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Access strategies for peripheral arterial intervention

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Abstract

An operator's ability to determine the optimal vascular access strategy for patients undergoing peripheral endovascular intervention is critical to maximizing procedural safety and success. Individualizing an approach to access requires careful planning, and is contingent upon a solid general knowledge of normal and abnormal vascular anatomy, as well as the particulars of each patient's history, physical examination, and non-invasive test results. An awareness of the technical nuances, relative safety, and indications for obtaining percutaneous arterial access at all potential sites is essential. Available means for approaching lower extremity arterial disease include the retrograde and antegrade common femoral approaches, the contralateral crossover technique, upper extremity approaches from the radial, brachial, or axillary arteries, or occasionally retrograde access via the popliteal, dorsalis pedis, or tibial arteries. These techniques, as well as important considerations for approaching disease of the renal, subclavian, and carotid arteries are reviewed. (Cardiol J 2009; 16: 88–97)

Key words: peripheral vascular diseases, angiography, stents

Introduction

With increasing frequency, cardiologists are becoming trained and qualified to perform peripheral vascular angiography and intervention [1, 2]. While many of the techniques used to obtain arterial access for peripheral procedures parallel those employed for coronary angiography, determining the appropriate access strategy for peripheral vascular studies often requires a much greater degree of planning and foresight than with cardiac catheterization. Poor preparation can result in incomplete visualization of the peripheral arterial anatomy and potentially hinder one's ability to complete a successful endovascular intervention. While the coronary circulation arises from the proximal aorta, and therefore can be approached only in a retrograde manner, peripheral arterial disease is distributed throughout the vascular tree, often leaving multiple potential options to approach a particular target lesion.

Planning how best to image and intervene in a diseased peripheral artery, whether in the lower extremity, aorta, renal, subclavian, carotid or other vascular territory, requires (1) a sound knowledge of the pathophysiology and potential treatment options for the disease process; (2) a complete understanding of normal vascular anatomy and possible variants; (3) performance of a careful history and physical exam; (4) review of non-invasive imaging studies; and (5) facility with a variety of potential vascular access strategies [3]. Often, more than one approach may be available to treat a given disease pattern, and variation in technique may exist even among experienced operators based on their training and individual experiences. The purpose of this review is to discuss the basic principles that should be considered when planning a peripheral endovascular procedure, and to provide a practical framework by which operators can develop sound strategies for vascular access on a case-by-case basis.

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Abdominal aorta and lower extremity disease

Overview

Typically, femoral artery access provides the most practical approach for imaging and performing percutaneous revascularization for disease located in the infra-renal aorta and lower extremity arterial system. In deciding which femoral artery (right or left) to access, or whether a non-femoral approach may be preferable, the operator must obtain and synthesize a wide range of information with the goal of determining the most likely pattern of disease for each individual patient. Careful review of the patient history, physical exam and non-invasive studies are essential.

History

Vital information from the patient's history includes determination of which lower extremity is most symptomatic and the level of symptoms, as pain in the hip, thigh or buttock typically implies iliac disease, and calf claudication is usually associated with disease of the superficial femoral artery [4]. Knowledge of the location of prior arterial bypass grafts and/or stents is also critical. For example, if a femoral-to-femoral artery bypass graft is present, it is important to determine whether the graft was placed because of compromise of the right or left iliac system, since accessing the diseased side will likely hinder the ability to advance catheters to image the aorta and contralateral extremity. Likewise, if an aorto-bifemoral graft is present, the operator must ensure that the graft rather than the occluded native vessel is cannulated to permit access to the aorta and contralateral extremity. The presence of an axillary-bifemoral graft typically mandates use of the radial or brachial artery ipsilateral to the proximal anastomosis of the graft to allow graft engagement and visualization of the lower extremity circulation. In addition, the presence of unilateral or bilateral ostial common iliac artery stents may restrict the operator's ability to advance catheters and /or sheaths across the aortic bifurcation to the contralateral lower extremity.

Physical exam

Examination of pulses throughout the extremities also provides helpful clues as to the probable location of disease. Normal common femoral artery pulses with diminished or absent popliteal and distal extremity pulses implies arterial obstruction of the superficial femoral artery, whereas preserved popliteal pulse intensity coupled with absent dorsalis pedis and/or posterior tibial pulses typically signifies infra-popliteal obstruction. Absent or weakened femoral pulses point to aorto-iliac occlusive disease, and, depending on the degree to which the pulses are diminished, may warrant or mandate that diagnostic angiography be performed using upper extremity access. Palpation of the radial and brachial artery pulses is necessary if upper extremity access is being contemplated, and an Allen's test should be performed to document preservation of palmar arch flow before radial access is undertaken [5, 6]. Use of the radial artery is also typically contraindicated in the presence of an ipsilateral upper extremity arteriovenous dialysis fistula. Apart from a thorough evaluation of extremity pulses, a careful physical exam prior to angiography should also include close inspection of the feet and hands for the presence of skin breakdown or ulcerations.

