Alternative access for peripheral vascular interventions

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ABSTRACT

Percutaneous endovascular interventions for advanced lower extremity peripheral arterial disease are becoming increasingly used, often as first-line treatment of chronic limb threatening ischemia. Advancements in endovascular techniques have provided safe and effective alternative revascularization options, especially for high-risk surgical patients. Although the classic transfemoral approach results in high technical success and patency rates, an estimated 20% of lesions remain challenging to access via an antegrade approach. As such, alternative access sites are important in the endovascular armamentarium for the management of chronic limb threatening ischemia. The goal of this review is to discuss alternative access sites, specifically the transradial, transpopliteal, and transpedal approaches, in addition to transbrachial and transaxillary access, and their outcomes in peripheral arterial disease and limb salvage. (J Vasc Surg Cases Innov Tech 2023;9:101232.)

Keywords: Peripheral artery disease; Peripheral vascular intervention; Transpedal access; Transpopliteal access; Transradial access

An increase has occurred in the prevalence of peripheral arterial disease (PAD), correlating with an aging population with chronic disease. More than 230 million people live with PAD worldwide.[1,2] In the United States, 8 to 10 million Americans have a known diagnosis of PAD with an estimated prevalence of 12%.[3] Up to 1 in 10 patients with PAD have the most severe form of the disease, chronic limb threatening ischemia (CLTI). Approximately 5% to 10% of those with asymptomatic PAD or intermittent claudication will progress to CLTI after 5 years.[4] The treatment of CLTI includes medical therapy and timely revascularization.

Although infrainguinal bypass remains the gold standard treatment of CLTI when an adequate conduit is available, advancements in minimally invasive techniques have made endovascular revascularization a safe and effective option for complex and multilevel infrainguinal occlusive disease. This minimally invasive option is especially favorable for patients with high surgical risk, a limited life expectancy, poor autogenous vein conduits, limited occlusive disease, and/or the lack of a suitable bypass target vessel.[5] In many institutions, endovascular revascularization is used as first-line treatment of CLTI, given the reasonable patency and limb salvage rates.[6] In addition, the BEST CLI (best endovascular vs best surgical therapy in patients with CLTI) trial, an international randomized controlled trial evaluating the outcomes between surgical bypass and endovascular therapy for CLTI, found no difference in the incidence of major adverse limb events or death for patients with an inadequate saphenous vein conduit between the surgical bypass group and the endovascular revascularization group.[7] However, in those with an adequate saphenous vein conduit, surgical bypass resulted in a significantly lower incidence of major adverse limb events or death.[7] As such, it is important to consider all revascularization options and their appropriate usage for each patient.

Peripheral vascular interventions (PVIs) for infrainguinal disease are traditionally conducted via the common femoral artery (CFA), either antegrade on the ipsilateral limb or retrograde via the contralateral limb.[8] However, femoral artery access has several limitations, including limited push-ability for infrapopliteal lesions and challenging access in total complete occlusions of the CFA. Previously repaired femoral disease, either from prior surgery or stenting, also poses challenging access. It has been reported that ≤20% of infrainguinal lesions cannot be traversed through the classical antegrade transfemoral approach owing to an inability to traverse the true lumen.[9] Therefore, the use of safe and effective alternative access sites for PVI is crucial in the management of PAD and for limb salvage. The most commonly used alternative access sites are the transradial, transpopliteal, and transpedal approaches. Other options include transbrachial and transaxillary access sites.

