

Chapter 1

Vascular Access

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*Basic; **Advanced; ***Rare, exotic, or investigational.

From: Nguyen T, Hu D, Saito S, Grines C, Palacios I (eds), *Practical Handbook of Advanced Interventional Cardiology*, 2nd edn. © 2003 Futura, an imprint of Blackwell Publishing.

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FEMORAL ACCESS: STANDARD TECHNIQUE

Locate the femoral artery and 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.¹ The femoral pulse at the inguinal crease is not a reliable landmark for the common femoral artery (CFA), particularly in obese patients.² 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.³

TECHNICAL TIPS

***Preparations in obese patients:** The femoral pulse at the inguinal crease is not a reliable landmark for the common femoral artery (CFA), particularly in obese or elderly patients, whose crease tends to be much lower than the inguinal ligament.² 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 as taut as possible, so the needle will not be deflected outside the projected angle and selected pathway.

***Directing the needle:** Once the needle tip is near the artery, it tends to pulsate except in patients with severe local scarring (after many prior remote femoral artery cannulations, ilio-femoral bypass, after total hip replacement, etc.). If the hub inclines to the right, the needle should be withdrawn by 1 or 2 cm and the tip redirected to the left before advancing forward. If the hub inclines to the left side, the reverse maneuver is used to change the course. If the needle pulsates on the vertical axis, it just needs to be inserted more deeply.³

***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, and the wire may be able to be inserted. If there is difficulty, it is better to withdraw the needle and re-puncture the artery rather than dissect the artery.⁴ After the sheath is inserted and the wire is not able to negotiate the tortuous iliac artery then a diagnostic Judkins right catheter can be advanced to the tip of the

wire in order to help steer the wire tip. A gentle injection of contrast may help to delineate the anatomy and determine the reason why the wire could not be advanced. The use of hydrophilic wires for the initial introduction through the needle should be avoided because they can easily travel subintimally and cause later dissection. Also, they can be easily cut by the sharp needle tip.

***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 1 minute later, after puncturing the artery, we would insert the sheath into the artery and the vein. Because there is only a wire in the vein, we do not disturb the anatomic landmark of the common femoral artery, which we try to locate and puncture. Less than 1 minute without a sheath will not produce a hematoma at the venous site. If the artery is inadvertently punctured first, we would cannulate the artery, then puncture the vein under fluoroscopy, with the needle medial and parallel to the arterial sheath.

****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 that may lead to uncontrollable bleeding. However, these proportions are valid only in the AP, neutral position (Figure 1-1). Internal or external rotation of the femur can considerably change the relationship of the femoral artery to the femoral head.⁵ Doppler guidance is very helpful in puncturing an artery with very weak pulse or a pulseless artery, especially when the standard anatomy is deranged by a large hematoma, or thick scar after surgery. The most common cause of weak pulse is hypovolemic hypotension, heavy calcification, and is only rarely due to narrow pulse pressure such as in constrictive pericarditis (in contrast to aortic regurgitation).

*****Puncture in cyanotic patients:** In children with cyanotic heart disease, especially those weighing less than 15 kg and with severe polycythemia, the blood flow from a femoral puncture can resemble a venous sample: a gentle flow of dark blood. This color is due to arterial desaturation and hyperviscosity secondary to polycythemia. If there is doubt, confirm the arterial puncture by attaching the needle to a pressure transducer or by making a small contrast injection into the arterial lumen.⁶

*****Insertion and removal of IABP through diseased iliac artery:** When an IABP needs to be inserted and an



Figure 1-1: Needle position on the femoral head for arterial and venous puncture and cannulation.

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. To remove the IABP deflated balloon, insert a large femoral sheath and withdraw the winged balloon into the sheath so the folds of the winged balloon are not caught by struts at the stent edges. Chronic endothelialization of the stent struts should diminish 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.⁷ Inadvertent entry to the native arterial system may lead to the dead-end stump in the common femoral or iliac artery.