Non-invasive test findings

The availability of non-invasive imaging tests such as arterial ultrasonography, CT angiography (CTA) and magnetic resonance angiography (MRA) varies from patient-to-patient, but when available these studies can provide helpful information in planning one's approach to invasive angiography. The resting ankle-brachial index (ABI) is a simple and valuable test that is essentially cost-free, is very specific for the presence of peripheral artery disease (PAD) and can be performed quickly at the bedside prior to angiography, if not previously determined [7, 8]. Apart from its utility in estimating the presence and severity of obstructive PAD, a baseline ABI can serve as a gauge to the completeness of revascularization if rechecked soon after the procedure, and as a measure of durability when repeated serially in the months and years after the procedure [9]. CTA and MRA can provide imaging of the aorta and lower extremity vasculature that often rivals that of invasive angiography [10–13], although the availability of these studies remains sporadic because of issues related to expense, accessibility and the potential toxicity of iodinated contrast required for CTA or gadolinium-based contrast agents required for MRA if pre-existing renal insufficiency is present [14].

General approach

For purposes of definition, the term "ipsilateral" is used to indicate that the diseased vessel is on the same side of the body (right or left) as the vascular sheath, and "contralateral" signifies that the vessel of interest is on the opposite side of the

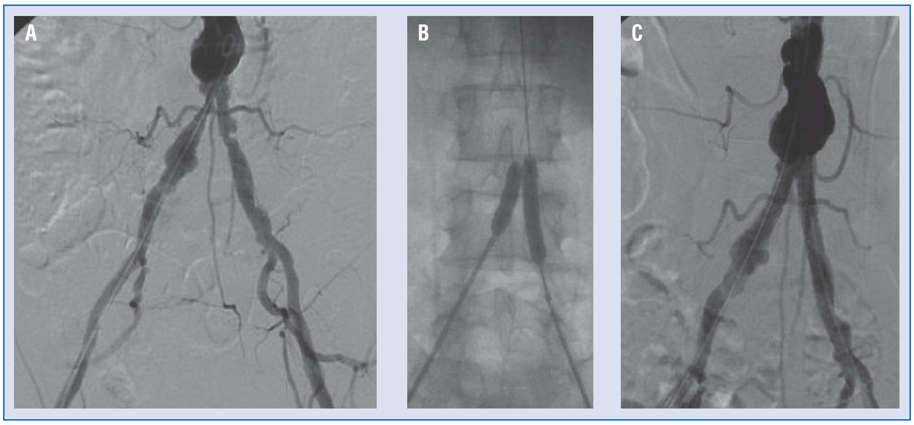

Figure 1. Bilateral common iliac artery stent placement. **A.** Severe ostial and proximal bilateral common iliac artery stenoses. A small distal aortic aneurysm is present; **B.** Simultaneous stent implantation using bilateral retrograde femoral access; **C**. Angiographic result.

body. "Antegrade" denotes that a vascular sheath is oriented in the same direction as blood flow, and "retrograde" indicates that the sheath is pointed in the opposite direction to the flow of blood within the vessel that the sheath is placed.

For diagnostic angiography of the lower extremities, most operators prefer to obtain retrograde common femoral artery access on the less symptomatic extremity. This permits unobstructed visualization of the contralateral limb, which is the most likely target for revascularization. If the culprit lesion is located in the contralateral superficial femoral artery, it is usually approached through the contralateral crossover approach as described below. In addition, the contralateral femoral artery remains available for placement of an additional sheath if contralateral common iliac disease requiring intervention is present. If severe distal arterial disease is discovered in the contralateral extremity, placement of an antegrade-directed femoral sheath in that extremity also remains an option.

One possible exception to the rule of preferentially accessing the less symptomatic extremity occurs if a known severe stenosis in the common iliac artery is present. Accessing the common femoral artery ipsilateral to the stenosis may allow visualization and treatment of the common iliac lesion without the need for additional sheath placement. However, if the iliac disease happens to extend distally to involve the distal external iliac or common femoral artery, a retrograde sheath placed in the common femoral artery may obstruct flow and impair angiographic visualization. Likewise, with distal extension of disease, the sheath may "get in its own way" and hinder the ability to treat the diseased segment. A common preference, if there is any question as to whether an iliac lesion is confined to the common iliac artery, is to perform initial angiography from the contralateral femoral approach, and then place an additional retrograde sheath in the opposite femoral if necessary to perform iliac stenting. If disease involves the ostium of either common iliac artery or extends into the distal aorta, it is usually preferable to have bilateral femoral access to perform bilateral iliac stenting (Fig. 1) [15].

Specific approaches

Retrograde femoral. The retrograde femoral approach is the preferred strategy for angioplasty and stenting of the ipsilateral common iliac and proximal/mid external iliac arteries. This approach provides direct access to the target lesion, and affords excellent guidewire support when trying to cross a chronic iliac occlusion. Despite upstream iliac occlusion, it is typically possible to access this ipsilateral common femoral artery even if no palpable pulse is present, if the vessel can be visualized via collateral flow (Fig. 2). Use of fluoroscopic landmarks and possibly ultrasound or Doppler needle guidance can be helpful in obtaining femoral access in this situation. One shortcoming of the retrograde femoral approach is that it does not permit access to the ipsilateral internal iliac artery. Because the internal iliac artery originates from the common iliac with an inferior orientation, if this vessel is compromised before or after common or external iliac stent placement and needs to be accessed, a contralateral femoral or upper extremity approach is necessary.

