CHAPTER 1

Vascular Access

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*Basic; **Advanced; ***Rare, exotic, or investigational
$, <$US100.00 extra; $$, >$US100.00 extra
⌛, <10 min extra; ⌛⌛, >10 min extra
💧, low risk of complications; 💧💧, high risk of complications

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CHALLENGES
To gain vascular access without early or late bleeding is a major challenge for every operator during diagnostic or interventional cardiovascular procedure.

FEMORAL APPROACH

Usually the femoral artery is palpated below the inguinal ligament that runs from the anterosuperior iliac spine to the pubic tubercle. The true position of the inguinal ligament is 1–2 cm below that line.

STANDARD OF TECHNICAL EXCELLENCE
Ideal Location of Femoral Access 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, 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 epigastrum, can be used to define an unequivocally high puncture [1].

The technique employs visualization of the femoral head under fluoroscopy in a posteroanterior projection, and by starting the skin puncture at the level of the lower border of the head of femur with an 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 femoral artery bifurcation in reference to the femoral head. Although in most 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. So one of the ways to perform a near-perfect femoral puncture is to use the fluoroscopically guided micropuncture access [2] (Figure 1.1).

TECHNIQUE The fluoroscopically guided micropuncture access The micropuncture vascular access technique involves the use of needles and wires typically in the 21-gauge and 0.018″ 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.

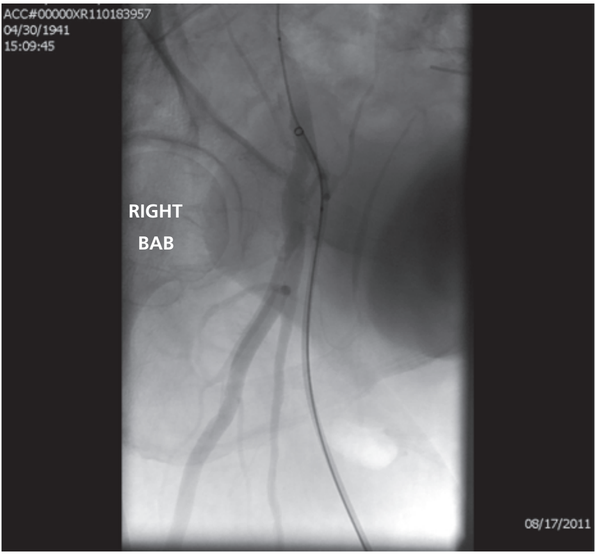

Figure 1.1 Ideal puncture location of the common femoral artery is above the bifurcation of the profunda femoral artery and below the origin of the inferior epigastric artery. In this iliofemoral angiogram, the sheath is seen entering the common femoral artery at a point above the origin of the inferior epigastric artery. This is an unacceptable high stick. (Courtesy of Dr Aravinda Nanjundappa.)

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. Following 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 could be adjusted several times if necessary, as it traverses deep into the subcutaneous tissue [1].

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. If 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 minutes before attempt of a new puncture based on the angiogram.

Technical 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 has 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 and use 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 prior remote femoral artery cannulations, total hip replacement, in severely calcified arteries, 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, 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 hit the contralateral wall. Just move the needle by a slight pull or rotate it a little; it may then be possible to insert the wire. 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 back flow and the wire is not able to negotiate the tortuous iliac artery, pull 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 back flow, 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 would also help to find out why there is a problem advancing the wire.

*__Sequential order for arterial and venous puncture__ The order of arterial and venous access 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, less than a few seconds later, after puncturing the artery, we would insert the sheath into the artery and the vein. As there is only a wire in the vein, there is minimal distortion of the arterial puncture site. There could be more anatomical shifting caused by the placement of the venous sheath. Less than 1 minute without a sheath will not produce a hematoma at the venous site. If inadvertently the artery is punctured first, we would cannulate the artery, then inject contrast into the arterial sheath. Puncture the vein under fluoroscopy, with the needle medial and parallel to the contrast-filled arterial sheath.