TRANSRADIAL ACCESS

Transradial access was first used in coronary angiography, with the earliest reports of this technique in 1989. These studies reported that the advantage of radial

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artery (RA) access over CFA access was not only closer proximity to coronary vessels, but also reduced access site complications.[10] In the RIVAL (radial vs femoral access for coronary intervention) trial, a randomized controlled study assessing transfemoral vs transradial access for coronary intervention, no difference was found in the 30-day composite of death, myocardial infarction, stroke, and non–coronary artery bypass grafting-related major bleeding.[11] The outcomes of that large study suggested that radial access is both safe and effective for coronary intervention. Furthermore, it found that local rates of vascular complications were lower with the radial approach.[11] Thus, the transradial approach has largely replaced the transfemoral approach for coronary interventions. This "radial-first" strategy has been endorsed by the American and European cardiology societies.[12,13] Although the use of transradial access instead of femoral access has been adopted more slowly in the United States, compared with Europe, the trend from 2013 to 2017 revealed an increase in transradial percutaneous interventions from 25.9% to 45.2%.[14]

In PVIs for lower extremity disease, this approach has become increasingly used for patients as an alternative access site when femoral artery (FA) access is not possible because of factors such as prior surgery, body habitus, prior endovascular treatment on the CFA, or severe CFA disease.[15] In addition to its low access site complications, the transradial approach also avoids postoperative immobility. RA access is most often used for aortoiliac disease, followed by femoropopliteal disease, and least often for infrapopliteal disease.[16] The disadvantages of this approach for PVIs, in contrast to its use for coronary interventions, include decreased push-ability and torque-ability for long distance lesions. Other disadvantages include arterial vasospasms and the presence of tortuous subclavian arteries and aortic arches that increase the risk of cerebrovascular accident in the setting of atherosclerotic disease in these vessels, in addition to longer learning curves for interventionalists.[17] This method is also particularly more challenging for taller patients in whom the passage of devices to target long distance vessels becomes more difficult.

Slender sheaths, primarily 5F and 6F sheaths, are used for the transradial approach given the smaller arterial diameter.[15,17] The guidewire lengths are typically 300 cm, and both self-expanding stents and balloon-expandable stents can be used. Hemostasis is achieved by manual compression, bandaging, or the use of a compression device.[10] The left transradial artery approach is reported to provide a direct route to the descending aorta and theoretically reduces the risk of stroke, although other studies have found no differences in the incidence of periprocedural stroke after the transradial approach for cardiac catheterizations.[18-20] Vasodilators are used to help prevent RA spasm. Although standard agents have not been identified, verapamil at a dose of 5 mg, combined with nitroglycerin at both 100 μg (4%) and 200 μg (2%), has been found to be the most effecting combination in reducing RA spasm.[21]

The technical success rates of the transradial approach for PVIs is reported to be 91% overall, 63% for occlusive disease, 98% for stenotic disease, 91% for suprainguinal disease, and 90% for infrainguinal disease.[22] In a meta-analysis that included 19 studies comparing transradial access and transfemoral access for the treatment of lesions from the aortic bifurcation down to the popliteal artery, no difference was found in the technical success rates for either approach.[23] The rate of conversion to the transfemoral approach was 9.9%, with complications reported to be low at 1.9% with the transradial approach.[23] The most common reason for technical failure with the transradial approach was the inability to cross a lesion.[23] The length of stay was also found to be nonsignificant between the two access site groups.[23]

Although RA access has reportedly resulted in fewer access site complications compared with FA access, a major complication with this technique is RA occlusion. This poses a theoretical risk of severe hand symptoms and permanent arterial occlusion.[24] Although RA occlusion is not routinely screened for in the postoperative period, this complication is reported to occur $<$1% of the time,[13] and studies evaluating functional outcomes after the transradial approach reported no patients with symptomatic RA occlusion.[22] The use of an increased intraprocedural dosage of heparin (5000 U) has been suggested as an effective measure for preventing RA occlusion.[21] Other rare complications include hematoma ($<$5%), repeat interventions ($<$1%), and pseudoaneurysms (PSAs; 1%).[16] The rate of these complications is significantly increased with the use of larger diameter sheaths.