Contralateral femoral (crossover). The contralateral crossover approach represents the most commonly employed means of treating disease

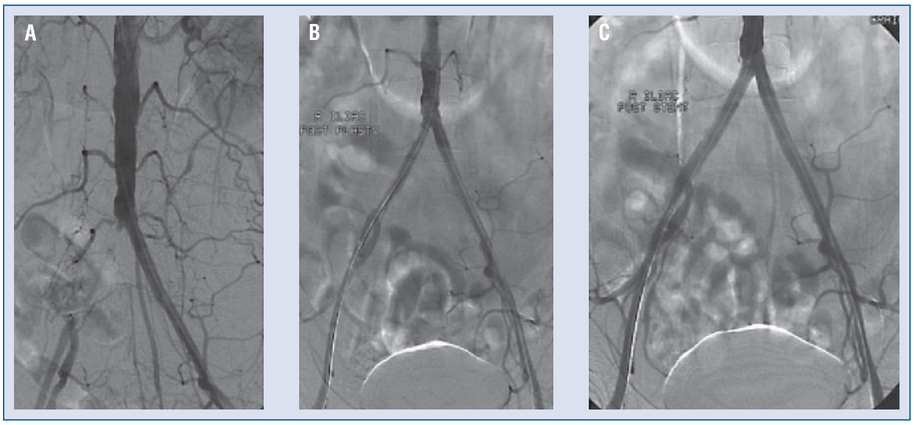

Figure 2. Stenting of a totally occluded right common iliac artery. **A.** Diagnostic angiography from a left retrograde femoral approach demonstrates total occlusion of the right common iliac artery with reconstitution at the external iliac level; **B.** A retrograde right femoral sheath is placed and the occlusion is crossed and dilated; **C.** Result following stent placement.

located in the distal external iliac, femoral and popliteal arteries, and also is often used for below-knee interventions. With this approach, a long sheath or, less commonly, a specially shaped catheter (Balkin, Cook Medical Inc, Bloomington, IN, USA) is placed in the common femoral artery contralateral to the target lesion. The sheath or catheter is then advanced around the aorto-iliac bifurcation and advanced in an antegrade fashion through the contralateral iliac system and positioned with its tip proximal to the target lesion. With the availability of highly conformable sheaths, specialty guidewires and flexible stent and balloon delivery systems, the ability to access the contralateral extremity and perform revascularization using the crossover technique is excellent. Heavy calcification of the distal aorta and iliac arteries, especially if combined with substantial iliac tortuosity and/or extreme angulation of the common iliac arteries as they arise from the aorta, are the primary factors that deter successful sheath advancement around the aorto-iliac bifurcation.

The following example describes the use of the femoral crossover technique to treat a stenosis in the distal left superficial femoral artery (Fig. 3). Following placement of a short 4 F retrograde sheath in the right common femoral artery, a 4 F internal mammary (IM) catheter is advanced to the distal aorta then used to engage the left common iliac artery origin and perform diagnostic angiography. Using the roadmap function of the fluoroscopy unit (which is helpful but not essential), a 0.035” Glidewire (Terumo Medical, Somerset, NJ, USA) is then advanced through the IM catheter and guided into the proximal left superficial femoral artery. If there is aorto-iliac calcification or tortuosity, the IM catheter can be advanced over the wire to the superficial femoral artery, and the Glidewire is exchanged for a stiffer wire such as a TAD (Mallinckrodt, Hazelwood, MO, USA) or Amplatz Superstiff (Boston Scientific, Natick, MA, USA) wire to provide better support for sheath advancement around the aortic bifurcation. The IM catheter and 4 F sheath are then removed, and the long sheath (usually 6 F in diameter and 45 to 70 cm in length) is

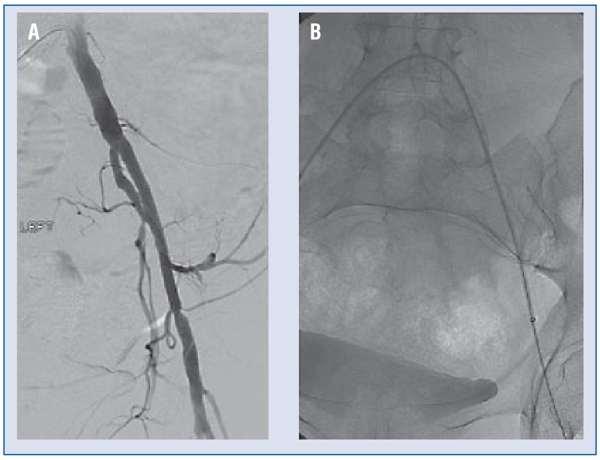

Figure 3. The contralateral femoral (crossover) technique. **A.** To position the sheath to treat a left superficial femoral artery stenosis, retrograde access is obtained via the right common femoral artery and an internal mammary catheter is advanced to engage the left common iliac artery; **B.** After a guidewire is placed, the internal mammary catheter is exchanged for a long sheath that is advanced over the aortic bifurcation.

advanced over the wire from the right femoral access site, around the aortic bifurcation, and positioned in the proximal left superficial femoral artery. Contrast injections through the sidearm of the sheath permit visualization of the target lesion during the subsequent intervention.