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 may not be able to stop the bleeding from the puncture hole in the extravascular segment of the venous sheath by manual pressure.

**__Kinked wire__ It is not unusual that the wire will 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 the wire is not too crooked, the first best maneuver is to advance the wire further, so the dilator can be advanced to dilate the entry site on a straight and stiff segment of the wire. If the wire is too soft, then the second best maneuver is to exchange the soft wire for a stiffer wire over a 4-Fr dilator.

**__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 high punctures (above the lowest border of the inferior epigastric artery). However, these proportions are valid only in the antero-posterior (AP), neutral position. Internal or external rotation of the femur can considerably change the relationship of the femoral artery to the femoral head. Another way to puncture the femoral artery is to use Doppler guidance with the SmartNeedle, which is an arteriotomy needle that incorporates a continuous Doppler probe, and enable the identification of arterial or venous vessels by means of continuous auditory feedback. This technique is very helpful in puncturing an artery with a very weak pulse or a pulseless artery, especially when the standard anatomy is disturbed by a large hematoma, or thick scar after surgery for artificial femoral head replacement [3].

Trouble-shooting Tricks

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 CFA or iliac artery.

TECHNIQUE Bypass graft puncture As 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. Sometimes, as a result of severe scarring, the entry site has to be prepped by sequential dilation with small to progressively larger dilators up to 1-Fr size larger than the sheath selected for the procedure.

Trouble-shooting Tricks

*****Parallel technique* If the native artery is punctured and the wire could not be advanced because the artery ends up with a dead-end pouch, then leave the small 4-Fr sheath inside as a landmark. Palpate again the femoral artery and try to feel the two pulsations there: the first one is the native artery with the 4-Fr sheath and the second is the bypass graft if the graft is superficial or is not well palpable as a result of the thick wall of the bypass graft. Then 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.

****Insertion of intra-aortic balloon pump through diseased iliac artery* When an intra-aortic balloon pump (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 has been removed. When a balloon pump is to be inserted through a previously stented iliac artery, do it under fluoroscopy to be sure that the balloon does not get stuck on the stent struts. Chronic endothelialization of the stent struts should diminish this problem.

****Two catheters inserted with one puncture technique*
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, then change the sheath to an 8-Fr introducer. The two 4-Fr diagnostic catheters can be inserted and attached to separate manifolds [4].

ANTEGRADE PUNCTURE

The antegrade femoral puncture can be greatly simplified and is more successful if the tissue thickness 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 details in chapter 26.

TECHNIQUE 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 superficial femoral artery (SFA) or the profunda femoral artery (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. A 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] (see Figure 26.1).

Technical Tips
****Manipulation of 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 that 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 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 the rare cases of high bifurcation, it may not be possible to puncture the CFA that 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 this appears without significant atherosclerotic disease and 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, after the procedure, the local compression of the artery should be in the 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. The radial access is discussed in Chapter 7.

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 the ideal location for percutaneous access of this vessel (Figure 1.2). The

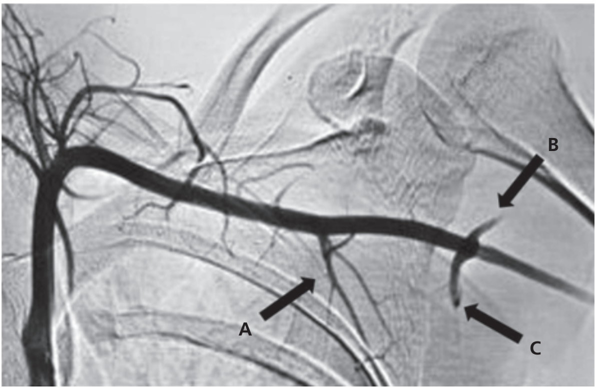

Figure 1.2 Normal subclavian and axillary artery angiogram. Subscapular artery (A) and anterior and posterior humeral circumflex arteries (B, C) are labeled in the third part of the axillary artery [6].

axillary artery was chosen over the subclavian artery due to its accessibility outside the chest wall, which would allow manual compression should closure procedures fail, and was chosen over the brachial artery due to its larger diameter and presence of collateral circulation that would decrease 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 is 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].