TECHNICAL TIPS

****Puncture location:** 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.

****Angle of introduction:** To avoid kinking of the catheter at the puncture site, it is better to introduce the needle at an angle of approximately 30° to 45° to the estimated long axis of the graft.⁷

****Sequential dilation:** Sometimes, because of severe scarring, the entry site has to be prepared by sequential dilation with progressively larger dilators up to 1F size larger than the sheath selected for the procedure.

****Kinked wire:** It is not unusual that the wire will pass into the lumen easily but attempts to advance any dilator over the wire will result in kinking of the wire at the point of entry. Instead of exchanging the wire, if the wire is not too crooked we would advance the wire farther, so we use the dilator to dilate the entry site on a straight and stiff segment of the wire. If the wire is too soft, then it should be exchanged for a stiffer wire over a smallest size 4F dilator.⁷

CLOSURE DEVICES

The choice between collagen plugs and suture closure is largely a matter of personal preference and experience. The time needed to deploy the various devices is unique to each system. When physicians' time to utilize the device and staff time for adjunctive compression or puncture site management are considered together, sealing devices do not provide an advantage over manual pressure in decreasing complications.⁸ Current arteriotomy closure devices were found to be independent predictors of major hematoma as body surface area (BSA). Infection has been reported with all

of these devices.⁸ Thorough training of operators in how to use any device is warranted to reduce vascular access complications. When deploying an AngioSeal device (St Jude Medical Devices, Minneapolis, MN), an iliac angiogram needs to show the artery diameter is at least 4 mm and there is no bifurcation within 2 cm of the arterial entry site.

TECHNICAL TIPS

*****Pre-closure of large arterial access:** In cases of need of large size sheath (e.g. for valvuloplasty), preplacement of untied sutures using the Closer percutaneous suture delivery system (Abbotts Vascular, Redwood City, CA) prior to placement of a large intended sheath can be done. A 5F to 6F sheath may be used for arterial angiography to identify appropriate anatomy, and then a suture delivery system is used to place untied sutures. At the end of the procedure, the existing “purse string” is then closed around the arteriotomy.⁹

*****Non-surgical removal of the AngioSeal device:** After PCI, many closure devices can be used to close the puncture site. In a case reported by Stein *et al.*, a possible intra-arterial deployment of the collagen plug was suspected during an AngioSeal deployment. At that time, while inserting the tamper tube more deeply, it was observed that it could be inserted much deeper than is usually found during routine AngioSeal deployment. The patient continued to bleed. A tension spring was placed as usual. At that time, the author used a hemostat to secure the end of the suture, and a FemoStop compression device (Femostop, Radi Medical Systems AB, Sweden) was applied above the AngioSeal to stop bleeding. Then the author waited for 4 hours, so that the anchor, composed of an absorbable polymer material, would become softened and thus 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 minutes, the plug was removed. The FemoStop was reapplied and hemostasis was achieved. The Take-Home Message is summarized below.¹⁰

TAKE-HOME MESSAGE

What to do if collagen is inserted intra-arterially:

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 string in the usual fashion; secure suture with hemostat at 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 lbs of force.
9. If removal of the device is achieved, maintain manual compression to achieve hemostasis.
10. Femo-Stop device should be ready for rapid deployment after device is removed.

*****When to suspect intra-arterial deployment of collagen plug:** During deployment of an AngioSeal device, intra-arterial deployment of the collagen plug can be due to inadequate tension on the suture, vigorous tamping, too deep insertion of the device into the artery, so that the anchor is caught in the posterior wall, etc. Suspicion of the problem is aroused when there is a long travel distance of the tamper tube or continued bleeding.¹⁰ Precaution tips during deployment of the AngioSeal device are summarized in Table 1-1.

ANTEGRADE PUNCTURE

A contralateral femoral artery puncture is used to reach lesions in the profunda femoral (PFA) and proximal SFAs. An antegrade puncture is used to reach more distal lesions for interventions in the superficial femoral, popliteal, tibial, and peroneal arteries.