TRANSPOPLITEAL RETROGRADE ACCESS

First described by Tønnesen et al[25] in 1988, the retrograde transpopliteal approach has been shown to be an effective alternative access site for popliteal artery and superficial FA (SFA) disease when the CFA remains inaccessible.[25] Initial data on transpopliteal retrograde access showed high rates of complications, such as dissection, arterial rupture, arteriovenous fistula, PSA, bleeding, and hematoma, that made this an unpopular approach. The rate of these complications significantly improved with the use of ultrasound, smaller diameter instruments, and low-profile angioplasty devices. From the popliteal artery, the shorter distance to the targeted lesions allows for improved push-ability and torque-ability. Historical disadvantages to the popliteal approach include prone positioning of the patient, although the retrograde popliteal approach with the patient in the supine position and the knee gently flexed and medially rotated has been found to be a safe and effective method to recanalize the SFA.[26] Other disadvantages might include accessing a flexed leg and vessel compression after sheath removal.

Because the retrograde transpopliteal approach is often used for limb salvage in the presence of difficult lesions, the transpopliteal approach has been observed to be significantly more likely to be used for TASC (Inter-Society Consensus for the Management of Peripheral Arterial Disease) II class D lesions compared with transfemoral access.[27] The technical success rate is reported to range from 82% to 100% from multiple, single-center studies, with significantly lower success and patency rates at 6 months compared with the transfemoral antegrade approach.[27] However, no difference was found in amputation-free survival, survival at 6 months, or major adverse limb events. Also, no differences were found in 30-day mortality, arterial dissection, distal embolization, or access site hematoma.[27]

Although the current studies do not have sufficient power to detect the variables associated with the unsuccessful transpopliteal approach, some factors observed with unsuccessful revascularization include target lesion lengths farther away from the access site, a greater lesion length, and claudication distance in the first 50 meters.[28,29] In a small cohort study, the complications associated with this access site included hematoma from the popliteal artery, reported to occur at a rate of 4.8%.[29] Small studies also reported low rates of PSA, arteriovenous fistula, and arterial dissection.[30,31]

A retrospective study evaluated the technical success and complication rates of transpopliteal vs upper extremity access (UEA) for isolated SFA occlusive disease and found no difference in their success rates.[32] Although they did not explicitly state whether the cases using UEA and transpopliteal access were initial attempts, they did exclude patients who had required multiple access sites. The study also reported that the transpopliteal approach was used to treat more TASC II class D lesions.[32] Technical failure was associated with TASC II class D lesions and severe calcifications. Reportedly, significantly more access site complications occurred in the UEA group than in the transpopliteal group. However, within the UEA group, the brachial artery (BA) access subgroup had a higher rate of complications compared with the transradial approach.[32]

TRANSPEDAL RETROGRADE ACCESS

The transpedal approach can be considered as an alternative access site for challenging infrapopliteal lesions. First reported in 1990 by Iyer et al,[32] this technique was first described as a cutdown on the posterior tibial artery to facilitate endovascular revascularization of occluded tibial arteries for which conventional antegrade techniques had failed.[33] Since then, this approach has been reproduced in multiple small studies.[34,35] The major indication for this approach is treatment of tibial occlusive lesions and is primarily used when standard endovascular techniques fail, although some would use it as a first-line approach.[36,37] A large prospective cohort study evaluating the outcomes after a transpedal retrograde approach for infrainguinal disease demonstrated that technical success did not differ significantly between those with prior failed antegrade attempts and those with a primary tibiopedal attempt.[38]

Advantages of transpedal access include increased push-ability and torque-ability owing to the smaller diameter of the tibial vessels and closer proximity to the lesions. The distal cap of an infrapopliteal lesion is generally softer than its proximal segment. Additionally, because collateral vessels usually arise in a caudal angle, wires traveling cranially are less likely to enter side branches through a retrograde approach.[38] Given the smaller diameter of the pedal arteries, calcium channel blockers and nitroglycerin can also be used to reduce the risk of vasospasm.[37,38]