Both procedures were performed under conscious sedation with fentanyl and midazolam. Before obtaining access in the left axillary artery, a 7-Fr sheath was inserted into both the right and left radial arteries. An angiogram of the right radial artery was obtained to ensure that there were no contraindications for using this approach for the percutaneous coronary intervention (PCI). An angiogram of the left upper extremity was 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 was then inserted through the left radial artery sheath extending to the axillary artery. A micropuncture needle was used to gain access to the axillary artery using the J-wire as a fluoroscopic guide, and a 6-Fr sheath was placed via the modified Seldinger technique (Figure 1.3).

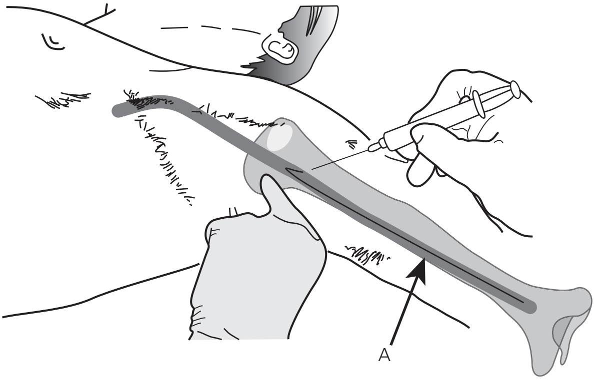

Figure 1.3 Patient in supine position with left arm abducted. J-wire (A) inserted via 7-Fr left radial sheath is visualized under fluoroscopy and marks the ideal location for needle insertion between origin of subscapular and humeral circumflex arteries [6].

TRANSEPTAL APPROACH

Femoral and radial access is universally used for interventional procedures. However, in some patients with pulseless disease (Takayasu's arteritis), there are no arterial pulses in four extremities, then the PCI has to be done through the femoral vein approach. Tips and tricks for puncturing the septum are discussed and illustrated extensively in Chapter 18.

CLOSURE DEVICES

Closure device can be used after any procedure such PCI, valvuloplasty, intra-aortic balloon pump (IABP) or due to inadvertent arterial puncture 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.

Collagen Plug Device: Mynx

The Mynx Vascular Closure device (AccessClosure, Inc, Mountain View CA. USA) 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 [7].

Clip Device: Starclose

The Starclose device (Abbott Vascular, Redwood City, CA, USA) 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 proper 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 [7].

The Perclose (Abbott Vascular, Redwood city, CA, USA)
TECHNIQUE Preclosure of large arterial access In cases where a large-sized sheath is needed (e.g. for aortic valvuloplasty), preplacement of untied sutures using the Perclose percutaneous suture delivery system before placement of a large intended sheath can be done. 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 then closed around the arteriotomy [8].

TECHNIQUE 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- or 8-Fr dilator, before 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 and, after the sutures have been 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 betadine-soaked gauze. 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]

Technical Tips

***__Differences in technical details for preclosure of venous access__ As 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, back flow is 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 in a deep breath or by performing the Valsalva maneuver [8].

***__Double Angio-Seal closure for a 10-Fr vascular access__ Although Angio-Seal (St. Jude Medical, Inc. St Paul MN USA) 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 are 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 "back up/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 sheath tip 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 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 and 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, vascular compromise, or hematoma on inspection [10].

Discriminating Differences

Which vascular closure devices for which patients? Vascular closure devices (VCDs) are not 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 the above 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 [11].

In devices with a significant intravascular component, such as the Angio-Seal device, usage is not recommended for bifurcation punctures, because there is a risk of obstruction by the intravascular portion of the device of the smaller branches. Moreover, accurate alignment of the intravascular part might be difficult due to the complex angles at the site of bifurcation. In addition, there is also a risk of deployment of the collagen plug intravascularly (Figure 1.4). Thus, access-site closure in patients with bifurcation

Figure 1.4 An emergency angiogram showed total occlusion of the superficial femoral artery while there is contrast extravasation at the puncture site. An intravascular foreign body is seen at the bifurcation of the superficial and profunda femoral arteries. (Courtesy of Dr Aravinda Nanjundappa.)

punctures continues to be a challenge. Devices that do not have any significant intravascular component (such as 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].

