiac complications, including myocardial infarction and congestive heart failure, but also with a higher frequency of infection and/or sepsis, gastrointestinal bleeding, and contrast nephropathy. Of the patients who developed RPH, 92.3% were treated medically and 7.7% underwent surgical repair. A trend toward a higher in-hospital mortality was observed in patients with RPH treated surgically than in those treated medically, possibly reflective of the fact that a surgical approach might be performed in more unstable patients in whom fluid resuscitation and blood transfusions are inadequate in re-establishing a stable hemodynamic status [17].

Tricks and Tips

****How to detect retroperitoneal hematoma in a 1-second maneuver** An AP view of the pelvic area under fluoroscopy may give a clue to the problem. Usually, the bladder is seen as round and filled with contrast. If the opacified bladder is seen displaced and its round shape is dented, RPH is strongly suspected (Figure 1.9b). However, a significant quantity of blood needs to be sequestered before unilateral external compression of the bladder occurs.

Real-time Actions

How to seal a perforation with a balloon The initial angiogram reveals laceration of the inferior epigastric artery arising at the origin of the right CFA. A 6-Fr crossover sheath is positioned in the right external iliac artery, and a 6-Fr right Judkins-4 guide is then advanced over the crossover sheath to select the ostium of the lacerated inferior epigastric artery. A 0.014-inch Balance Middleweight wire is advanced into the inferior epigastric artery, and the tip positioned distal to the lacerated area. A 2 mm × 10 mm balloon catheter is then advanced and parked at the level of the laceration and inflated at 1 atm on three sequential occasions for up to 20 min. Adequate balloon occlusion can be confirmed by injecting contrast through the guide. Nevertheless, if the angiogram reveals persistent and significant bleeding after each balloon deflation, attempts should be made to thrombose the lacerated vessel in order to stop the hemorrhage.

How to close a perforation with a microcoil or injection of thrombin Microcoils can be used for closure of the small artery. If there are no microcoils available, infusion of thrombin through the lumen of the inflated over-the-wire (OTW) balloon can be done. Careful positioning and sealing of the vessel are confirmed with injection of contrast from the guide and through the balloon lumen to ensure that there is no passage of contrast from the vessel lumen into the CFA. Thrombin-JMI® is diluted in normal saline at a concentration of 50 IU/mL. Subsequently, a total of three consecutive doses of 100 IU of thrombin can be administered through the balloon catheter lumen. Contrast can be injected through the balloon lumen after each dose of thrombin. When there is no further evidence of blood flow and no extravasation of contrast through the laceration, the balloon can be deflated [18] (Figure 1.10a–d).

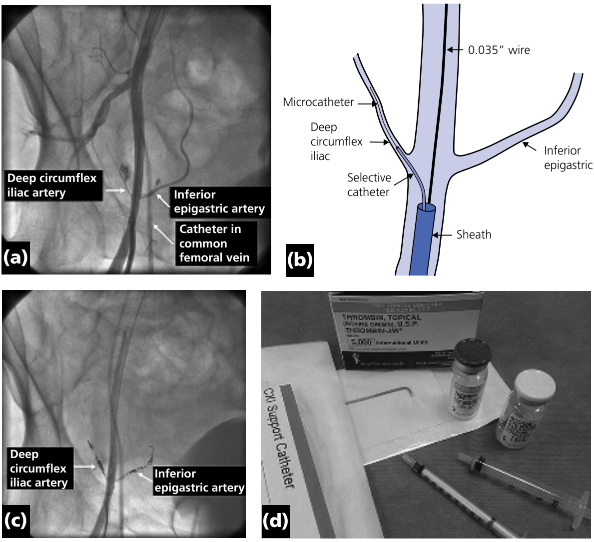

Figure 1.10 (a) After coronary stenting, an angiogram of the common femoral artery showed bleeding at the deep circumflex iliac artery and the inferior epigastric artery. (b) A selective catheter was advanced into the deep circumflex iliac artery and with it a microcatheter was positioned near the perforated area. (c) Microcoils were delivered into the deep circumflex iliac artery and the inferior epigastric artery and successfully closed the perforations. (d) How to mix thrombin: use 2–3 mL of the patient's blood mixed with 1000–2000 IU of thrombin. Inject the thrombin–blood patch into the track.