Antegrade common femoral. This technique involves placing a sheath in the common femoral artery that is directed distally (toward the ipsilateral foot), and represents an invaluable method for approaching lesions distal to the common femoral artery in instances where aorto-iliac disease, angulation or tortuosity precludes the use of the crossover technique [16]. For example, in the setting of a distal right superficial femoral artery target stenosis with concomitant occlusion of the left common iliac artery that prevents placement of a crossover sheath, an antegrade right common femoral artery puncture would allow the distal lesion to be treated. The antegrade approach can also allow easier guidewire manipulation and better catheter support relative to the crossover technique, which can prove useful especially when approaching a more complex disease in the distal extremity, such as heavily calcific disease or total occlusions of the distal SFA or tibial vessels.

Among its drawbacks, antegrade femoral access is more technically challenging than the traditional retrograde femoral approach, is associated with a substantial learning curve, and even among experienced operators carries a greater likelihood of vascular complications [17]. In addition, antegrade femoral access may not be possible when obesity is present, as a large abdominal pannus can prohibit appropriately oriented needle entry into the common femoral artery. Some authors have reported a method whereby a femoral arterial sheath initially inserted in a traditional retrograde manner can be reoriented to face in the antegrade direction, but most operators have limited or no experience with this technique, and its success and complication rates remain poorly studied [18–20].

Upper extremity. Obtaining access via the upper extremity arterial system can serve as an alternative means to image, and in some circumstances intervene, upon the lower extremity vasculature and can be especially valuable when severe aorto-iliac disease is present and renders the femoral approach problematic. As a consequence of the heightened risks of local vascular complications associated with brachial artery access, the radial artery has become the favoured access site in the upper extremity [21–23]. Obtaining high quality diagnostic images of the lower extremity vessels via the radial artery is usually easily achieved. While long guiding catheters that can extend from the radial to the common iliac arteries in most individuals are available and allow iliac stenting, the physical distance of the radial artery from the lower extremities generally renders infrainguinal interventions impossible with currently available equipment [24].

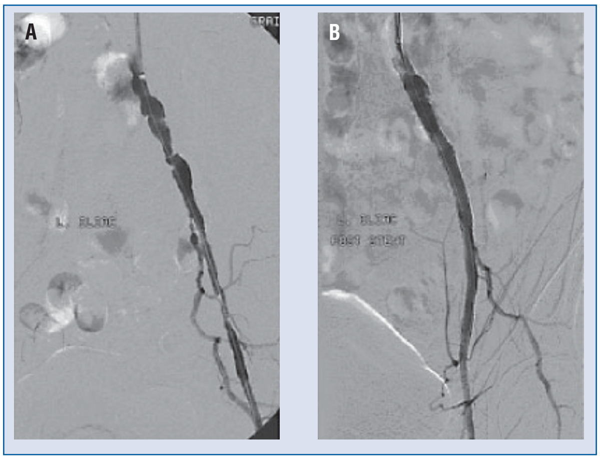

Figure 4. Left iliac stent placement from a left axillary artery approach in the setting of a right iliac occlusion. **A.** Diagnostic angiography performed with a multipurpose catheter shows extensive common and external iliac artery disease; **B.** Result following stent placement

The small diameter of the radial artery, which typically permits safe placement of catheters only up to 6 F in size, poses another potential shortcoming of the transradial approach for aorto-iliac interventions [25]. Nevertheless, use of the radial artery can at times be invaluable to define lower extremity arterial anatomy and help the operator identify an appropriate location for placement of another lower extremity sheath through which intervention can be performed if indicated. The axillary artery provides an alternate access site in the upper extremity. The closer proximity of the axillary artery to the lower extremity vasculature is advantageous, and its larger calibre permits insertion of larger diameter sheaths than the radial artery (Fig. 4). While axillary artery access can be considered in special situations, this vessel is not commonly used because of concerns relating to potential vascular complications and injury of the adjacent brachial plexus.

Other access options. As endovascular techniques become more refined, operators continue to seek novel approaches to treat more complex disease patterns. Accessing the popliteal artery to treat occlusive disease in the ipsilateral superficial

