Radial Access for Lower Extremity Peripheral Arterial Interventions: Do We Have the Tools?

Raghuram Posham, MD¹ Lindsay B. Young, MD¹ Robert A. Lookstein, MD¹ Constantino Pena, MD²
Rahul S. Patel, MD¹ Aaron M. Fischman, MD¹

¹ Icahn School of Medicine at Mount Sinai, New York, New York

² Miami Cardiac and Vascular Institute, Miami, Florida

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Address for correspondence Aaron M. Fischman, MD, Vascular and Interventional Radiology, Mount Sinai Health System, Radiology and Surgery, Icahn School of Medicine at Mount Sinai, 1176 Fifth Avenue, MC Level, New York, NY 10029 (e-mail: aaron.fischman@mountsinai.org).

Abstract

Keywords

- transradial access
- peripheral arterial disease
- interventional radiology
- vascular intervention

The benefits of transradial arterial access (TRA) versus transfemoral arterial access (TFA) have been extensively described in the literature; however, TFA remains the predominant access site choice in the management of peripheral arterial disease (PAD). There are still significant unmet needs for operators wishing to provide the same effective interventions for lower extremity PAD via TRA as with TFA. This article provides an up-to-date review of the literature and devices currently available for operators wishing to treat lower extremity PAD via TRA and the limitations they may face.

Objectives: Upon completion of this article, the reader will be able to discuss the indication for, technique associated with, and potential complications of transradial arterial access for peripheral arterial intervention indications.

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Peripheral arterial disease (PAD) affects more than 41 million people through the United States and Western Europe. Increased exposure to known PAD risk factors, including tobacco, diabetes, hypertension, and hypercholesterolemia, has led to a stark increase in diagnosis and disability from PAD much earlier in life.¹ In the United States, the United

States Preventative Services Task Force (USPSTF) does not recommend routine screening in asymptomatic patients for PAD,² and as such, PAD remains underdiagnosed. Approximately 2% of patients initially presenting with symptomatic PAD have already progressed to critical limb ischemia (CLI), while the majority present with claudication symptoms.³ While medical management and control of modifiable risk factors such as smoking cessation are widely accepted as the first step in slowing down disease progression, the majority of patients with CLI will require endovascular or surgical revascularization to prevent disease progression to limb loss from lack of blood flow.

Given comorbidities that make PAD patients high-risk surgical candidates, there has been a shift toward endovascular intervention as first-line therapy for the invasive management of PAD. Classically, the majority of endovascular interventions throughout the body have been performed through transfemoral arterial access (TFA), including PAD interventions. The femoral artery allows for easy access to target organs and has a large diameter to allow operators to introduce larger size tools for various interventions. For central arterial disease, for example, in the management of abdominal and thoracic aortic aneurysms that require large balloons and stent grafts, TFA remains the gold standard for

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Parag J. Patel, MD, MS, FSIR

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endovascular access and repair. For interventions that do not have such significant size requirements, such as for the treatment of coronary artery disease or visceral organs, alternative access sites including transradial arterial access (TRA) have extensively been studied. The RIFLE study by Romagnoli et al⁴ demonstrated a 60% decrease in access site-related bleeding for TRA compared to TFA (2.6 vs. 6.8%, respectively, $p = 0.002$) and a 17.3% reduction in net adverse clinical events (13.6 vs. 21%, respectively, $p = 0.003$) in more than 1,000 patients undergoing percutaneous coronary intervention (PCI). Overall length of hospital stay was also found to be reduced in TRA patients (5 vs. 6 days, respectively, $p = 0.008$). Similar reductions in overall access site-related complications have been demonstrated in larger prospective studies as well, including the 2012 RIVAL study by Mehta et al⁵ and more recently the 2015 MATRIX study by Valgimigli et al,⁶ which recommended that TRA should be the “default approach in patients with an acute coronary syndrome undergoing invasive management.” Similar reduction in access site complications using TRA has been reported in noncoronary interventions as well.⁷ TRA has also been found to be significantly more cost-effective^{8,9} than TFA and patient preference for TRA has also been documented.^{10,11} Furthermore, TRA has allowed for operators to perform procedures on fully anticoagulated patients, without significant added bleeding risk.^{12,13}

Despite the growing body of literature highlighting the benefits of TRA and the clear shift in operator access site preference to TRA during coronary¹⁴ and more recently visceral interventions,^{7,15,16} TFA remains the predominant access site choice in the management of PAD. This article aims to highlight recent literature evaluating TRA in PAD interventions, currently available tools to treat PAD via TRA, their limitations, and future needs to successfully implement the published benefits of TRA in the management of PAD.