Retrograde pedal access can be performed using a 4F micropuncture coaxial introducer catheter to obtain sheathless access using a 0.014-in. or 0.018-in. bareback wire to support balloon angioplasty catheters to cross and treat tibial chronic total occlusions. The use of extra support wires that are exchange length is suggested to allow for treatment with retrograde balloons or for snaring the retrograde wire through an antegrade approach.[37] Alternatively, a 4F sheath or 6F Glidesheath Slender (Terumo Interventional Systems) can be used for stenting from the transpedal approach.[39] To avoid vasospasm, verapamil and nitroglycerin in heparinized saline can be used to flush the microcatheter access every 10 to 15 minutes. A proposed mixture includes 2.5 mg of verapamil hydrochloride, 100 μg of nitroglycerin, and 2500 U of heparin in 50 mL of 0.9% normal saline.[38] In a prospective, multicenter observational trial, the anterior tibial artery (25.9%) and posterior tibial artery (35%) were the most commonly accessed, followed by the dorsalis pedis artery (22.3%). Access via the peroneal artery is reportedly attempted $<$10% of the time. Imaging modalities used to guide or confirm access include angiography (33.5%) or ultrasound (36%), or both (29.4%).[37]

Antegrade access can be used to treat lesions requiring stent placement after a retrograde wire is snared and brought through the antegrade guiding catheter.[38] The SAFARI (subintimal arterial flossing with antegrade-retrograde intervention) technique can be used when subintimal angioplasty fails during recanalization attempts of chronic total occlusions to reenter the true lumen.[34,39,40] This technique requires both antegrade and retrograde access, with retrograde subintimal recanalization up to the antegrade subintimal space. The retrograde wire is then snared into an antegrade catheter, creating a “flossing-type” wire access.[40] This facilitates tracking of an angioplasty balloon catheter across a chronic total occlusion.[40]

The technical success of this approach has been reported to be between 69% and 93%.[10,32,33] Technical success is reported as the ability to achieve percutaneous entry into a tibiopedal artery and deliver the guide wire to facilitate introduction of a catheter. In a small cohort study, technical failures resulted from an inability to cross the chronic total occlusions in patients for whom antegrade access had failed.[38] A study with a mean follow-up of 17 months found that the limb salvage rate was 77% for patients who underwent transpedal access after antegrade access had failed.[38]

Compared with transfemoral access, transpedal access has not resulted in differences in technical failure rates, and complications with this approach are rare. It has been observed that the rate of minor access site-related complications, including pain, infection, ecchymosis, bleeding, and acute vessel dissection, is <2%. However, one study reported a significant increase in major adverse cardiac events in patients who underwent retrograde pedal access compared with femoral access but had comparable amputation-free survival at 1 year.[41] However, the patients in this retrospective study who underwent pedal access were older and a greater proportion of patients had tibial peroneal disease and, therefore, likely had more advanced arterial disease.[41]

Debate has ensued regarding the safety of tibiopedal access given the concern for injury or thrombotic occlusion of a pedal vessel in patients with single runoff artery to the foot. Although this could theoretically lead to loss of a distal bypass target or limb loss, this outcome has only rarely been reported.[33,39] Only a single pedal occlusion was described in a patient in whom pedal access was deemed the only viable route for SFA disease, with limb salvage ultimately achieved.[37] Techniques to preserve accessed tibial arteries include accessing the vessels with ultrasound imaging, using lower profile endovascular devices, avoiding multiple attempts that could lead to vasospasm and potential thrombotic occlusion, and frequently flushing the pedal vessels with calcium channel inhibitors and direct vasodilators. Completion angiography can be performed at the end of the procedure to evaluate the accessed tibial arteries and treat any iatrogenic injuries identified.[42]

Although larger prospective studies are needed to assess the safety, efficacy, and long-term outcomes of the transpedal approach, the current literature suggests it is a safe and effective alternative access option with acceptable limb salvage rates for patients in whom antegrade intervention has failed and might be more liberally used as a first-line intervention given its low rate of complications, high technical success rates, and the improved tools for this technique.