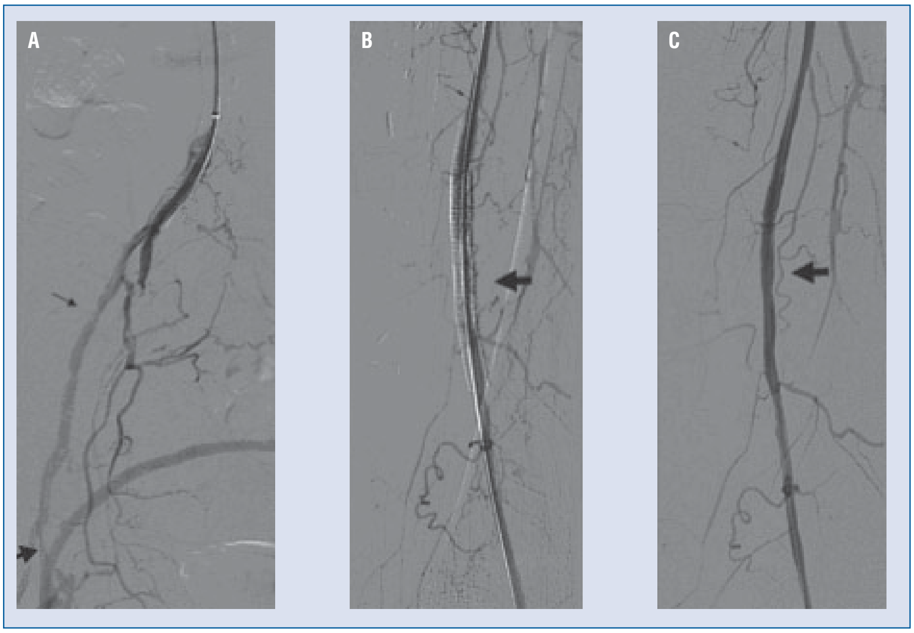

Figure 5. A. Angiogram through multipurpose catheter advanced from the left brachial artery to the right common iliac artery. Lesions in the external iliac (thin arrow) and common femoral (thick arrow) arteries are seen; **B.** In-stent restenosis in the left superficial femoral artery; **C.** Following balloon angioplasty of the in-stent stenosis, performed via direct access of the fem-fem graft.

femoral artery has been described [26, 27]. The retrograde popliteal approach is typically considered for chronic occlusions of the superficial femoral artery that cannot be traversed from above, as the distal "cap" of the occluded arterial segment may be easier to penetrate with a guidewire than the proximal aspect of the occlusion. The use of ultrasound to mark the precise location of the popliteal artery prior to obtaining access is highly recommended and may serve to minimize the occurrence of vascular complications and nerve injury. Obtaining retrograde access via the dorsalis pedis artery to perform revascularization of the distal extremity has also been described, but experience with this interesting method remains anecdotal [28]. Directly accessing a bypass graft, as described in the following case example, also may represent an invaluable option in certain situations.

Case example

Several of the considerations involved in determining an appropriate access plan are exemplified in the following brief case report. A 71-year-old woman presented with ischemic rest pain of the distal left lower extremity and dry gangrene involving the left 5th toe. Her history was remarkable for the placement of a femoral-to-femoral artery bypass graft 11 years earlier in the setting of a left common iliac artery occlusion and previous left superficial femoral artery stent placement. There were diminished common femoral pulses bilaterally. A lower extremity ultrasound suggested the presence of severe disease involving the right external iliac artery, occlusion of the left common iliac artery, stenosis of both the left and right femoral anastomoses of the fem-fem graft, and possible in-stent restenosis involving the left superficial femoral artery.

Given the presence of multiple potential targets for revascularization in this patient, including possible involvement of both common femoral arteries, we chose to obtain initial access via the left brachial artery (an abnormal Allen test did not permit radial access). This approach allowed unobstructed visualization of the lower extremity circulation and avoided femoral artery sheath placement, since the physical presence of a common femoral sheath may have interfered with femoral angioplasty if needed. Following abdominal aortography, a long (125 cm) multipurpose catheter was advanced over a guidewire from the brachial artery to selectively engage the right common iliac artery. This allowed complete visualization of the right lower extremity arterial system as well as the left sided vessels via right-to-left flow of contrast through the fem-fem graft (Fig. 5). Severe stenoses were present in the

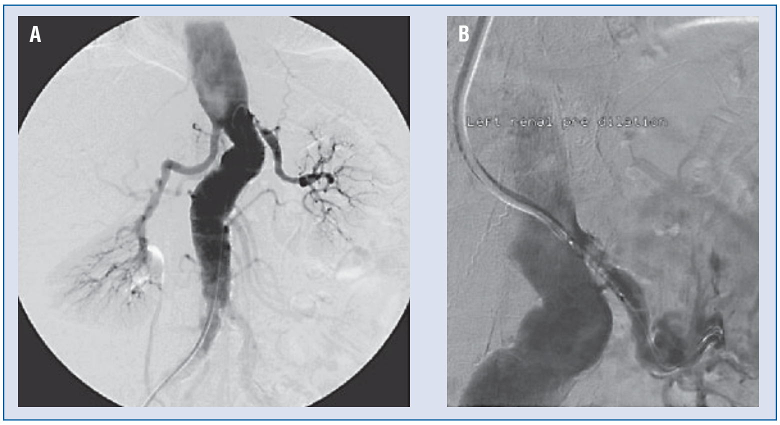

Figure 6. A. Abdominal aortogram demonstrating a left renal artery stenosis with aortic tortuosity and extreme inferiorly directed takeoffs of the renal arteries favouring an upper extremity approach; **B.** The left renal artery has been engaged and wired using a 6 F AL2 guide advanced from the left radial artery.

right external iliac and common femoral arteries. The fem-fem graft was widely patent; however, severe in-stent restenosis was present in the left superficial femoral artery. Through a long 6 F Shuttle sheath advanced from the right brachial artery, the right external iliac stenosis was stented and the right common femoral stenosis was treated with cutting balloon angioplasty. Given its distance from the brachial artery, the left superficial femoral artery stenosis could not be reached using this approach. A left femoral antegrade approach was considered, but would have been difficult as the patient was obese. We opted to access directly the fem-fem graft with a 6 F sheath oriented to face the left lower extremity, and the left SFA stenosis was treated successfully.