Aortoiliac Disease

Among the most notable advantages of TFA in the management of PAD is the relative proximity and standard anatomy to reach the diseased vessels. Currently, widely available tools allow operators to reach the target lesions quickly via TFA, and provide excellent support and trackability of guidewires to traverse lesions and treat them via various means including angioplasty, atherectomy, or stent placement. The use of some of these tools to treat aortoiliac disease via transradial access has been described in the literature previously and has been shown to be safe and feasible.^{17–23} In the largest two studies published on TRA to treat aortoiliac disease by Ruzsa et al²³ ($n = 156$) and by Cortese et al¹⁹ ($n = 147$), the authors reach and image the target lesions using a standard guidewire and pigtail diagnostic angiographic catheter through a 5- or 6-Fr short introducer sheath (Terumo, Japan). The pigtail and short sheath are removed and swapped for a dedicated sheathless guiding catheter which does not require an introducer sheath (8.5-Fr 100-cm or 6.5-Fr 120-cm Sheathless Eaucath, Asahi, Japan, or 7-Fr 90-cm Destination Introducer, Terumo). The lesions were then

traversed using a stiff guidewire followed by balloon-expandable (Omnilink Elite, Abbott, United States) and self-expandable stents (Absolute, Abbott) with shaft working lengths of 130 to 135 cm.

There is variability in the marketing of various catheter/sheath systems which can be confusing for operators. At present, the 6.5-Fr and 7.5-Fr 100-cm Sheathless Eaucath systems (Asahi, Japan; slightly larger inner diameters vs. 4- and 5-Fr standard sheaths) and very recently the 6-Fr (inner diameter 2.21 mm) Destination Slender Sheath 119 cm and 149 cm systems (Terumo) have been approved for use in the United States. It is worth noting that the Asahi “sheathless” systems are marketed as catheters and thus the sizing refers to the outer diameter, despite being used in practice as sheaths. Thus, in order to accommodate a 5-Fr compatible stent or balloon, a 7.5-Fr SheathLess Eaucath (inner diameter 2.06 mm) would be required.

Specifically regarding aortoiliac disease, operators have had the tools to cross the majority of these diseased segments and treat with angioplasty and bare metal stents that expand to reach the diameters required for these large vessels (~9–11 mm) for many years. Operators have also had access to adjunctive support and crossing catheters on 4 Fr platforms that can easily reach diseased iliac segments. The recently introduced 6 Fr 119 cm Destination Slender sheath (Terumo) will allow operators to park just proximal to the diseased segments and provide additional support to successfully cross difficult iliac CTOs. Of note, for infradiaphragmatic interventions that require bilateral iliac artery access, such as during prostate artery embolization, procedural and fluoroscopy time was shown to be lesser via TRA than via TFA largely due to the ability to easily select either iliac artery from above the aortic bifurcation.¹⁶ This suggests a similar saving in time and radiation dose given that TRA allows operators to treat diseased segments of both extremities with a single access site.