Perforation

If a balloon bursts and perforates a peripheral artery below the inguinal ligament, local bleeding can be controlled by direct pressure. In the case of higher perforation, a large peripheral balloon should be inflated above or at the rupture site to stop the bleeding and to seal the puncture site [19].

Real-time Actions

How to seal a perforation with a covered stent Access is gained via the left femoral artery for a retrograde approach to right iliofemoral angiography. A 6-Fr internal mammary catheter is inserted over a 0.035-inch Glidewire®, and this wire is used to cross into the right SFA. This wire is exchanged for an 0.035-inch Amplatz super stiff wire, and an 8-Fr 65 cm long Super Arrow-Flex® sheath is advanced under fluoroscopy over the aortoiliac bifurcation to give good support in the right external iliac artery. Balloon tamponade of the perforation site is performed with a 5-min inflation of a balloon at 2 atm with persistent extravasation of contrast. An undersized self-expanding covered stent is then placed across the perforation site with a persistent leak. The stent graft can then be postdilated with a balloon at 8 atm with complete hemostasis and resolution of the free-flow contrast into the retroperitoneum (Figure 1.11a–c).

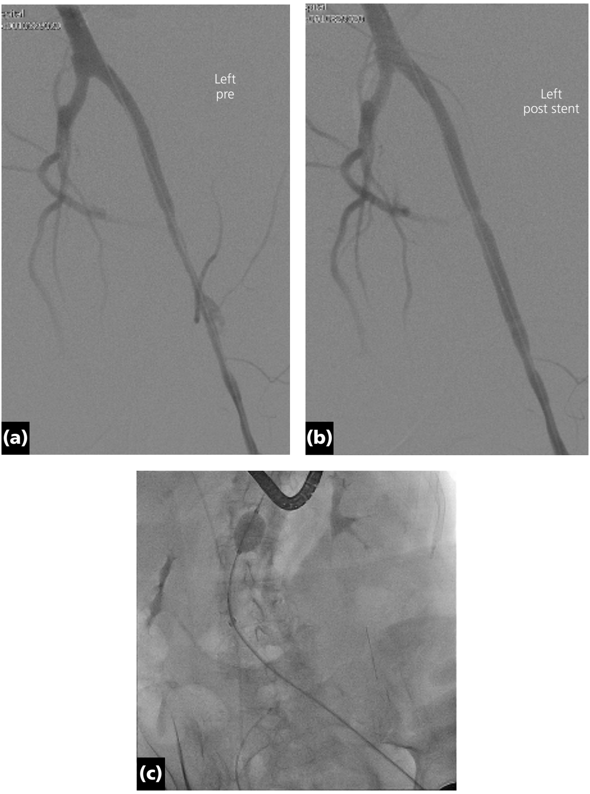

Figure 1.11 (a) and (b) Bleeding from the left external iliac artery treated with a covered stent. (c) When there is a lot of bleeding, a large aortic balloon can be inflated at the distal end of the aorta to stop the bleeding through the iliac arteries.

Pseudo-aneurysm

The main cause of pseudo-aneurysm (PA) is inadvertent puncture of the SFA. A femoral PA forms when the puncture site does not close and there is continuous flow into a small perivascular space contained by the surrounding fibrous tissue and hematomas. It is suspected by the presence of a laterally pulsatile mass, an arterial bruit, and tenderness at the vascular access site. Confirmation is made by ultrasound, which shows a hypoechogenic cavity with flow through a neck directly visible by color Doppler, and pulsed Doppler evidence of to-and-fro flow between the cavity and the arterial lumen during systole and diastole [20]. Hematomas are seen as hypoechoic collections without any Doppler flow movement.

Indications for aggressive management include: large size of the PA, increase in size, and the need for continued anticoagulation. Usually, small PAs (<3 cm in diameter) will close spontaneously, presumably due to thrombosis. A follow-up ultrasound 1–2 weeks later often demonstrates spontaneous thrombosis and obviates the need for surgical repair. The >3-cm diameter PAs are less likely to close spontaneously. When PAs persist beyond 2 weeks or expand, the risk of femoral artery rupture necessitates correction. The simplest method of treatment is to use a mechanical compression device such as FemoStop™. The success rate is 74% with a mean compression of 33 min [20]. The failed patients underwent successful compression guided by ultrasound.