OTHER ALTERNATIVE ACCESS SITES: TRANSBRACHIAL AND TRANSAXILLARY ACCESS

Other upper extremity percutaneous access sites include BA access and axillary artery access. Alternative access sites in the upper extremities are particularly useful when targeting bilateral lower extremity lesions. A 10-year, single-center review evaluating BA access to treat peripheral vascular lesions reported a success rate for access of 98.9%.[43] The average sheath size ranged from 4F to 7F. The most commonly performed procedure was balloon angioplasty. Most of the interventions via this approach were for lesions in the SFA or profunda FA, followed by iliofemoral lesions. These extended to the tibial lesions. In only six cases, constituting 2.7% of the interventions, could the target lesion not be reached owing to the catheter length. The complication rate for this access site was 3.8% and included, in order of frequency, hematoma formation (1.9%), PSA (1.5%), and bleeding (0.38%).[43]

Complications from BA access sites have otherwise been reported to be as high as 6% to 11%, with the most common complications being PSA, hematoma, and thrombosis.[44,45] When comparing the safety profiles of BA access to those of the transradial and transfemoral approach, the BA access approach was observed to have significantly more access site complications, defined as those requiring treatment, compared with the transradial and transfemoral approaches. These complications were not different between the transradial and transfemoral approaches.[46] Overall, studies have reported that BA access has high success rates, but also higher complication rates, compared with transradial and transfemoral access. However, given its closer proximity to the FA than to the RA, its use is of value when device length is an issue.

The axillary access site is a less commonly used, but useful, alternative access site. Historically, this site has been avoided, given the theoretical risk to the brachial plexus and difficulty achieving hemostasis in this area.[47] However, this access site has been increasingly used, especially as an alternative access site for transcatheter aortic valve implantation.[48] Similar to other alternative access site indications, the axillary artery is accessed when the anatomy is favorable and when challenging aortoiliac disease or preexisting aortoiliac stents or grafts is present.

The axillary artery is typically accessed with the arm adducted to the site, and the artery is visualized with ultrasound guidance. A single-center, retrospective study evaluation of BA access noted successful access entry for 98.3% of cases. This site was often used to address lesions in the SFA (15%), popliteal artery (12.7%), external iliac artery (11.2%), common iliac artery (11.2%), and CFA (9.7%). Differences in the incidence of minor and major complications between axillary access and CFA access were insignificant statistically; however, the total procedure time and fluoroscopy time were significantly longer statistically in the axillary access group. The benefit of axillary artery access over RA access includes a larger caliber vessel size and shorter distance to the target vessels.[49]

Table. Alternative access sites: technical advantages and disadvantages

Access site	Advantages	Disadvantages
Transradial		
	Local rates of access site complications lower than transfemoral approach; avoids accessing challenging or inaccessible CFA; no postoperative immobility	Decreased push-ability and torque-ability for long distance lesions; can be challenging to reach popliteal or infrapopliteal lesions; arterial vasospasm and RAO; tortuous subclavian arteries and aortic arch, introducing an increased risk of CVA; small caliber sheaths for interventions; challenging for tall patients
Transpopliteal		
	Increased push-ability and torque-ability primarily for SFA or popliteal lesions; avoids accessing challenging or inaccessible CFA; larger diameter lumen compared with transpedal approach	Could require prone patient position; more likely to require knee flexion; difficult vessel compression following sheath removal
Transpedal or tibial		
	Increases push-ability and torque-ability primarily for infrapopliteal, and infrainguinal lesions; distal cap of infrapopliteal lesions generally softer than proximal segment; wire is less likely to enter side branches via retrograde approach; avoids accessing challenging or inaccessible CFA	Arterial spasm; risk of occlusion and/or iatrogenic injury to tibial-peroneal single vessel runoff to extremity; small caliber sheaths for interventions

CFA, Common femoral artery; *CVA*, cerebrovascular accident; *RAO*, radial artery occlusion; *SFA*, superficial femoral artery.