CAVEAT

Suspecting intra-arterial deployment of collagen plug

During deployment of an Angio-Seal device, the intra-arterial deployment of the collagen plug can be due to inadequate tension on the suture, vigorous tamping, too deep insertion of device into the artery causing anchor to be 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].

Trouble-shooting Tricks

****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 that period, 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 hours, the anchor, which is composed of an absorbable polymer material, becomes softened and therefore pliable. A hemostat was placed on the suture at the level of 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]. The management is summarized in Box 1.1.

COMPLICATIONS

Hematoma

The frequency of hematomas increases with the increasing size of the sheath, increasing level of anticoagulation, and the obesity

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 ultrasonography can document intra-arterial collagen
4. Apply tension string in the usual fashion; secure suture with hemostat at the skin level to add security
5. **Do not cut suture:** Embolization of the anchor and plug may occur
6. If there are signs of embolism and thrombosis, obtain vascular surgery consultation
7. Wait at least 4 hours to allow softening of the anchor
8. Steady vertical traction on suture with approximately 10 lb (4.5 kg) of force
9. If removal of the device is achieved, maintain manual compression to achieve hemostasis
10. FemoStop device should be ready for rapid deployment after device is removed
11. Remove the collagen plug by atherectomy device (not needed)

of the patient. Surgical evacuation is not required even for large hematomas, unless there is undue tension on adjacent structure 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 femoral artery, and the presence of a false aneurysm.

Arteriovenous Fistula

This happens rarely (>0.4%) when the puncture is made where the artery overlies the vein. Most small ateriovenous fistulas (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.

TECHNIQUE 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 is then introduced over the wire and tries to remove any thrombi. If normal distal flow is established without any residual stenosis, the procedure is terminated. It there is still residual thrombus, 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] (Figure 1.5).

If a 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); 4 hours later, an angiogram can be performed to check the progress and, if there is persisting 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 ultrasonography. Angiography is mandatory and should not be delayed. The purpose of angiography is to identify the location (aortoiliac inflow circulation, infrainguinal outflow circulation, or run-off circulation) and cause (dissection, thrombosis, distal embolization, sheath/vessel mismatch) of ischemia, because these factors will help to determine the treatment strategy (vascular surgery, percutaneous revascularization, thrombectomy,

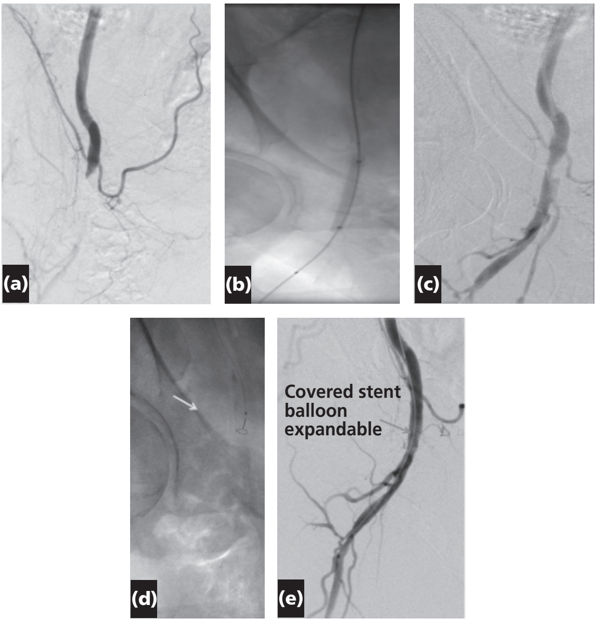

Figure 1.5 (a) An emergency angiogram showed total occlusion of the common femoral artery at the puncture site where patient had a closure device with intravascular component. (b) A balloon is advanced to the obstruction site and inflated. (c) There is renormalization of the blood flow; however, the lesion is still significant. (d) A snare failed to remove the intravascular anchor. (e) The patient received successfully a covered stent to stop the bleeding. (Courtesy of Dr Aravinda Nanjundappa.)

intra-arterial thrombolytic infusion). In most cases, digital subtraction angiography is best, because cineangiography may not permit adequate visualization of the runoff circulation [14].

