Chapter 6
Access Complications and Management

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Introduction

As cardiologists have adopted the transradial approach (TRA) as their preferred access for diagnostic and interventional coronary angiography, the TRA has become an increasingly popular option for visceral and peripheral endovascular procedures. Several large prospective multicenter trials, predominantly studying the TRA for percutaneous coronary interventions, have demonstrated high patient satisfaction scores and decreased complication rates [1–4]. In a large-scale retrospective analysis of 1500 patients who underwent the TRA for noncoronary interventions, the TRA was described as a well-tolerated approach with a major complication rate of 0.1% and minor complication rate of 2.4% [5].

As the TRA has become more widely adopted for noncoronary interventions, many interventional practices have transitioned to a predominantly TRA model. There is a significant learning curve associated with the TRA, with literature reporting that approximately 30–50 TRA procedures are needed before procedural metrics and complication rates plateau for new TRA operators [6]. Despite its safety profile, it is important to remember that the TRA is not without risk and has its own unique complications. In this chapter, we detail potential complications and roadblocks operators may face when using the TRA during IR procedures (Table 6.1), preventive measures, and the appropriate procedural and post-procedural management of these complications.

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Table 6.1 Incidence of complications from transradial catheterization

Complication	Incidence
Radial artery spasm	5–10% [7–9]
Radial artery occlusion	2–18% [10–13]
Access-site hematoma	1–6% [14–19]
Radial artery perforation	0.1–1.0% [15, 20–22]
Radial artery dissection	0.1–1.3% [8]
Pseudoaneurysm	0.1–0.2% [8, 15]
AV fistula	Extremely rare
Compartment syndrome/hand ischemia	Extremely rare
Neurologic deficits	Extremely rare
Catheter/sheath entrapment	Extremely rare
Catheter granuloma	Extremely rare

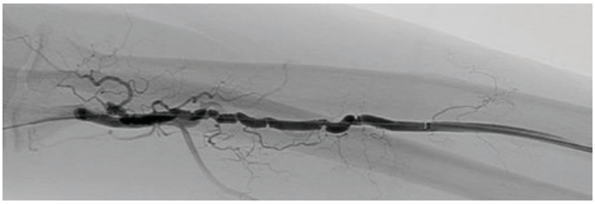

Fig. 6.1 Radial artery angiography revealing multifocal radial artery spasm

Radial Artery Spasm

Radial artery spasm (RAS) is the most common complication of the TRA, occurring in approximately 5–10% of cases (Fig. 6.1) [10–13]. RAS can manifest as forearm or upper arm pain or resistance while inserting sheaths or advancing wires and catheters. The small arterial diameter, thick arterial media, and high density of alpha-adrenergic receptors to the smooth muscle cells in the radial artery contribute to its high vasospastic potential. RAS is associated with female sex, diabetes, low BMI, smaller radial artery diameters, increased number of catheter exchanges, and the use of large catheter sizes [23]. RAS most commonly occurs at the onset of a transradial procedure with initial puncture and sheath placement, but can also occur later during the procedure from local release of catecholamines, endothelin-I, and angiotensin-II from shear stress.

Tactics to Minimize RAS

An effective prophylactic method to minimize RAS when obtaining access involves application of topical lidocaine-prilocaine cream (EMLA) and nitroglycerin ointment covered with an adhesive 30 minutes prior to the start of the procedure.

Because the majority of procedures do not require general anesthesia, it is important to administer adequate sedation prior to arterial puncture to dampen catecholamine release from pain and anxiety. After the vascular sheath is in place, administration of an intra-arterial cocktail consisting of verapamil, nitroglycerin, and heparin prior to guidewire and catheter insertion reduces the rate of RAS. In addition, the use of specially designed hydrophilic coated sheaths is crucial to minimize RAS during the insertion and removal of sheaths. While many visceral and peripheral interventions require 5–7 French sheaths, the operator should attempt to use the smallest sheath feasible.