CONCLUSIONS

In patients with CLTI deemed likely to benefit from endovascular revascularization over surgical bypass, expanding the interventionalists' armamentarium of access site options facilitates access to complex lesions. These are notably advantageous for patients with a severely diseased CFA or previously treated FAs resulting in challenging antegrade or retrograde transfemoral access. The three main types of alternative access sites discussed in the present review, including transradial, transpopliteal, and transpedal access, have specific technical advantages and disadvantages compared with the transfemoral approach, summarized in the Table. All have longer learning curves. Depending on user preference and familiarity with these techniques, alternative access sites can be used judiciously as either first-line approaches for infrainguinal disease or additional strategies for limb salvage. Although additional studies are needed to evaluate the long-term patency rates and outcomes for transradial, transpopliteal, and transpedal access, the current literature reports acceptable technical success, amputation-free survival, and low access site complications with these techniques for the management of CLTI.

REFERENCES

1. Virani SS, Alonso A, Benjamin EJ, et al; American Heart Association Council on Epidemiology and Prevention Statistics Committee and stroke Statistics Subcommittee. Heart disease and stroke statistics: 2020 update: a report from the American Heart Association. Circulation 2020;141:e139-596.
2. Song P, Rudan D, Zhu Y, et al. Global, regional, and national prevalence and risk factors for peripheral artery disease in 2015: an updated systematic review and analysis. Lancet Glob Health 2019;7:e1020-30.
3. Criqui MH, Matsushita K, Aboyans V, et al; American Heart association Council on Epidemiology and prevention; Council on Arteriosclerosis, thrombosis and vascular Biology, Council on Cardiovascular Radiology and intervention; Council on Lifestyle and Cardiometabolic Health, Council on peripheral vascular disease; and stroke Council. Lower extremity peripheral artery disease: contemporary epidemiology, management gaps, and future directions: a scientific statement from the American Heart association. Circulation 2021;144:e171-91. Erratum in: Circulation. 2021 Aug 31;144(9):e193.
4. Norgren L, Hiatt WR, Dormandy JA, Nehler MR, Harris KA, Fowkes FGR. Inter-society consensus for the management of peripheral arterial disease (TASC II). J Vasc Surg 2007;45(Suppl S):S5-67.
5. Farber A. Chronic limb-threatening ischemia. N Engl J Med 2018;379:171-80.
6. Gallagher KA, Meltzer AJ, Ravin RA, et al. Endovascular management as first therapy for chronic total occlusion of the lower extremity arteries: comparison of balloon angioplasty, stenting, and directional atherectomy. J Endovasc Ther 2011;18:624-37. Erratum in: J Endovasc Ther. 2011 Dec;18(6):A-5.
7. Farber A, Menard MT, Conte MS, et al. BEST-CLI Investigators. Surgery or endovascular therapy for chronic limb-threatening ischemia. N Engl J Med 2022;387:2305-16.
8. Siracuse JJ, Farber A, Cheng TW, et al; Vascular Quality Initiative. Common femoral artery antegrade and retrograde approaches have similar access site complications. J Vasc Surg 2019;69:1160-6.e2.
9. Montero-Baker M, Schmidt A, Bräunlich S, et al. Retrograde approach for complex popliteal and tibioperoneal occlusions. J Endovasc Ther 2008;15:594-604.
10. Rao SV, Stone GW. Arterial access and arteriotomy site closure devices. Nat Rev Cardiol 2016;13:641-50.
11. Jolly SS, Yusuf S, Cairns J, et al; RIVAL Trial Group. Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (RIVAL): a randomised, parallel group, multicentre trial. Lancet 2011;377:1409-20. Erratum in: Lancet. 2011 Apr 23;377(9775):1408. Erratum in: Lancet. 2011 Jul 2;378(9785):30.
12. Neumann FJ, Sousa-Uva M, Ahlsson A, Alfonso F, Banning A, Benedetto U. "2018 ESC/EACTS guidelines on myocardial revascularization". Eur Heart J 2018;40:87-165.