Unfortunately, there are no covered stent options available on a 6-Fr platform that reaches the required diameter to stent vessels in this region successfully via TRA. In the event of iliac vessel dissection or rupture during TRA, operators are extremely limited in their bail-out options and would be required to convert to TFA. In addition, there are no covered stent options on a 6-Fr platform that could reach the minimum 9-mm outer diameter to treat iliac disease. The ability to deploy covered iliac stents via TRA is an unmet need, as data suggest that covered stents offer longer primary stent patency versus bare metal stents in more complex aortoiliac lesions.²⁴

Infrainguinal Disease

In contrast to aortoiliac disease treatment via TRA, operators aiming to treat infrainguinal disease via TRA have had limited access to adequate length tools to successfully treat complex lesions in this area. Combined radial and pedal access ($n = 37$ total) has been published recently as an advanced technique to overcome these limitations^{25,26} and have been effective in treating infrainguinal complex lesions including TASC D lesions. Despite favorable outcomes in

patients undergoing pedal access for PAD treatment,^{26–30} there is notable risk to cannulating the pedal vessels in this patient population, as they tend to have significant atherosclerotic burden and poor collateral circulation. Brachial access has also been used to reduce device length requirements; however, it is not frequently used because of risk of vessel and nerve complications.³¹

The role of TRA in the treatment of infrainguinal disease has largely been limited to treatment of focal lesions and in-stent restenosis.^{32–34} In the largest study to date published on TRA to treat infrainguinal disease by Lorenzoni et al³⁴ ($n = 93$), the authors were able to cross TASC A-C SFA lesions with 90% technical success with TRA preferentially using a 8.5-Fr 120-cm Sheathless PV (Asahi, Japan; not available in the United States) or a 6-Fr 125-cm guiding catheter (Cordis, United States), and treat with balloon angioplasty using a 180-cm-long shaft Pacific balloon (Medtronic, United States) and a 180-cm-long shaft 5-Fr Sinus-SuperFlex-518 (OptiMed, Germany) self-expanding stent if needed. Unfortunately, this self-expanding stent is not available in the United States. The widely available hydrophilic 6-Fr 125-cm guiding catheter (Cordis) fails to provide operators with adequate support to cross TASC D SFA lesions via TRA, and this patient population was excluded from the study by Lorenzoni et al.³⁴ Until recently, the longest support system available to operators in the United States was the 110-cm reinforced Shuttle sheath (Cook, United States); however, this fails to provide adequate support for SFA disease in the majority of the population. With the introduction of the recently released 6 Fr 119 and 149 cm Destination Slender sheath (Terumo), operators should be able to place the sheath much closer to the diseased segments and have the support to successfully cross more complex lesions. Additionally, although operators have had access to the 180-cm-long shaft Pacific over-the-wire (OTW) balloon (Medtronic), it requires a minimum of 360 cm 0.018-in wire to facilitate safe exchange, and can be cumbersome to handle. The recently released Metacross 200-cm shaft rapid exchange balloon (Terumo) should allow operators to use readily available 260 and 300-cm guidewires versus longer 350- to 450-cm guidewires that would be required for OTW balloons. There is also a 200-cm-long shaft Ultraverse RX rapid exchange 0.014-in angioplasty balloon (Bard, United States) that was recently made available for use. With adequate sheath support, it is feasible for operators to angioplasty vessels up to the ankle in select patients, if required (► **Fig. 1**). Additionally, the Diamondback Atherectomy system (Cardiovascular Systems, United States) was recently made available with a 200-cm working length on a 5-Fr platform, allowing operators to perform infrapopliteal atherectomy. Following angioplasty and/or atherectomy, operators unfortunately do not have access to long-shaft stents of any kind in the United States to treat via TRA. At present, the longest stent available in the United States is the 150-cm-long shaft Everflex self-expanding stent (Medtronic), which allows operators the ability to treat SFA lesions resistant to angioplasty in a select patient population (► **Fig. 2**).

Although the 200-cm-long shaft 5-Fr Misago self-expanding stent (Terumo) has been approved for use in the United States, it is not readily available for use. The recently

approved 4 Fr Pulsar-18 self-expandable stent (Biotronik, United States) would theoretically be an excellent choice for operators choosing to treat SFA disease via TRA given its slim profile and size compatibility with available TRA sheaths; however, it is available only on a 135-cm-long shaft and thus incompatible for TRA infrainguinal treatment. Drug-eluting stents such as the Zilver PTX (Cook) have also proven to be excellent choices for infrainguinal disease treatment with greater primary patency versus bare metal stents^{35,36} and are approved in the United States for SFA disease; however, these stents are also excluded from use via TRA given a 125-cm-long shaft. Lastly, while the Viabahn Covered Endoprosthesis (Gore, United States) is available on a 6-Fr platform and can reach up to 6 mm in diameter to treat SFA disease in a select patient population, it is excluded from use via TRA given a 120-cm-long shaft. At present, there are no covered stent options for treatment or bail out during TRA infrainguinal intervention.