Procedural Management of RAS

The overwhelming majority of TRA procedures will have smooth and seamless advancement of the guidewire and catheter from the puncture site to the descending aorta. If RAS presents when obtaining radial artery access, ensure that adequate time has elapsed since administration of sedation. Subcutaneous injection of nitroglycerine in the peri-arterial region can assist with radial artery cannulation. When RAS manifests as catheter resistance, it is important to restrain from further catheter manipulation to prevent additional release of local inflammatory mediators. In many cases, RAS spontaneously resolves within a few minutes, and the procedure can continue without issue. Administration of verapamil or nitroglycerin as well as increasing sedation and pain control in awake patients can mitigate RAS and allow operators to proceed in the vast majority of cases.

It is important to ensure that resistance associated with transradial catheter advancement is not prematurely labeled as RAS instead of variant anatomy such as remnant radial arteries, curvatures, or loops. When RAS is suspected and not relieved with medication, operators should maintain a low threshold to perform a radial angiography via the catheter or side port of the introducer sheath to define the anatomy. If RAS is confirmed, the operator can attempt to cross the region of RAS with a hydrophilic guidewire to minimize shear stress. After successfully traversing the area of spasm, a catheter can be negotiated over the wire using gentle cork-screw forward movements instead of a pushing movement, and the procedure can proceed in the usual manner.

Take-Home Points

While its incidence can be dependent on operator experience, RAS is an inevitable occurrence even for the most experienced operators. Although permanent effects from RAS are rare, it can cause significant patient discomfort and prolonged procedure times and potentially result in conversion to alternative access sites in cases of spasm refractory to medication. With appropriate management, RAS will subside, and operators can proceed with the procedure in the regular manner.

Radial Artery Occlusion

Radial artery occlusion (RAO) has been reported to occur in 2–18% of TRA procedures, with the majority of the literature reporting RAO rates of 5–10% [10–13]. RAO arises from a combination of factors, including local vascular inflammatory mediators from endothelial shear stress, disruption of normal antegrade flow, and inappropriate post-procedure compression. Although RAO generally has a benign and clinically silent course due to the protective effects of retrograde flow from the ulnar artery, proper patient selection and appropriate hemostasis are of the utmost importance in minimizing this complication.

Risk Factors for RAO

Introducer sheath size has been reported to be a predictor for RAO. The radial artery has a mean intraluminal diameter of 2.7 ± 0.4 mm in males and 2.4 ± 0.4 mm in females [24], in comparison to 5 French radial introducer sheaths with outer diameters measuring approximately 2.4 mm. For patients with smaller radial arteries, it is important to minimize the sheath size when possible. Saito et al. demonstrated that the RAO rate when the ratio of the radial artery inner diameter to sheath outer diameter is <1.0 is 4% compared to 13% when the ratio is >1.0 [19]. Diabetes, female gender, and low BMI are associated with increased rates of RAO [25].

Techniques to Reduce RAO

Administration of adequate systemic anticoagulation (50 IU/kg or 5000 U UFH) is the simplest method to minimize the risk of RAO. Studies have demonstrated that patients undergoing TRA procedures with suboptimal doses of unfractionated heparin develop RAO in up to 30% of cases [26]. Some operators inject subcutaneous nitroglycerin at the puncture site to reduce rates of RAO [27].

The PROPHET study demonstrated that patent hemostasis decreases the risk of RAO compared to the traditional occlusive hemostasis technique [11]. The vast majority of IR practices have adopted the principles of patent hemostasis with commercially available transradial (TR) bands, allowing antegrade blood flow through the radial artery and decreasing the likelihood of local thrombus formation. In addition, shorter duration of hemostatic compression is associated with decreased rates of RAO [28]. Nursing staff in the post-procedure recovery area should frequently assess and relieve pressure from the TR band to minimize the duration of compression. Some studies have demonstrated that prophylactic ipsilateral ulnar artery compression reduces RAO, presumably from increasing blood flow in the radial artery [29].

Treatment of RAO

Duplex ultrasound examinations have demonstrated spontaneous recanalization of occluded radial arteries after 3 months in the majority of cases [30]. Because of the clinically silent nature of RAO, the predominance of providers do not treat RAO with anticoagulation. Focal ulnar compression is a tactic used by some providers after detecting RAO, by placing a TR band over the ulnar artery for 1–2 hours, thereby preferentially increasing flow through the occluded radial artery [31].

