CHAPTER 1

General principles of endovascular therapy

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Cardiovascular disease remains a major cause of mortality in the developed world since the beginning of the twenty-first century. Although surgical revascularization has played a predominant role in the management of patients with vascular disease, the modern treatment paradigms have evolved significantly with increased emphasis of catheter-based percutaneous interventions over the past two decades. The increasing role of this minimally invasive vascular intervention is fueled by various factors, including rapid advances in imaging technology, reduced morbidity, and mortality in endovascular interventions, as well as faster convalescence following percutaneous therapy when compared to traditional operations. There is little doubt that with continued device development and refined image-guided technology, endovascular intervention will provide improved clinical outcomes and play an even greater role in the treatment of vascular disease. In this chapter, a framework is provided for a brief history of endovascular therapy along with an overview of commonly used endovascular devices. The fundamental techniques of percutaneous access is also discussed.

Brief history of endovascular therapy

Evolution of diagnostic imaging

The discovery of the X-ray imaging system by Charles Röentgen in 1895, marked one of the most remarkable milestones in the history of medicine. Within months after its discovery, X-rays were used by battlefield surgeons to locate and remove bullet fragments.[1] This imaging modality quickly gained acceptance from physicians around the world in providing valuable diagnostic information in the care of their patients. As a natural evolution of this discovery, X-rays were soon adapted to evaluate the vascular system in conjunction with the use of a contrast material. In 1910, Frank performed the first venography in rabbits and dogs by injecting a solution of bismuth and oil intravenously and following its flow fluoroscopically.[2] Heuser is credited (in 1919) for performing the first contrast study in humans by injecting a solution of potassium iodide into the dorsal vein of a child and following the flow of the substance to the heart.[3] The use of such materials was initially quite toxic. This led to the development of safe contrast media, for example water soluble iodine-based organic contrast called Selectran-Neutral by Binz in 1929.[4] Concurrently, newer injection methods were also being developed. In 1927, Moniz was the first to perform direct arterial injections, and he used this technique to inject sodium iodide into the internal carotid arteries.[5] This direct approach was initially used to image the heart and thoracic aorta but was soon abandoned due to its hazards.

Castellanos used an indirect method of injection whereby a contrast agent was injected into a vein in the arm and, after a delay, the aorta was visualized.[6] Due to dilution of the agent in the heart and lungs, the aorta could be visualized only 75% of the time. For a better study of these vessels, Werner Forssmann, a resident surgeon in Berlin in 1929, ran a urethral catheter through his own basilic vein to visualize his right ventricle. This earned him the Nobel prize in 1956.[7] Also in 1929, dos Santos *et al*. described a technique of visualizing the aorta using a direct puncture technique by translumbar injection of a contrast medium directly into the abdominal aorta.[8] The modern aortogram via a femoral approach was first performed by Farinas in 1941,[9] a technique that was quickly adapted by physicians around the world. With the advent of guidewires in the early 1950s, selective angiography with catheter-directed injection was developed further. In 1962, Guzman and colleagues reported a large series of patients who underwent coronary angiography using selective coronary catheterizations.[10] Since then, the application of guidewires, catheters, and introducer sheaths has become a standard approach when performing diagnostic angiography.