Additional adjunctive devices such as drug-coated balloons (DCBs) or reentry catheter devices are unavailable for operators to use for infrainguinal disease treatment via TRA. DCBs have been shown to be superior to PTA in preventing femoropopliteal restenosis³⁷ and are used frequently in cases where the vessel lumen is restored following atherectomy or with cutting balloons. While the 5-Fr compatible Lutonix DCB (Bard) is frequently used for infrainguinal disease treatment as adjunctive therapy via TFA, it is excluded from use via TRA given a 130-cm working length. The inability to provide synergistic debulking atherectomy and DCB angioplasty via TRA to treat infrainguinal disease is a significant unmet need for operators wishing to treat via TRA.

While operators have access to long-shaft PTA balloons via TRA, there are currently no comparable DCB options available for infrainguinal disease treatment via TRA. The most frequently used Lutonix DCB (Bard) is available on a 5-Fr system; however, it is excluded from use via TRA given a 130-mm shaft.

The ability to reach and treat the infrapopliteal arteries in PAD represents the final frontier for operators wishing to treat via TRA. There have been no studies to date describing exclusive TRA approach for treating lesions in this region. Devices with approximately 150 to 180 cm working lengths are required to treat infrapopliteal PAD.³⁸ A recent meta-analysis by Almasri et al³⁹ examining revascularization outcomes of infrainguinal CLI (44 studies, 8,602 total patients) showed that drug-eluting stents have improved patency over bare metal stents in infrapopliteal arteries (73 vs. 50%) and comparable to balloon angioplasty (66% primary patency) at 1 year. There are no stents or drug-coated balloons that reach this distance.

Conclusion

The benefits of TRA have been extensively described in the literature. Among the greatest benefits include significantly reduced access site and major complications,^{4,5,7,11} ability to treat fully anticoagulated patients with low bleeding risk,¹² faster mobilization,^{10,40} and cost-effectiveness.⁹ TRA also allows operators opportunity for bilateral lower extremity

Fig. 1 A 45-year-old male, 5'9" height, with hypertension, hyperlipidemia, type 1 diabetes mellitus, and severe peripheral arterial disease, requiring right fourth and fifth metatarsal amputation for osteomyelitis, noted to have poor wound healing. RLE arterial duplex notable for 50 to 99% stenosis of tibioperoneal (TP) trunk and anterior tibial artery. Left radial artery access is obtained and a 0.035" wire and 4-Fr glide catheter are used to navigate to the proximal SFA. The catheter is exchanged for a 6-Fr 119-cm Destination Slender sheath (Terumo; not shown) which is parked in the proximal SFA. A 400-cm Viper wire is advanced through the TP trunk into the posterior tibial (PT) artery and the (a) Diamondback orbital atherectomy device (Cardiovascular systems) is positioned over the wire just proximal to the TP stenosis. (b) Atherectomy is performed of the TP trunk lesion followed by (c) balloon angioplasty using a 4-mm 180-cm-long shaft Ultraverse Rx (Bard) balloon. (d) Postangioplasty runoff shows severe focal stenosis of the lateral plantar artery. The Viper wire is advanced distal to the stenosis and 3 mm 180-cm-long shaft Ultraverse Rx (Bard) balloon is used to angioplasty the stenosed segment. (f) Postangioplasty angiogram shows markedly improved flow through the lateral plantar artery. Patient evaluated in clinic 1 month after procedure and noted to have completely healed right foot wounds.

treatment during the same procedure, and alternative access for treatment in cases where TFA may not be suitable such as in patients with severely calcified femoral arteries, tortuous iliac arteries preventing retrograde access, or having pros-

thetic endografts. Until recently, the biggest limitations to lower extremity intervention via TRA included sheath size and device length limitations, and as such, transfemoral access has remained widely adopted for lower extremity