Trouble-shooting Tricks

****Temporary relief of iatrogenic ischemic limb: percutaneous technique for in vivo femoral artery bypass* During PTA of high-risk patients, if the acute limb ischemia arises during femoral artery catheterization, the antegrade sheath in the a femoral artery and the retrograde sheath in the contralateral common femoral artery 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 allow the use of devices for invasive hemodynamic pport, when such devices cause limb ischemia and there are no other therapeutic alternatives [14].

CAVEAT

Preventing limb ischemia

The steps to prevent limb ischemia include: (1) Careful examination of femoral pulses and bruits before catheterization; (2) angiography before 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 1.6).

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

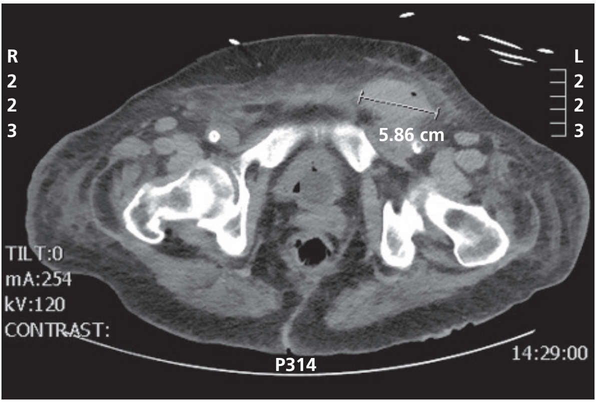

Figure 1.6 Retroperitoneal bleeding (arrow) due to high femoral puncture. (Courtesy of Dr Aravinda Nanjundappa.)

motor innervations to 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 the femoral nerve palsy. Weakness of the quadriceps muscle and decreased patellar reflex are the most striking examination findings [15].

The management 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 towards 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 with the above measures being 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 reflecting 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].

Technical Tips

How to detect retroperitoneal hematoma in a 1-second maneuver? Just an AP view of the pelvic area under fluoroscopy may give a clue to the problem. Usually, the bladder is seen round, filled with contrast. If the opacified bladder is seen displaced and its round shape is dented, RPH is strongly suspected (Figure 1.7). However, significant blood needs to be sequestered before unilateral external compression of the bladder occurs. [19]

TECHNIQUE How to seal a perforation with a balloon The initial angiogram revealed 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 Balanced Middleweight wire is advanced into the inferior epigastric artery, and the tip positioned distal to the

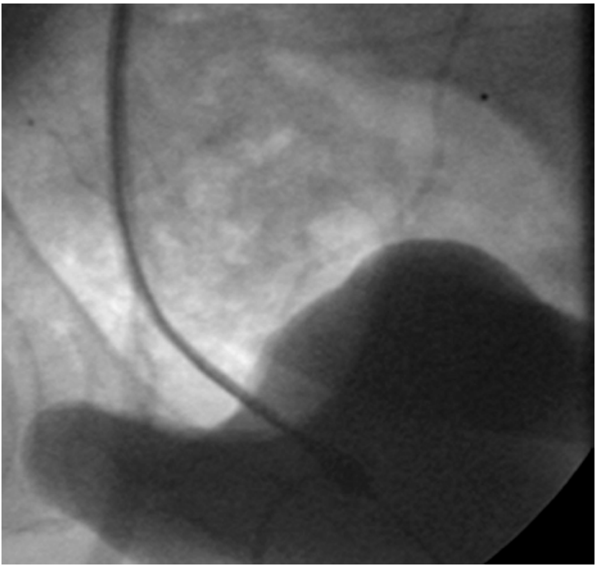

Figure 1.7 A dented bladder due to retroperitoneal hematoma. It looks different from the round shape of the bladder. (Courtesy of the Cardiac Catheterization Laboratories of Community Healthcare System, St Mary Medical Center.)