13. Mason PJ, Shah B, Tamis-Holland JE, Bittl J, Cohen M, Safirstein J. An update on radial artery access and best practices for transradial coronary angiography and intervention in acute coronary syndrome: a scientific statement from the American Heart Association. Circ Cardiovasc Interv 2018;11:e000035.
14. Kopin D, Seth M, Sukul D, Dixon S, Aronow H, Lee D. Primary and secondary vascular access site complications associated with percutaneous coronary intervention: insights from the BMC2 registry. J Am Coll Cardiol Intv 2019;12:2247-56.
15. Sanghvi K, Kurian D, Coppola J. Transradial intervention of iliac and superficial femoral artery disease is feasible. J Interv Cardiol 2008;23:385-7.
16. Levin SR, Carlson SJ, Farber A, et al. Percutaneous radial artery access for peripheral vascular interventions is a safe alternative for upper extremity access. J Vasc Surg 2022;76:174-9.e2.
17. Khatri P, Kasner SE. Ischemic strokes after cardiac catheterization: opportune thrombolysis candidates? Arch Neurol 2006;63:817-21.
18. Pitta S, Barsness G, Lerman A. Transradial iliac artery intervention with dual downstream embolic protection. J Vasc Surg 2011;53:808-10.
19. Grenon S, Reilly L, Ramaiah V. Technical endovascular highlights for crossing the difficult aortic bifurcation. J Vasc Surg 2011;54:893-6.
20. Matějka J, Varvařovský I, Tužil J, Doležal T, Bobak M, Pospíchal J. Accession site does not Influence the risk of stroke after diagnostic coronary angiography or intervention: results from a large prospective registry. Cerebrovasc Dis Extra 2021;11:122-30.
21. Kwok CS, Rashid M, Fraser D, Nolan J, Mamas M. Intra-arterial vasodilators to prevent radial artery spasm: a systematic review and pooled analysis of clinical studies. Cardiovasc Revasc Med 2015;16:484-90.
22. Sciahbasi A, Rigattieri S, Sarandrea A, et al. Radial artery occlusion and hand strength after percutaneous coronary procedures: results of the HANGAR study. Catheter Cardiovasc Interv 2016;87:868-74.
23. Meertens MM, Ng E, Loh SEK, Samuel M, Mees BME, Choong AMTL. Transradial approach for aortoiliac and femoropopliteal interventions: a systematic review and meta-analysis. J Endovasc Ther 2018;25:599-607.
24. Rashid M, Kwok C, Pancholy S. Radial artery occlusion after transradial interventions: a systematic review and meta-analysis. J Am Heart Assoc 2016;5:e002686.
25. Tønnesen KH, Sager P, Karle A, Henriksen L, Jørgensen B. Percutaneous transluminal angioplasty of the superficial femoral artery by retrograde catheterization via the popliteal artery. Cardiovasc Intervent Radiol 1988 Jun;11:127-31.
26. Fanelli F, Lucatelli P, Allegritti M, Corona M, Rossi P, Passariello R. Retrograde popliteal access in the supine patient for recanalization of the superficial femoral artery: initial results. J Endovasc Ther 2011;18:503-9.
27. Komshian S, Cheng TW, Farber A, et al; Vascular Quality Initiative. Retrograde popliteal access to treat femoropopliteal artery occlusive disease. J Vasc Surg 2018;68:161-7.
28. Kuserli Y, Kavala AA. Retrograde popliteal access and balloon Dilatation of chronic total occlusion of superficial femoral arteries. Ann Vasc Surg 2020;64:253-62.
29. Matsumi J, Takada T, Moriyama N, et al. Initial and long-term results of a microcatheter-based retrograde approach for the endovascular treatment of chronic total occlusion in iliac or femoropopliteal arteries. Ann Vasc Surg 2017;41:176-85.
30. Ibrahim G, Nabhani S, Feghaly M. Retrograde popliteal access for challenging superficial femoral artery occlusion. Int J Vasc Med 2021;2021:8833025.