Fig. 2 A 63-year-old male, 5'10" height, with treated hepatitis C, HIV, prior deep vein thrombosis/pulmonary embolism on therapeutic anticoagulation, prior EVAR for symptomatic aortic thrombus, now presenting with progressive RLE claudication symptoms developing while walking greater than 1/2 block. (a) CT angio MIP showing diffuse right SFA atherosclerotic disease with an approximately 11 cm segment of severe stenosis from mid to distal SFA. Left radial artery access is obtained and a 0.035" wire and 125 cm 5 Fr guide catheter (Cordis) are used to navigate to the proximal SFA. The guide catheter was left in place as it was felt that the patient's radial artery was not adequately sized for a support sheath. The 0.035" wire is exchanged for a 480-cm 0.018" guidewire (Boston Scientific) which is advanced distal to the lesion into the popliteal artery. (b) Digital subtraction angiogram confirms CT Angio findings of the mid-distal SFA stenotic segment. (c) Angioplasty of the stenosed segment is performed using a 4-mm 180-cm-long shaft Ultraverse Rx (Bard) balloon and a (d) postangioplasty angiogram shows significant residual stenosis. (e) A 6 mm × 15 cm Everflex self-expanding stent (Medtronic) is deployed across the stenotic segment and postdilated with a 4-mm balloon. (f) Completion angiogram shows markedly improved flow through the SFA. Patient evaluated in clinic 1 month after procedure and noted to have significantly decreased claudication symptoms.

Table 1 Devices considered in transradial infrainguinal arterial interventions

Device types	Name/Characteristics length limitations/Comments
Sheaths and guiding catheters	5 Fr shuttle sheath (Cook) 110 cm 6 Fr guiding catheter (Boston Scientific) 110 cm, 125 cm 5 Fr, 6 Fr guiding catheter (Cordis) 125 cm 4 Fr Glidecath (Terumo) 150 cm 6 Fr R2P Destination Slender sheath (Terumo) 119 cm, 149 cm 7 Fr (6 Fr ID) R2P Slenguide catheter (Terumo) 120 cm, 150 cm hydrophilic tip only 6.5–7.5 Fr (4–5 Fr ID) Sheathless Eaucath (Asahi) 100 cm 8.5 Fr (6 Fr ID) Sheathless Eaucath (Asahi) 120 cm NA
Guidewires	Nitrix 0.035" (Medtronic) 400 cm Viper 0.014" (Cardiovascular Systems) 335–475 cm Glidewire 0.035" (Terumo) 350–450 cm Novagold 0.018" (Boston Scientific) 480 cm off-label for vascular intervention
Support catheters	Various 135 cm, 150 cm 4–6 Fr
PTA balloons	Advance 14LP (Cook) 170 cm 4 Fr Pacific Plus 7 mm max OD (Medtronic) 180 cm 4 Fr Ultraverse Rx 0.014" 5 mm max OD (Bard) 200 cm 4 Fr, 5 Fr, REx Metacross 8 mm max OD (Terumo) 200 cm 6 Fr, REx
Drug-coated balloons and stents	NA
Reentry devices	NA
Self-expanding stents	Everflex Entrust 7 mm max OD (Medtronic) 150 cm 5 Fr; longest shaft available in the United States Sinus SuperFlex 518 10 mm max OD (OptiMed) 180 cm 5 Fr; NA Misago 8 mm max OD (Terumo) 200 cm 6 Fr; FDA approved but NA, REx
Atherectomy	Diamondback (Cardiovascular Systems) 200 cm 5 Fr

Abbreviations: Fr, French; ID, inner diameter; NA, not available in the United States (as of September 2018); OD, outer diameter; REx, rapid exchange. Source: Table updated from Hanna and Prout²⁸ and Endovascular Today Device Guide.⁴⁷

endovascular intervention. Brachial⁴¹ and pedal artery access^{26–30} have also been explored; however, they also carry their own set of major risks and complications.