Optimal preparation: The antegrade femoral puncture can be greatly simplified and more successful if the tissue thickness between the skin surface and the artery is as thin as possible. This may be achieved by placing a pillow under

Table 1-1
Tips during deployment of AngioSeal device

1. Insert the insertion sheath exactly 1.5 cm after seeing squirt of blood.
 2. After that, pull back the whole device, feel that the anchor is tightly apposed to the arterial wall.
 3. Advance the tamper tube while keeping steady traction on the suture.
 4. Be sure there is no severe blood oozing.
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the buttocks. The hyperextension of the hip joint caused by this maneuver stretches the skin taut over the puncture site and tremendously decreases the tissue thickness. 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

Standard puncture: The next 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.⁴ 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 or the profunda femoral arteries. 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.

TECHNICAL TIPS

****Antegrade puncture:** 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 profunda femoral artery. The wire can be withdrawn and the needle tip deflected medially to redirect the wire into the SFA.

****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 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

****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 AP puncture, the needle is seen to point more toward the PFA that 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 2.

TRANSLUMBAR APPROACH

In patients with total occlusion of arteries to lower and upper extremities, PCI can still be performed through the translumbar approach.¹¹ This problem occurs rarely, only once in 6000 to 9000 cases. However, if the lumbar approach is the only access available in those rare circumstances in which conventional sites are not available, then it is worth offering the option to the patient.¹²

Technique

The patient is placed in the prone position. Utilizing the left flank approach, an appropriate puncture site is selected, which is approximately 4 finger breadths lateral to the midline and 2 finger breadths below the left 12th rib margin. Verification that this position is below the posterior sulcus of the lung is made by fluoroscopy. After local anesthesia, a small skin incision is made with a blade and enlarged by the hemostat. The tip of the translumbar access needle (TLA) and the outer Teflon sheath (Cook, Bloomington, IN) are placed in the skin incision and directed toward the T12 vertebral body. Three

successive attempts are made, with each increasing the vertical degree of the pass in order to “step off” of the vertebral body. When the needle tip abuts the aorta, pulsation can be felt against the fingertip. The TLA needle is then given a short thrust until the initial resistance is not felt. The tip of needle is watched closely and should never cross the midline of the body. The inner stylet of the TLA needle is removed, and blood is seen at the hub. A floppy J wire is inserted and an introducer sheath is inserted in the usual fashion. Coronary angiogram and angioplasty are performed by the standard technique. After documentation of ACT less than 150 sec, the sheath is removed without complication while the patient is in the prone position.¹¹

TECHNICAL TIP

*****Reverse image:** Given the prone position of the patient, the fluoroscopic images appear in reverse, compared to standard images. This problem can be corrected by using the sweep reversal mode on the video monitor.¹¹

TRANSSEPTAL 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 Chapters 24 and 25.

Technique

A transseptal puncture was performed through the femoral vein with a modified Brockenbrough technique. A 7F pulmonary artery balloon-tipped catheter was advanced through the mitral valve, looped around the LV apex, and passed out of the aortic valve successfully to the ascending aorta. An 8F Mullins transseptal sheath (USCI, C.R. Bard, Galway, Ireland) was advanced into the LA. Heparin was given. The pulmonary artery catheter was exchanged for a 6F AL-1 (Cordis Europa, Roden, The Netherlands), then to a 6F Multipurpose catheter (Cordis) over a 0.038" exchange wire. The LM was engaged easily and selective coronary was performed. Selective right coronary selection was unsuccessful with the AL, JR, or Multipurpose catheters. At the end, selective opacification of the right coronary artery (RCA) was achieved with the JL4. There were no complications, except for asymptomatic intermittent nonsustained VT due to the wire.¹³

TECHNICAL TIP

*****Manipulation of catheter:** At all times, care was taken to maintain a loop of catheter or wire in the left ventricular apex. Shortening of this loop to the straight path between the mitral and aortic valves could result in trauma to the anterior mitral leaflet.¹⁴ There were few problems cannulating the LM; however, it was difficult to cannulate the RCA because the catheters kept dropping into the ventricle when manipulated.¹³ The total procedure time was 120 minutes with 42 minutes for the RCA engagement, compared with 12 minutes for a complete coronary angiography through the femoral approach.