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.

TECHNIQUE How to close a perforation with 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 spilling of contrast from the vessel lumen into the CFA. Thrombin-JMI is to be diluted in 0.9% saline at a concentration of 50 IU/ml. Subsequently, a total of three consecutive doses of 100 IU 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] (Figures 1.8–1.11).

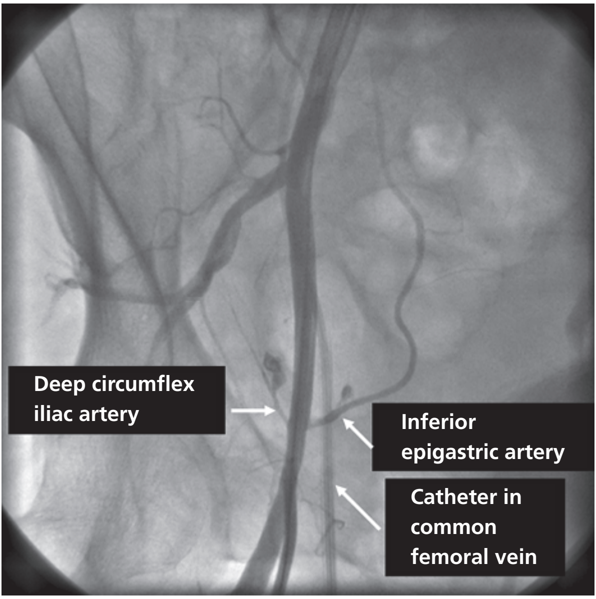

Figure 1.8 The iliofemoral angiography showed blood extravasation in the deep circumflex iliac artery and the inferior epigastric artery. (Courtesy of Dr Aravinda Nanjundappa.)

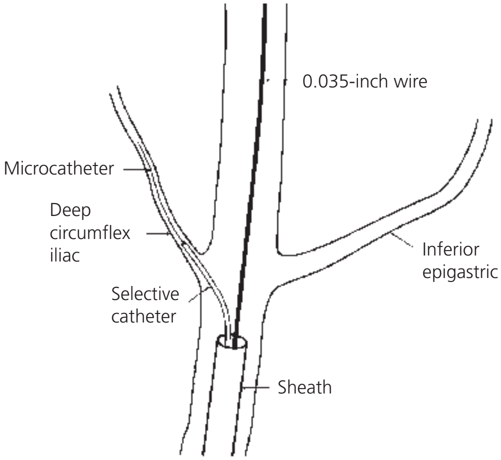

Figure 1.9 A microcatheter was inserted into the deep circumflex iliac artery. (Courtesy of Dr Aravinda Nanjundappa.)

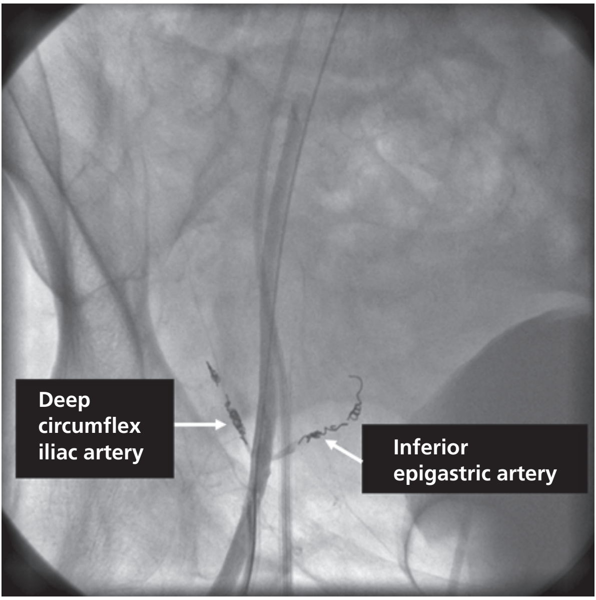

Figure 1.10 Coil embolization was successful in stopping the bleeding of the inferior epigastric for an expanding rectus sheath hematoma and of the deep circumflex iliac artery for expanding lateral abdominal wall hematoma. (Courtesy of Dr Aravinda Nanjundappa.)