Newly developed tools have helped facilitate TRA as a viable access site for lower extremity PAD interventions (►Table 1). Recently developed hydrophilic and reinforced sheaths as described in this article have allowed operators to introduce devices up to 6 Fr and even 7 Fr in some instances via the radial artery to treat these lesions. These larger sheath sizes pose their own risk of complications, as the radial artery is more prone to spasm and radial artery occlusion (RAO) with larger sheaths.^{42,43} There has also been evidence suggesting that radial artery catheterization can lead to late-term narrowing of the lumen and impaired vasodilatory response,⁴⁴ although the clinical implications of these changes are unclear. There is also a risk of stroke secondary to arch manipulation and crossing the great vessels during TRA. While left TRA theoretically has less chance of embolic stroke versus right TRA (i.e., crossing only one great vessel vs. three great vessels), there are no statistically significant differences in the literature.^{45,46} Of note, operators in many of the studies discussed earlier in this article used right-side TRA depending on operator preference and also as it allows increased distal reach via TRA versus the left side.^{19,23,26,34}

There are still significant unmet needs for operators wishing to provide the same effective interventions for lower extremity PAD via TRA as with TFA; however, we are one step closer to bridging the gap with the latest tools that are

discussed in this article. There is also ample opportunity for industry to recognize and develop tools to meet these needs and shift access site choice for lower extremity interventions in the same way they have for cardiac interventions.

References

- 1 Sampson UK, Fowkes FG, McDermott MM, et al. Global and regional burden of death and disability from peripheral artery disease: 21 world regions, 1990 to 2010. *Glob Heart* 2014;9(01): 145–158.e21
- 2 Curry SJ, Krist AH, Owens DK, et al; US Preventive Services Task Force. Screening for peripheral artery disease and cardiovascular disease risk assessment with the ankle-brachial index: US preventive services task force recommendation statement. *JAMA* 2018;320(02):177–183
- 3 Gerhard-Herman MD, Gornik HL, Barrett C, et al. 2016 AHA/ACC Guideline on the management of patients with lower extremity peripheral artery disease: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation* 2017;135(12): e686–e725
- 4 Romagnoli E, Biondi-Zoccai G, Sciahbasi A, et al. Radial versus femoral randomized investigation in ST-segment elevation acute coronary syndrome: the RIFLE-STEACS (Radial Versus Femoral Randomized Investigation in ST-Elevation Acute Coronary Syndrome) study. *J Am Coll Cardiol* 2012;60(24):2481–2489
- 5 Mehta SR, Jolly SS, Cairns J, et al; RIVAL Investigators. Effects of radial versus femoral artery access in patients with acute coronary syndromes with or without ST-segment elevation. *J Am Coll Cardiol* 2012;60(24):2490–2499