Contraindications to mechanical compression are listed in Box 1.2. Ultrasound-guided compression is commonly used; success with this technique is related to the anticoagulation status and a PA that can be readily visualized and compressed [20]. However, the newest modality of treatment is to inject thrombin into the PA. The technique is simple, quick, and painless. Surgery is rarely indicated unless the previously mentioned management fails. Occasionally thrombin may escape into the peripheral circulation with formation of an intra-arterial thrombosis (seen in less than 2% of cases) and is usually managed conservatively. The best maneuver ranking of each method in excluding a femoral PA is listed in Box 1.3.

BOX 1.2 CONTRAINDICATIONS TO MECHANICAL COMPRESSION FOR PSEUDO-ANEURYSM

1 Sign of local infection
2 Critical limb ischemia
3 Large hematoma with overlying skin necrosis
4 Injuries above the inguinal ligament

BOX 1.3 TACTICAL MOVE

Best options for exclusion of femoral pseudo-aneurysm

1 ⌛ **FIRST Best option:** Mechanical compression therapy if there is no thrombin available
2 **$** ⌛ **SECOND Best option:** For patients who fail empiric compression: ultrasound-guided compression
3 **$** ⌛ 💧💧 For patients on anticoagulant or having contraindication to compression: percutaneous injection of thrombin

Femoral Dissection

Femoral artery dissection is a recognized complication of the Perclose (and other) closure devices and could occur if the needles are deployed too early and they interact with the posterior wall of the vessel, or if the needles are deployed through a plaque in the anterior wall of the vessel. Meticulous attention and gentle manipulations while puncturing the artery and advancing the wire may lower the risk of access site complications. Routine femoral angiography during cardiac catheterization could lead to early diagnosis not only of arterial dissections, but also of other complications, such as bleeding from laceration of the inferior epigastric artery.

Open surgical repair has historically been the treatment of choice for flow-limiting femoral artery dissections, but percutaneous techniques are increasingly being used to treat these injuries. Stenting of the CFA is not recommended because of the high risk of stent fracture. Balloon angioplasty or atherectomy of the CFA might be better alternatives to stenting if they provide an acceptable angiographic result.

Patients with non-flow-limiting iliac artery dissections can often be treated conservatively, because the blood flow tends to "tuck" iliac dissections caused during retrograde insertion of catheters, wires, or other equipment. Conservative management for non-flow-limiting dissections consists of bed rest with follow-up noninvasive imaging and clinical exams. If dissections are flow limiting, then stenting (using self-expanding stents for the exterior iliac artery or either self-expanding or balloon-expandable stents for the common iliac artery) may be the treatment of choice.

CASE REPORT

Retrograde Abdominal and Thoracic Dissection from the Iliac Artery

A patient with suspected coronary disease was prepared for cardiac catheterization via the femoral approach. A standard right femoral artery puncture was performed and the wire passed easily to the mid-aorta. However, there was difficulty advancing the wire and the catheter beyond the aortic arch and the procedure was abandoned. Half an hour later, the patient complained of severe back pain and became temporarily hypotensive. A CT scan confirmed the aortic dissection, with the entry point in the iliac artery extending to the aortic arch. Initially, the patient was managed conservatively but she had recurrent transient episodes of severe back pain associated with transient hypotension (75/40 mmHg) so, under fluoroscopic guidance, a 10-mm × 4-cm stent was placed in the right common iliac artery via the contralateral femoral approach. The new stent occluded the entry point. Follow-up CT showed thrombosis of the false lumen and sealing of the dissection flap. The favorable outcome in this patient was likely due to two factors: (1) the retrograde direction of the dissection, in contrast to the antegrade direction of the usual spontaneous aortic dissection; and (2) the absence of re-entry, which contributed to stagnation of blood flow in the false lumen, resulting in the formation of thrombus and the rapid disappearance of the retrograde dissection [21].

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