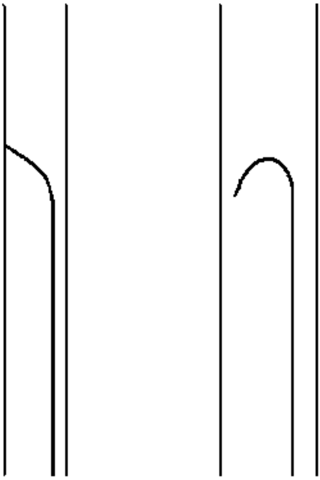

Figure 1.11 Cause of perforation in the branches of the iliofemoral artery, if the patient does not have a large common femoral artery and if a large J-wire is used. In a small vessel the J tip cannot be formed and the laterally pointing tip will preferentially direct the wire into side branches of the main artery and lead to perforations, as seen in this case. Be careful when advancing a wire up the femoral artery in a patient with small stature and low weight. (Courtesy of Dr Aravinda Nanjundappa.)

Perforation If a balloon bursts and perforates a peripheral artery below the inguinal ligament, the 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 seal the puncture site [18].

TECHNIQUE 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 a 0.035-inch Amplatz super stiff wire, and an 8 Fr × 65 cm long Superflex sheath, 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-minute inflation of a balloon at 2 atm with persistent extravasation of contrast. An under-sized, self-expanding, covered stent is then placed across the perforation site with a persistent leak. The stent graft can then be post-dilated with a balloon at 8 atm with complete hemostasis and resolution of the free-flow contrast into the retroperitoneum.

Pseudoaneurysm The main cause of a pseudoaneurysm (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 ultrasonography, 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, whether it has increased in size, and the need for continued anticoagulation. Usually the small PAs (<3 cm in diameter) will close spontaneously, presumably due to thrombosis. A follow-up ultrasound scan 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 (FemoStop St. Jude Medical, Inc. St Paul MN USA). The success rate is 74% with a mean compression of 33 min [20]. The failed patients underwent successful compression guided by ultrasonography.

Contraindications to mechanical compression are listed in Box 1.2. Ultrasound-guided compression is commonly used with success related to the anticoagulation status and a PA that can be readily visualized and compressed [20]. However, the best modality of treatment is to inject thrombin into the PA. The technique is simple, quick, and painless. Surgery is indicated rarely

BOX 1.2 CONTRAINDICATIONS TO MECHANICAL COMPRESSION OF A PSEUDOANEURYSM

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

when the above-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.

TACTICAL MOVE

BEST options for exclusion of femoral pseudoaneurysm

1 **FIRST Best option:** Mechanical compression therapy if there is no thrombin available
2 **$ SECOND Best option**: For patients who fail empirical 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 access dissections, but percutaneous techniques are increasingly being used to treat these injuries. The CFA stenting 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 non-invasive imaging and clinical exams. If dissections are flow limiting, then stenting (using self-expanding stents for the external 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].

REFERENCES

1. Cilingiroglu M, Feldman T, Salinger MH, et al. Fluoroscopically-guided micropuncture femoral artery access for large-caliber sheath insertion. *J Invasive Cardiol* 2011;**23**:157–61.
2. Bangalore S, Vidi VD, Liu CB, et al. Efficacy and safety of the nitinol clip-based vascular closure device (StarClose) for closure of common femoral arterial cannulation at or near the bifurcation: A propensity score-adjusted analysis. *J Invasive Cardiol* 2011;**23**:194–9.
3. Mehan VK. Doubtful arterial puncture during cardiac catheterization in cyanotics. *Catheter Cardiovasc Diagn* 1990;**19**:148–9.
4. Nicholson WJ, Rab T. Simultaneous diagnostic coronary angiography utilizing a single arterial access technique. *Catheter Cardiovasc Interv* 2006;**68**:718.
5. Biondi-Zoccai GG, Agostoni P, Sangiorgi G, et al. Mastering the antegrade femoral artery access in patients with symptomatic lower limb ischemia: Learning curve, complications, and technical tips and tricks. *Catheter Cardiovasc Interv* 2006;**68**:835–42.