Evolution of therapeutic interventions

Ivar Seldinger, a Swedish radiologist, was the first physician to describe a unique method of establishing arterial access using a guidewire technique in 1953, which heralded an evolution from diagnostic to therapeutic angiography.[11] A decade later, Fogarty detailed the use of a balloon-tipped catheter to extract thrombus.[12] Building on this, Dotter and Judkin in 1964 described a method of dilating an arterial occlusion using a rigid Teflon catheter to improve the arterial circulation.[13] In the field of venous intervention, catheter-based vena caval filters were introduced by Greenfield in 1973, and have revolutionized the current approach in the prevention of pulmonary embolism.[14] The technique of balloon angioplasty was introduced by Gruntzig, who performed the first coronary artery intervention in 1974.[15] To this day, this remains the most commonly performed endovascular procedure in clinical practice. The application of the balloon angioplasty catheter subsequently led to the development of the first intravascular balloon-expandable stent by Palmaz *et al*. in 1985.[16] Several years later, Parodi, an Argentinean vascular surgeon, combined both a Dacron graft and balloon-expandable stent technology to create a stent-graft, which was successfully used to exclude an abdominal aortic aneurysm from the systemic circulation.[17] Technology in this field is rapidly evolving and more complex modular stents with thermal memory are in use today. There has also been an explosion in catheter-based technology, enabling access for the interventionalist to treat occlusive disease and increasingly, aneurysmal disease in nearly every vascular bed. Further development of this minimally invasive intervention is currently focused on combining a pharmacological agent with the current stent platform to create drug-eluting stents to improve the clinical outcome of endovascular therapy.

Basic vascular access

Percutaneous access can be achieved by a single- or double-wall puncture technique. In the former approach, a beveled needle is introduced, and a guidewire is passed after confirmation of arterial or venous access by visual inspection of back bleeding with or without the use of direct pressure measurement and inspection of arterial or venous waveforms. As a routine, we typically gain vascular access using a 21-gauge micropuncture needle and a 0.018-in. wire. The double-wall technique requires the use of a blunt needle with an inner cannula. The needle is inserted through the vessel, and then the inner cannula is removed, the introducer needle withdrawn until back bleeding is obtained, and a wire introduced. Although percutaneous access can be routinely achieved in nearly all patients, those with scarred access sites from prior interventions or patients with decreased pulses due to occlusive disease represent a specially challenging subset that may benefit from ultrasound guidance with Doppler insonation or B-mode visualization of the target vessel. Indeed, access site needles have been developed with integrated Doppler probes.

Retrograde femoral access

Percutaneous retrograde femoral puncture is the most commonly used arterial access technique. Both groins are prepped and draped in a sterile fashion. Visualization of the femoral head using fluoroscopy is recommended. In the majority of patients, the common femoral artery can be found over the medial third of the head of the femur (Figure 1.1). Another advantage of accessing the artery in this location is that the femoral head will serve as a hard surface to compress the artery against, after the completion of the procedure if manual compression is needed to achieve hemostasis. An 18-gauge angiographic needle is then advanced at a 45° angle through the skin until pulsatile back bleeding is encountered. As with all needle access, the bevel of the needle should point upward. Going through and through the artery should be avoided, as this can lead to problematic bleeding. Depending upon the body habitus, the artery may lie anywhere from 2–5 cm below the level of the skin. If venous entry is noted, it is useful to remember that the artery lies lateral to the vein. It is also important to remember that there is approximately 3 cm of common femoral artery that lies between the inferior ligament and the femoral bifurcation. Once brisk back bleeding is noted, a standard Bentson wire is passed through the needle into the artery for at least 20 cm. It is recommended

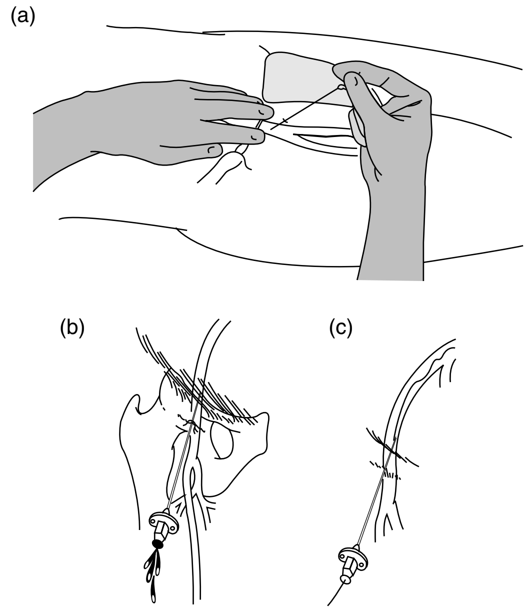

Figure 1.1 Retrograde femoral artery access. (a) The common femoral artery can usually be found medially 2–3 cm below the inguinal ligament. (b) Once the needle enters the common femoral artery, brisk back bleeding is seen. (c) The Bentson guidewire is next advanced through the needle under fluoroscopic guidance to establish the arterial access.