- 6 Valgimigli M, Gagnor A, Calabró P, et al; MATRIX Investigators. Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a randomised multicentre trial. *Lancet* 2015;385(9986):2465–2476
- 7 Posham R, Biederman DM, Patel RS, et al. Transradial approach for noncoronary interventions: a single-center review of safety and feasibility in the first 1,500 cases. *J Vasc Interv Radiol* 2016;27(02):159–166
- 8 Le Corvoisier P, Gellen B, Lesault PF, et al. Ambulatory transradial percutaneous coronary intervention: a safe, effective, and cost-saving strategy. *Catheter Cardiovasc Interv* 2013;81(01):15–23
- 9 Amin AP, House JA, Safley DM, et al. Costs of transradial percutaneous coronary intervention. *JACC Cardiovasc Interv* 2013;6(08):827–834
- 10 Kok MM, Weernink MGM, von Birgelen C, Fens A, van der Heijden LC, van Til JA. Patient preference for radial versus femoral vascular access for elective coronary procedures: the PREVAS study. *Catheter Cardiovasc Interv* 2018;91(01):17–24
- 11 Cooper CJ, El-Shiekh RA, Cohen DJ, et al. Effect of transradial access on quality of life and cost of cardiac catheterization: a randomized comparison. *Am Heart J* 1999;138(3, Pt 1):430–436
- 12 Titano JJ, Biederman DM, Zech J, et al. Safety and outcomes of transradial access in patients with international normalized ratio 1.5 or above. *J Vasc Interv Radiol* 2018;29(03):383–388
- 13 Baker NC, O'Connell EW, Htun WW, et al. Safety of coronary angiography and percutaneous coronary intervention via the radial versus femoral route in patients on uninterrupted oral anticoagulation with warfarin. *Am Heart J* 2014;168(04):537–544
- 14 Ratib K, Mamas MA, Anderson SG, et al; British Cardiovascular Intervention Society and the National Institute for Cardiovascular Outcomes Research. Access site practice and procedural outcomes in relation to clinical presentation in 439,947 patients undergoing percutaneous coronary intervention in the United Kingdom. *JACC Cardiovasc Interv* 2015;8(1, Pt A):20–29
- 15 Resnick NJ, Kim E, Patel RS, Lookstein RA, Nowakowski FS, Fischman AM. Uterine artery embolization using a transradial approach: initial experience and technique. *J Vasc Interv Radiol* 2014;25(03):443–447
- 16 Bhatia S, Harward SH, Sinha VK, Narayanan G. Prostate artery embolization via transradial or transfemoral versus transfemoral arterial access: technical results. *J Vasc Interv Radiol* 2017;28(06):898–905
- 17 Staniloae CS, Korabathina R, Yu J, Kurian D, Coppola J. Safety and efficacy of transradial aortoiliac interventions. *Catheter Cardiovasc Interv* 2010;75(05):659–662
- 18 Sanghvi K, Kurian D, Coppola J. Transradial intervention of iliac and superficial femoral artery disease is feasible. *J Interv Cardiol* 2008;21(05):385–387
- 19 Cortese B, Peretti E, Troisi N, Siquilberti E, Setti M, Pitì A. Transradial percutaneous iliac intervention, a feasible alternative to the transfemoral route. *Cardiovasc Revasc Med* 2012;13(06):331–334
- 20 Roy AK, Garot P, Louvard Y, et al. Comparison of transradial vs transfemoral access for aortoiliac and femoropopliteal interventions: a single-center experience. *J Endovasc Ther* 2016;23(06):880–888
- 21 Lorenzoni R, Mazzoni A, Lazzari M, Boni A, Gemignani C, Bovenzi F. Radial artery access for above the knee angioplasty: a feasibility study. *EuroIntervention* 2011;7(08):924–929
- 22 Shinozaki N, Minowa T, Murakami T, et al. Slender transradial iliac artery stenting using a 4.5 French guiding sheath. *Cardiovasc Interv Ther* 2018
- 23 Ruzsa Z, Tóth K, Nemes B, et al. Transradial and transfemoral access for iliac artery interventions using sheathless guiding systems: a feasibility study. *Catheter Cardiovasc Interv* 2016;88(06):923–931
- 24 Mwipatayi BP, Sharma S, Daneshmand A, et al; COBEST Co-Investigators. Durability of the balloon-expandable covered versus bare-metal stents in the Covered versus Balloon Expandable Stent Trial (COBEST) for the treatment of aortoiliac occlusive disease. *J Vasc Surg* 2016;64(01):83–94.e1
- 25 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(02):321–329
- 26 Ruzsa Z, Bellavics R, Nemes B, et al. Combined transradial and transpedal approach for femoral artery interventions. *JACC Cardiovasc Interv* 2018;11(11):1062–1071