6. Lotun K, Shetty R, Patel M, Arain SA. Percutaneous left axillary artery approach for Impella 2.5 liter circulatory support for patients with severe aortoiliac arterial disease undergoing high risk percutaneous coronary intervention. *J interven Cardiol* 2012;**25**:210–13.
7. Schwartz B, Burstein S, Economides C, et al. Review of vascular closure devices. *J Invasive Cardiol* 2010;**22**:599–607.
8. Feldman T. Femoral arterial preclosure: Finishing a procedure before it begins. *Catheter Cardiovasc Interv* 2001;**53**:448.
9. Bui QT, Kolansky DM, Bannan A, Herrmann HC. "Double wire" Angio-Seal closure technique after balloon aortic valvuloplasty. *Catheter Cardiovasc Interv* 2010;**75**:488–92.
10. Korngold EC, Inglessis I, Garasic JM. A novel technique for 14 French arteriotomy closure after percutaneous aortic valvuloplasty using two Mynx closure devices. *J Interven Cardiol* 2009;**22**:179–83.
11. Bangalore S, Vidi VD, Liu CB, et al. Efficacy and safety of the nitinol clip-based vascular closure device (Starclose) for closure of common femoral arterial cannulation at or near the bifurcation: A propensity score-adjusted analysis. *J Invasive Cardiol* 2011;**23**:194–99.
12. Stein B, Terstein P. Non-surgical removal of Angio-Seal device after intraarterial deposition of collagen plug. *Catheter Cardiovasc Interv* 2000;**50**:340–2.
13. Samal A, White C. Percutaneous management of access site complications. *Catheter Cardiovasc Interv* 2002;**57**:12–23.
14. Merhi WM, Turi ZG, Dixon S, et al. Percutaneous ex-vivo femoral arterial bypass: A novel approach for treatment of acute limb ischemia as a complication of femoral arterial catheterization. *Catheter Cardiovasc Interv* 2006;**68**:435–40.
15. Raja Y, Lo TS, Townend JN. Don't rule out retroperitoneal bleeding just because the angiogram was done from the radial artery. *J Invasive Cardiol* 2010;**21**:E3–E4.
16. Frank JJ, Kamalakannan D, Kodenchery M, Savoy-Moore RT, Rosman H. Retroperitoneal hematoma in patients undergoing cardiac catheterization. *J Interven Cardiol* 2010;**23**:569–74.
17. Trimarchi S, Smith DE, Share D, et al. Retroperitoneal hematoma after percutaneous coronary intervention: Prevalence, risk factors, management, outcomes, and predictors of mortality a report from the BMC2 (Blue Cross Blue Shield of Michigan Cardiovascular Consortium) Registry. *J Am Coll Cardiol Interv* 2010;**3**:845–50.
18. Silva JA, Stant J, Ramee SR. Endovascular treatment of a massive retroperitoneal bleeding: Successful balloon-catheter delivery of intra-arterial thrombin. *Catheter Cardiovasc Interv* 2004;**64**:218–22.
19. Chambers CE, Griffin DC, Omarzai RK. The "dented bladder": Diagnosis of a retroperitoneal hematoma. *Catheter Cardiovasc Diagn* 1993;**34**:224–6.
20. Zahn R, Thoma S, Fromm E, et al. Pseudoaneurysm after cardiac catheterization: Therapeutic interventions and the sequelae: Experience in 86 patients. *Catheter Cardiovasc Diagn* 1997;**40**:9–15.
21. Prasad A, Compton PA, Prasad A, et al. Incidence and treatment of arterial access dissections occurring during cardiac catheterization. *J Interven Cardiol* 2008;**21**:61–6.