COMPLICATIONS

Hematoma: Frequency is 1–3% and increases with the increasing size of the sheath, the higher level of anticoagulation, and the obesity of the patient.⁸ 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 the femoral artery and the presence of a false aneurysm.¹⁵

Arteriovenous fistula (AVF): This happens rarely (<0.4%) when the puncture is made where the artery overlies the vein.¹⁶ 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 rarely, 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. The management includes rapid clinical assessment, prompt initiation of anticoagulant to reduce or prevent thrombus propagation and protection against further embolization, pain control and rapid initiation of therapy to re-establish perfusion of the affected limb. Unlike in acute myocardial infarction, where intravenous bolus of fibrin-specific plasminogen activators (PA) dosing is necessary to rapidly achieve high concentration of plasmin activity at the site of thrombosis and facilitate rapid lysis of a relatively small thrombus, lysis of larger diameter and longer peripheral thromboses is best achieved with catheter-directed infusion of specific PAs over several hours to days.¹⁶ Compared with urokinase, which was recently re-introduced in the US market, bolus doses of the PAs may be associated with excessive risk of bleeding or cardiopulmonary complications, necessitating transfer to

intensive care units when followed by long continuous infusion.¹⁷

TECHNICAL TIPS

****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 6F crossover sheath is placed in the external iliac artery over a 0.035" stiff Amplatz guidewire. The occluded/thrombosed/embolized segment of the artery is crossed with a 0.014" or 0.018" wire. An AngioJet catheter (Possis Medical, Minneapolis, MN) is then introduced over the wire for thrombectomy. 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-PTA result is not optimal, a self-expanding stent may be deployed.¹⁸

****Thrombolytic therapy for acute thrombosis:** If heavy thrombotic burden still persists after mechanical thrombectomy, then tPA 0.05 mg/kg can be given along with heparin through a multi-hole delivery catheter (e.g. 5Fr Mewissen of Boston Scientific, Quincy, MA). Four hours later, an angiogram can be done to check the progress and if there is thrombus, the patient can undergo longer infusion (12–18 hours).¹⁸

Infection: The incidence is 0.2%. The risk factors include puncture of the groin area after a very recent procedure at the same site and with a fresh hematoma present and prolonged (>24 hours) sheath placement. Localized infection at a vertebral artery in the lumbar region proved to be due to injection of infectious material from the long-indwelling femoral sheath.¹⁹

Neuropathy: When there is a large inguinal hematoma compressing the femoral nerve, the patient feels numb at the anterior medial aspect of the thigh. Sometimes the patient has difficulty walking due to weakness of the quadriceps, the extensors of the knees. These problems should be resolved within 24 hours.

Retroperitoneal hematoma: The incidence was high at 3%²⁰ and is much lower now. Clinical clues include hypotension without apparent reason, blood loss without possible source, supra-inguinal tenderness and fullness, and ipsilateral (or rarely contralateral) flank discomfort. A small hematoma is not able to cause any hemodynamic disturbances or any increase of the retroperitoneal cavity pressure to cause neurologic symptoms. Only a huge hematoma compressing the lumbar plexus can really produce numbness and weakness of the muscles below the knee. Usually, bleeding into the retroperitoneal site is self-limiting unless the patient is