that this maneuver is performed under fluoroscopy to confirm that the wire is going into the aorta. Once the wire is in place, the introducer sheath with its dilator can be easily passed into the artery. If there is any doubt about the path of the wire, a small amount of contrast can be injected through the needle to delineate the needle location.

Arterial entry higher than the level of the femoral head can prove to be difficult in achieving hemostasis, and retroperitoneal hematoma often develops. Entry into the femoral artery far below the inguinal ligament can lead to entry into the superficial or profunda femoral arteries. Catheterization of either of these arteries can result in post-op hematoma and pseudoaneurysm development.

Antegrade femoral access

Antegrade femoral puncture is more challenging than retrograde but can be invaluable in problematic infrainguinal lesions. We recommend that the operator stand on the side that permits forehand approach of the needle (Figure 1.2). The needle is advanced at an angle of 45° to the skin until pulsatile back bleeding is noted. With this approach, it is even more important to avoid low punctures, as this would limit the working room to selectively catheterize the superficial femoral artery. With obese patients, it is often necessary to have

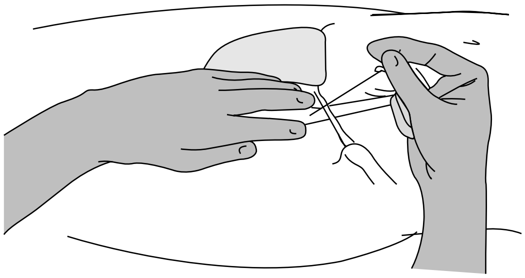

Figure 1.2 Antegrade femoral artery access. The needle is inserted just below the inguinal ligament in the common femoral artery whereby the guidewire is inserted in the ipsilateral superficial femoral artery.

an assistant retract the pannus cephalad out of the way. Once back bleeding is noted, the Bentson wire is placed, followed by a sheath. If there is little room between the site of entry of the wire and the femoral bifurcation, a sheathless technique may need to be employed. In order to selectively catheterize the superficial femoral artery, an angled catheter may help in directing the wire down the correct artery. If the guidewire begins to buckle, it should be withdrawn and retried using a different angle.

Difficult access

There are several techniques that can be employed to access the pulseless yet patent femoral artery. The common femoral artery almost always passes over the medial head of the femur, and attempts in this area will prove to be the most successful. Accessing the femoral artery via the contralateral side and placing a catheter over the bifurcation can be used to inject contrast and visualize the ipsilateral artery. Many patients have vessels that are calcified. Using magnification views, these calcifications can be used as a guide to determine the location of the femoral artery to which the needle can be inserted. Finally, a handheld ultrasound device can be used to determine the location of the noncompressible femoral artery with respect to the compressible femoral vein.

Crossing the aortic bifurcation

Crossing over the aortic bifurcation to gain access to the contralateral iliac artery is an indispensable technique in ileofemoral arterial interventions. This selective catheterization technique produces angiograms of significantly improved quality because of localized contrast injection. The first task is to determine the location of the aortic bifurcation. This can be done by either performing an aortogram for use as a road map or by using the L4 vertebrate and the iliac crest as a landmark. Calcifications in the arteries can help in establishing orientation. The catheter type can prove to be decisive in gaining access across the aortic bifurcation. We routinely use the Contra catheter, as this saves a step when an aortogram is also performed. The catheter is parked near where the bifurcation is suspected, and a glidewire is advanced. If initial attempts are

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