31. Lin SK, Conway AM, Zhou A, et al. Periprocedural outcomes of popliteal vs upper extremity access in the treatment of superficial femoral artery occlusive disease. J Endovasc Ther 2021;28:567-74. Epub 2021 May 10. PMID: 33970044.
32. Iyer SS, Dorros G, Zaitoun R, Lewin RF. Retrograde recanalization of an occluded posterior tibial artery by using a posterior tibial cutdown: two case reports. Cathet Cardiovasc Diagn 1990;20:251-3.
33. Botti CF Jr, Ansel GM, Silver MJ, Barker BJ, South S. Percutaneous retrograde tibial access in limb salvage. J Endovasc Ther 2003;10:614-8.
34. Spinosa DJ, Leung DA, Harthun NL, et al. Simultaneous antegrade and retrograde access for subintimal recanalization of peripheral arterial occlusion. J Vasc Intervent Radiol 2003;14:1449-54.
35. Hanna EB, Prout DL. Combined radial-pedal access strategy and radial-pedal rendezvous in the revascularization of complex total occlusions of the superficial femoral artery (the "no femoral access" strategy). J Endovasc Ther 2016;23:321-9.
36. Mustapha JA, Saab F, McGoff T, et al. Tibio-pedal arterial minimally invasive retrograde revascularization in patients with advanced peripheral vascular disease: the TAMI technique, original case series. Catheter Cardiovasc Interv 2014;83:987-94.
37. Walker CM, Mustapha J, Zeller T, et al. Tibiopedal access for crossing of infrainguinal artery occlusions: a prospective multicenter observational study. J Endovasc Ther 2016;23:839-46.
38. Bazan HA, Le L, Donovan M, Sidhom T, Smith TA, Sternbergh WC 3rd. Retrograde pedal access for patients with critical limb ischemia. J Vasc Surg 2014;60:375-81.
39. Kwan TW, Shah S, Amoroso N, Diwan R, Makker P, Ratcliffe JA, et al. Feasibility and safety of routine transpedal arterial access for treatment of peripheral artery disease. J Invasive Cardiol 2015;27:327-30.
40. Zhuang KD, Tan SG, Tay KH. The "SAFARI" technique using retrograde access via peroneal artery access. Cardiovasc Intervent Radiol 2012;35:927-31.
41. Perry M, Callas PW, Alef MJ, Bertges DJ. Outcomes of peripheral vascular interventions via retrograde pedal access for chronic limb-threatening ischemia in a multicenter registry. J Endovasc Ther 2020;27:205-10.
42. Lai SH, Fenlon J, Roush BB, Munn J, Rummel M, Johnston D. Analysis of the retrograde tibial artery approach in lower extremity revascularization in an office endovascular center. J Vasc Surg 2019;70:157-65.
43. Franz RW, Tanga CF, Herrmann JW. Treatment of peripheral arterial disease via percutaneous brachial artery access. J Vasc Surg 2017;66:461-5.
44. Alvarez-Tostado JA, Moise MA, Bena JF, Pavkov ML, Greenberg RK, Clair DG. The brachial artery: a critical access for endovascular procedures. J Vasc Surg 2009;49:378-85; discussion: 385.
45. Watkinson AF, Hartnell GG. Complications of direct brachial artery puncture for arteriography: a comparison of techniques. Clin Radiol 1991;44:189-91.
46. Maximus S, Kwong M, Harding J, Mell M. Radial arterial access is a safe alternative to brachial artery and femoral artery access for endovascular lower extremity peripheral arterial disease. J Vasc Surg 2023;77:870-6.
47. Cheney AE, McCabe JM. Alternative percutaneous access for large bore devices. Circ Cardiovasc Interv 2019;12:e007707.
48. Dahle TG, Kaneko T, McCabe JM. Outcomes following subclavian and axillary artery access for transcatheter aortic valve replacement: society of the Thoracic Surgeons/American College of Cardiology TVT registry report. JACC Cardiovasc Interv 2019;12:662-9.
49. Mordhorst A, Yan TD, Hoskins N, Gagnon J, Kazemi K. Percutaneous proximal axillary artery versus femoral artery access for endovascular interventions. J Vasc Surg 2022;76:165-73.

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