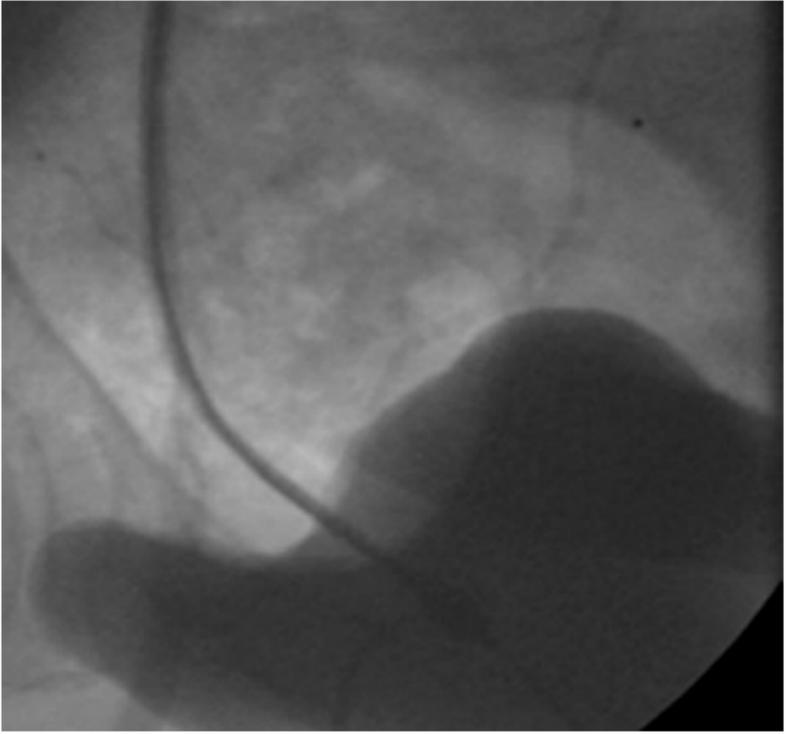


Figure 1-2: A dented bladder due to retroperitoneal hematoma. It looks different from the round shape of the bladder in Figure 1-1.

anticoagulated.²¹ Just an AP view of the pelvic area under fluoroscopy may give a clue to the problem. Usually, during an interventional procedure, the bladder is seen filled with dye. In contrast, if the opacified bladder is seen displaced and its round shape is dented, retroperitoneal hematoma is strongly suspected (Figure 1-2).²¹ However, significant blood needs to be sequestered before unilateral external compression occurs. The management includes stopping heparin and reversing anticoagulation with protamine, then rapid fluid resuscitation to reverse hypovolemia. Transfusion may be needed. If the above treatment fails, surgical exploration is required.

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 to seal the puncture site.²¹

TECHNICAL TIP

****Different patterns of ultrasound in the differential diagnoses of access site swelling:** Pseudoaneurysms are characterized by the presence of a to-and-fro blood flow across the PA neck during systole and diastole.

Hematomas are seen as hypoechoic collections without any Doppler flow movement. Deep vein thrombosis (DVT) is characterized by a lack of venous compressibility, obstruction of venous return, and a hypoechoic or isoechoic signal.²²

Pseudoaneurysm (PA): The incidence of PA is 1–3% by clinical examination or 6% by ultrasound.²³ The main cause is inadvertent puncture of the SFA. 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 hypoechoic 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.²³ 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 1–2 weeks later often demonstrates spontaneous thrombosis and obviates need of 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. In the past, the simplest method of treatment was to use a mechanical compression device (Femostop, Radi Medical Systems AB, Sweden). The success rate is 74% with a mean compression of 33 minutes.²³ The failed patients underwent successful compression guided by ultrasound. Contraindications to mechanical compression are listed in Table 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.²³

BEST METHOD

Best choice for the management of pseudoaneurysm:

The newest mode of treatment is to inject thrombin into the PA under the guidance of ultrasound.²⁴ With more experience in the past few years, it has become the treatment of choice.

Table 1-2

Contraindications to mechanical compression for PA

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

1. Best method: injection of thrombin under guidance of ultrasound, because it is simple, quick, and painless.
2. If there is no experience with injection of thrombin, then mechanical compression device is the next step.
3. If empiric compression fails to close the PA, then mechanical compression under ultrasound guidance.
4. Surgery is rarely necessary.
5. Other investigational techniques become obsolete: coil embolization (disadvantage: coils may fall through the skin or irritate when moving the leg) and covered stent (disadvantage: 12% risk of stent occlusion and more costly).

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