Other vascular territories

Renal arteries

Renal artery stent placement is typically performed via retrograde femoral access, although the option of engaging the renal arteries from an upper extremity approach is desirable or even mandatory in some circumstances. Imaging of the abdominal aorta by CTA, MRA or aortography is always helpful in determining how best to approach a renal artery stenosis. These studies allow assessment of the presence and degree of aortic tortuosity, atherosclerosis, calcification and aneurysmal dilation adjacent to the renal artery origins. Aortic imaging also serves to identify the location and orientation of the renal arteries. All of these features can influence the ease of selective renal artery engagement and stent delivery, therefore helping to guide access strategy.

Extreme downward angulation of a renal artery origin relative to the aorta represents the most common situation in which renal artery stenting may best be accomplished from an upper extremity approach (Fig. 6). Even if a renal artery with an acute downwardly oriented takeoff can be selectively engaged from the femoral approach, stent advancement still may not be possible. The presence of severe aorto-iliac tortuosity or occlusive disease may also mandate approaching the renal artery from an upper extremity approach [29].

Most pre-mounted renal artery stents up to 7 mm in diameter can be delivered through a 6 F guide catheter, which can be easily accommodated by most radial arteries. The distance from the radial artery to the renal artery ostia often exceeds the length of standard 100 cm long coronary guide catheters, especially in taller individuals, so specially made 115 or 125 cm guide catheters are frequently necessary. With radial access, usually a multipurpose shaped guide will easily engage a downwardly oriented renal artery, although in some instances alternative guide shapes such as the Amplatz Left (AL) or Hockey Stick (HS) may be required. When utilizing radial or brachial access to approach the renal arteries or lower extremity vasculature, many operators believe that it is preferable to utilize the left rather than the right upper extremity, which avoids the need to advance catheters through the potentially diseased aortic arch, thereby potentially lowering the risk of carotid embolic events.

Subclavian arteries

Subclavian stenosis most frequently involves the ostial and/or proximal segment of the subclavian artery, and statistically involves the left subclavian artery far more frequently than the right [30]. These lesions can usually be approached with high success rates via either the femoral or ipsilateral upper extremity (radial or brachial) arteries, a decision that often depends on operator preference [31]. From the femoral approach, we will typically selectively engage the origin of the subclavian artery with a diagnostic catheter, advance a 0.035” guidewire through the stenosis, and then exchange the diagnostic catheter and femoral sheath for a 90 cm sheath that is positioned at the subclavian ostium. When intervening upon the right subclavian artery ostium or the innominate artery from the femoral approach, use of a guide catheter, such as a JR4, rather than a long sheath may be desirable as the shape of the catheter tip can allow more precise positioning and orientation. The presence of a tortuous aorta favours use of the radial or brachial artery to approach a proximal subclavian stenosis. When attempting to traverse an ostial or very proximal total occlusion of a subclavian artery, an upper extremity approach is also usually preferable as this route provides superior catheter and wire support compared to the femoral approach.

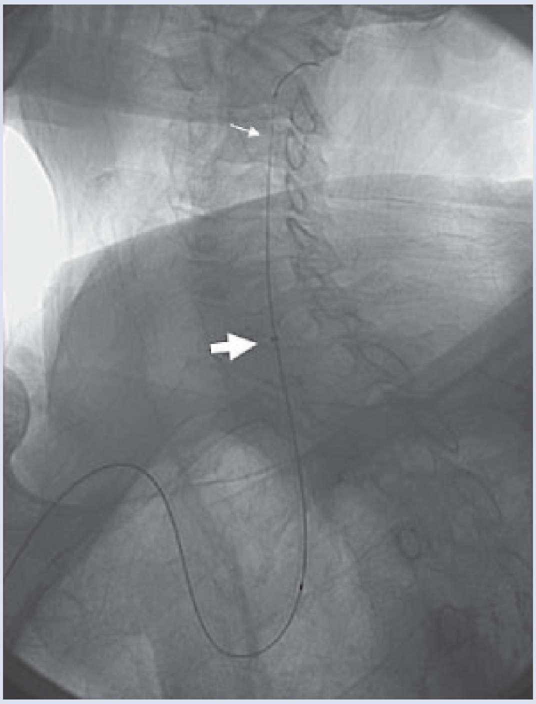

Figure 7. Left carotid artery stenting using right radial artery approach. A TAD wire has been advanced to the left external carotid artery (thin arrow), and a 6 F Shuttle sheath (thick arrow) is positioned in the left common carotid artery.

Carotid artery stenting

The presence of aorto-iliac disease or tortuosity that negates the possibility of advancing a sheath from the femoral to the carotid artery is considered by many to represent a contraindication to carotid stenting. Recently, however, some experience has begun to emerge regarding the performance of carotid angiography and stenting via a radial artery approach (Fig. 7) [32, 33]. Because the relative safety of using a radial approach to perform carotid stenting remains unknown, this technique is best reserved for experienced carotid stent operators in situations where carotid revascularization is deemed essential and alternate options are absent. Other unorthodox and highly technical approaches to access a carotid artery for stent placement in the setting of severe anatomical limitations have also been described, including direct puncture of the common carotid artery proximal to the stenosis, and left ventricular apical puncture with advancement of a stent through the aortic valve and ascending aorta to the involved carotid artery [34, 35].