- 27 Armstrong EJ, Valle JA. Hand, foot, and word of mouth: combined transradial and transpedal access for femoral artery interventions. *JACC Cardiovasc Interv* 2018;11(11):1072–1073
- 28 Hanna EB, Prout DL. Superficial femoral artery recanalization via transradial access or a combined radial-pedal access strategy. *JACC Cardiovasc Interv* 2018;11(17):1786–1787
- 29 Kwan TW, Shah S, Amoroso N, et al. Feasibility and safety of routine transpedal arterial access for treatment of peripheral artery disease. *J Invasive Cardiol* 2015;27(07):327–330
- 30 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(06):987–994
- 31 Calsina Juscafresa L, Lloret Pont C, Clará Velasco A. CUSUM analysis of brachial artery access for peripheral endovascular interventions. *Int Angiol* 2014;33(05):441–445
- 32 Trani C, Tommasino A, Burzotta F. Pushing the limits forward: transradial superficial femoral artery stenting. *Catheter Cardiovasc Interv* 2010;76(07):1065–1071
- 33 Trani C, Burzotta F, Tommasino A, Giammarinaro M. Transradial approach to treat superficial femoral artery in-stent restenosis. *Catheter Cardiovasc Interv* 2009;74(03):494–498
- 34 Lorenzoni R, Lisi C, Corciu A, Lazzari M, Bovenzi F. Tailored use of transradial access for above-the-knee angioplasty. *J Endovasc Ther* 2014;21(05):635–640
- 35 Dake MD, Ansel GM, Jaff MR, et al; Zilver PTX Investigators. Sustained safety and effectiveness of paclitaxel-eluting stents for femoropopliteal lesions: 2-year follow-up from the Zilver PTX randomized and single-arm clinical studies. *J Am Coll Cardiol* 2013;61(24):2417–2427
- 36 Duda SH, Bosiers M, Lammer J, et al. Sirolimus-eluting versus bare nitinol stent for obstructive superficial femoral artery disease: the SIROCCO II trial. *J Vasc Interv Radiol* 2005;16(03):331–338
- 37 Scheinert D, Duda S, Zeller T, et al. The LEVANTI (Lutonix paclitaxel-coated balloon for the prevention of femoropopliteal restenosis) trial for femoropopliteal revascularization: first-in-human randomized trial of low-dose drug-coated balloon versus uncoated balloon angioplasty. *JACC Cardiovasc Interv* 2014;7(01):10–19
- 38 Staniloae CS, Korabathina R, Coppola JT. Transradial access for peripheral vascular interventions. *Catheter Cardiovasc Interv* 2013;81(07):1194–1203
- 39 Almasri J, Adusumalli J, Asi N, et al. A systematic review and meta-analysis of revascularization outcomes of infrainguinal chronic limb-threatening ischemia. *J Vasc Surg* 2018;68(02):624–633
- 40 Fischman AM, Swinburne NC, Patel RS. A technical guide describing the use of transradial access technique for endovascular interventions. *Tech Vasc Interv Radiol* 2015;18(02):58–65
- 41 Treitl KM, König C, Reiser MF, Treitl M. Complications of transbrachial arterial access for peripheral endovascular interventions. *J Endovasc Ther* 2015;22(01):63–70
- 42 Aminian A, Iglesias JF, Van Mieghem C, et al. First prospective multicenter experience with the 7 French Glidesheath slender for complex transradial coronary interventions. *Catheter Cardiovasc Interv* 2017;89(06):1014–1020
- 43 Aminian A, Saito S, Takahashi A, et al. Comparison of a new slender 6 Fr sheath with a standard 5 Fr sheath for transradial coronary

- angiography and intervention: RAP and BEAT (Radial Artery Patency and Bleeding, Efficacy, Adverse eventT), a randomised multicentre trial. *EuroIntervention* 2017;13(05):e549–e556
- 44 Buturak A, Tekturk BM, Degirmencioglu A, et al. Transradial catheterization may decrease the radial artery luminal diameter and impair the vasodilatation response in the access site at late term: an observational study. *Heart Vessels* 2016;31(04):482–489
 - 45 Shah RM, Patel D, Abbate A, Cowley MJ, Jovin IS. Comparison of transradial coronary procedures via right radial versus left radial artery approach: a meta-analysis. *Catheter Cardiovasc Interv* 2016;88(07):1027–1033
 - 46 Elmahdy MF, ElMaghawry M, Hassan M, Kassem HH, Said K, Elfaramawy AA. Comparison of safety and effectiveness between right versus left radial arterial access in primary percutaneous coronary intervention for acute ST segment elevation myocardial infarction. *Heart Lung Circ* 2017;26(01):35–40
 - 47 Endovascular Today Device Guide: US Edition. 2018. Available at: <https://evtoday.com/device-guide/>. Accessed October 1, 2018