Final thoughts

While a brief review cannot possibly address all the scenarios that a clinician may encounter when planning to undertake a peripheral vascular intervention, this article has attempted to highlight many of the fundamental principles that should be considered (Table 1). With experience, operators will likely be able to modify and expand upon the observations presented herein. Likewise, as the equipment used to perform endovascular interventions continues to improve, newer methods for approaching complex disease patterns will undoubtedly evolve. It should be remembered that while technical skills related to catheter and guidewire manipulation can play a key role in determining the outcome of a given procedure, the ultimate success or failure of an endovascular intervention may rest just as heavily on the operator’s cognitive ability to plan and execute a safe and rational strategy by which to approach the intervention.

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Table 1. Review of potential access sites for lower extremity endovascular intervention

Approach	Target vessel	Advantages	Disadvantages
Retrograde femoral	Distal aorta Ipsilateral common iliac and proximal-to-mid external iliac	Direct approach	Not feasible if disease extends to ipsilateral distal external iliac or common femoral artery
Femoral crossover	Contralateral internal iliac Contralateral distal common iliac and external iliac Contralateral femoral, popliteal and below-knee vessels	Lower bleeding risk than antegrade femoral approach Permits approach to contralateral common femoral and ostial SFA disease	May not be technically feasible with angulated and/or calcified aorto-iliac bifurcations, or with prior aorto-bifemoral bypass Less catheter and wire trackability and support than antegrade femoral access
Antegrade femoral	Ipsilateral non-ostial SFA, popliteal, and below-knee	Optimal catheter and wire support and manipulation for distal disease, total occlusions	Higher vascular complication rate than femoral crossover approach Not technically feasible for very obese patients Steep learning curve
Retrograde popliteal	All ipsilateral vessels proximal to the distal SFA	Good support Potentially useful if unable to cross an SFA occlusion from above	Vascular complications Nerve injury
Retrograde dorsalis pedis, tibial	Tibial vessels	Potentially useful if unable to cross tibial stenosis from above	Obtaining access often technically challenging Limited experience
Radial	Aorta Proximal iliac vessels	Lowest vascular complication rate of all access sites	Distance from target vessels limits ability to reach infra-iliac lesions Limited to 6 F sheath size Subclavian and aortic tortuosity may limit catheter manipulation
Brachial	Aorta Iliac vessels	Permits larger diameter sheaths than radial artery	Substantially increased vascular complication rate compared to the radial approach
Axillary	Aorta Iliac vessels Proximal-to-mid femoral vessels	Ability to reach more distal lesions than with radial or brachial access	Vascular complications Brachial plexus injury

SFA — superficial femoral artery

References

1. Chan AW. Expanding roles of the cardiovascular specialists in panvascular disease prevention and treatment. Can J Cardiol, 2004; 20: 535–544.
2. Creager MA, Goldstone J, Hirshfeld JW Jr et al. ACC/ACP/SCAI/ /SVMB/SVS clinical competence statement on vascular medicine and catheter-based peripheral vascular interventions: A report of the American College of Cardiology/American Heart Association/American College of Physician Task Force on Clinical Competence (ACC/ACP/SCAI/SVMB/SVS Writing Committee to develop a clinical competence statement on peripheral vascular disease). J Am Coll Cardiol, 2004; 44: 941–957.
3. Hirsch AT, Haskal ZJ, Hertzer NR et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): A collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines. Circulation, 2006; 113: e463–e654.
4. Schmieder FA, Comerota AJ. Intermittent claudication: magnitude of the problem, patient evaluation, and therapeutic strategies. Am J Cardiol, 2001; 87 (12A): 3D–13D.
5. Greenwood MJ, Della-Siega AJ, Fretz EB et al. Vascular communications of the hand in patients being considered for transradial coronary angiography: Is the Allen's test accurate? J Am Coll Cardiol, 2005; 46: 2013–2017.
6. Hildick-Smith DJ, Walsh JT, Lowe MD, Shapiro LM, Petch MC. Transradial coronary angiography in patients with contraindications to the femoral approach: an analysis of 500 cases. Cath Cardiovasc Intervent, 2004; 61: 60–66.

7. Guo X, Li J, Pang W et al. Sensitivity and specificity of ankle-brachial index for detecting angiographic stenosis of peripheral arteries. Circulation, 2008; 72: 605–610.
8. McDermott MM, Liu K, Greenland P et al. Functional decline in peripheral arterial disease: Associations with the ankle brachial index and leg symptoms. JAMA, 2004; 292: 453–461.
9. Schillinger M, Sabeti S, Dick P et al. Sustained benefit at 2 years of primary femoropopliteal stenting compared with balloon angioplasty with optional stenting. Circulation, 2007; 115: 2745–2749.
10. Heijenbrok-Kal MH, Kock MC, Hunink MG. Lower extremity arterial disease: multidetector CT angiography meta-analysis. Radiology, 2007; 245: 433–439.
11. Ouwendijk R, de Vries M, Stijnen T et al. Multicenter randomized controlled trial of the costs and effects of noninvasive diagnostic imaging in patients with peripheral arterial disease: The DIPAD trial. AJR, 2008; 190: 1349–1357.
12. Thurnher S, Miller S, Schneider G et al. Diagnostic performance of gadobenate dimeglumine enhanced MR angiography of the iliofemoral and calf arteries: a large-scale multicenter trial. AJR, 2007; 189: 1223–1237.
13. Vahl AC, Geselschap J, Montauban van Swijndregt AD et al. Contrast enhanced magnetic resonance angiography versus intra-arterial digital subtraction angiography for treatment planning in patients with peripheral arterial disease: A randomised controlled diagnostic trial. Eur J Vasc Endovasc Surg, 2008; 35: 514–521 (discussion 522–513).
14. Perazella MA, Rodby RA. Gadolinium-induced nephrogenic systemic fibrosis in patients with kidney disease. Am J Med, 2007; 120: 561–562.
15. Scheinert D, Schroder M, Balzer JO, Steinkamp H, Biamino G. Stent-supported reconstruction of the aortoiliac bifurcation with the kissing balloon technique. Circulation, 1999; 100 (19 suppl.): II295–II300.
16. 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. Cath Cardiovasc Intervent, 2006; 68: 835–842.
17. Nice C, Timmons G, Bartholemew P, Uberoi R. Retrograde *vs*. antegrade puncture for infra-inguinal angioplasty. Cardiovasc Intervent Radiol, 2003; 26: 370–374.
18. Patel YD. Catheter for conversion of retrograde to antegrade femoral artery catheterization. AJR, 1990; 154: 179–180.
19. Kadir S, Baassiri A, Barth KH. Technique for conversion of a retrograde into an antegrade femoral artery catheterization. AJR, 1981; 136: 430–431.
20. Hartnell G. An improved reversal technique from retrograde to antegrade femoral artery cannulation. Cardiovasc Interven Radiol, 1998; 21: 512–513.
21. Cox N, Resnic FS, Popma JJ, Simon DI, Eisenhauer AC, Rogers C. Comparison of the risk of vascular complications associated with femoral and radial access coronary catheterization procedures in obese versus nonobese patients. Am J Cardiol, 2004; 94: 1174–1177.
22. Kiemeneij F, Laarman GJ, Odekerken D, Slagboom T, van der Wieken R. A randomized comparison of percutaneous transluminal coronary angioplasty by the radial, brachial and femoral approaches: the access study. J Am Coll Cardiol, 1997; 29: 1269––1275.
23. Pristipino C, Pelliccia F, Granatelli A et al. Comparison of access-related bleeding complications in women versus men undergoing percutaneous coronary catheterization using the radial versus femoral artery. Am J Cardiol, 2007; 99: 1216–1221.
24. Flachskampf FA, Wolf T, Daniel WG, Ludwig J. Transradial stenting of the iliac artery: a case report. Cath Cardiovasc Intervent, 2005; 65: 193–195.
25. Archbold RA, Robinson NM, Schilling RJ. Radial artery access for coronary angiography and percutaneous coronary intervention. BMJ, 2004; 329: 443–446.
26. Matsi PJ, Manninen HI, Soder HK, Mustonen P, Kouri J. Percutaneous transluminal angioplasty in femoral artery occlusions: Primary and long-term results in 107 claudicant patients using femoral and popliteal catheterization techniques. Clin Radiol, 1995; 50: 237–244.
27. Yilmaz S, Sindel T, Luleci E. Ultrasound-guided retrograde popliteal artery catheterization: experience in 174 consecutive patients. J Endovasc Ther, 2005; 12: 714–722.
28. Fusaro M, Tashani A, Mollichelli N, Medda M, Inglese L, Biondi-Zoccai GG. Retrograde pedal artery access for below-the-knee percutaneous revascularisation. J Cardiovasc Med, 2007; 8: 216–218.
29. Kessel DO, Robertson I, Taylor EJ, Patel JV. Renal stenting from the radial artery: A novel approach. Cardiovasc Intervenl Radiol, 2003; 26: 146–149.
30. Shadman R, Criqui MH, Bundens WP et al. Subclavian artery stenosis: prevalence, risk factors, and association with cardiovascular diseases. J Am Coll Cardiol, 2004; 44: 618–623.
31. Rigatelli G, Cardaioli P, Giordan M, Panin S, Ferro S, Roncon L. New subclavian artery angioplasty technique for treating subclavian coronary steal syndrome. Ann Thorac Surg, 2007; 84: 688–689.
32. Wu CJ, Hung WC, Chen SM et al. Feasibility and safety of transradial artery approach for selective cerebral angiography. Cath Cardiovasc Intervent, 2005; 66: 21–26.
33. Janjua N, Verma N, Alkawi A, Kirmani JF, Qureshi AI. Carotid stent-supported angioplasty via radiobrachial route. J Neuroimaging, 2006; 16: 212–215.
34. Feldtman RW, Buckley CJ, Bohannon WT. How I do it: Cervical access for carotid artery stenting. Am J Surg, 2006; 192: 779–781.
35. Harjai KJ, Anderson J. Repair of right carotid artery pseudoaneurysm in a patient with hostile aortic arch through left ventricular approach. J Intervent Cardiol, 2008; 21: 239–241.