Consequences of RAO

Histopathological studies have demonstrated that patients undergoing TRA procedures can have non-occlusive radial artery injuries in the segments corresponding to the sheath location. Radial artery intimal hyperplasia, intima-media thickening, and smaller mean radial artery diameter were demonstrated in short-term follow-up in one study, while another study demonstrated resolution after 1 year [32, 33]. Despite non-occlusive injuries and RAO, studies of repeated transradial catheterization report technical success rates ranging from 95% to 98% [34–37]. However, another study reported that failed repeat TRA and conversion to TFA were primarily attributed to radial artery luminal narrowing and RAO [38]. Although clinical symptoms and conversion rate to TFA on repeat procedures are low, strategies to minimize RAO should be taken for patients to benefit from subsequent TRA procedures.

TRA procedures resulting in symptomatic ischemia are very rare due to the dual blood supply to the hand. Proper patient selection using pre-procedure Barbeau testing should routinely be done to ensure adequate ulnar collateral flow. Even with abnormal pre-procedure testing (Barbeau C and D), hand ischemia is still unlikely because of the recruitment of collaterals from the interosseous arterial system [39]. There are rare case reports detailing distal ischemia after TRA in patients undergoing cardiac catheterization [40]. In this particular case report, the operator did not perform a pre-procedure Barbeau test, and it was later determined that the ulnar artery was not present, leading to ischemia after RAO.

Hematomas

Access-Site Hematoma

Due to the radial artery's small caliber and superficial location, access-site complications are infrequently encountered using the TRA. When a hematoma is detected near the puncture site with a TR band already placed, it is important to assess for appropriate location of the TR band. If the TR band has migrated, placing an additional TR band or BP cuff proximal to the arteriotomy site can temporarily occlude blood flow while readjusting the TR band to the appropriate position. If the TR band is well positioned with swelling proximal to the device, an additional proximal TR band can be applied.

Radial Artery Perforation

Radial artery perforation is a rare incident, most commonly the result of forceful pushing of a wire into variant anatomy, such as radial artery side branches. When extravasation is observed (Fig. 6.2), it is important to attempt to cross the lesion and advance a catheter to occlude the extravasation site. In the majority of these situations, the catheter will seal the perforation and the extravasation will subside. In fact, many operators have achieved resolution of radial artery perforation even when proceeding with full anticoagulation throughout the case [21]. Additional tactics include inserting a long sheath across the extravasation site for tamponade or placement of a covered stent for refractory bleeding [41]. Even if extravasation is not present on subsequent angiograms prior to sheath removal, strict post-procedure observation is required to screen for hematomas and forearm compartment syndrome.

Failure to recognize perforations without treatment can lead to gradual intramuscular bleeding. A hematoma classification system was designed by investigators in the EASY trial to guide operators and nursing staff [42]. In this system, hematoma <5 cm (grade 1) and <10 cm (grade II) are related to the access site, while hematomas distal to the elbow (grade III) (Fig. 6.3) and proximal to the elbow (grade IV) are thought to result from vessel perforation from wire damage. For grade III and IV hematomas, arm elevation, external compression of the brachial artery with a blood pressure cuff, and application of an ace compression bandage should be used to prevent hematoma growth. Grade V is reserved for compartment syndrome.

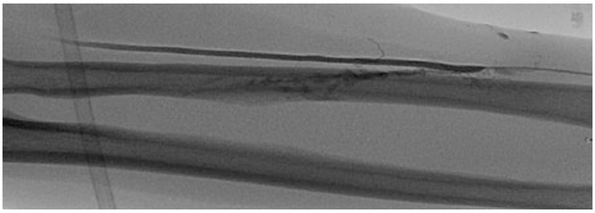

Fig. 6.2 Radial artery angiogram demonstrating radial artery perforation with contrast extravasation

Fig. 6.3 Photograph of a grade III hematoma with extensive ecchymosis extending from the access site to the hand and forearm

Compartment Syndrome

Forearm compartment syndrome is an extremely rare occurrence, occurring in fewer than 0.01% of cases [43]. When a forearm hematoma is present, there should be very frequent monitoring for signs of perfusion, such as skin color, pulse, pain, paresthesia, and capillary refill. Signs of compartment syndrome such as expanding hematoma, extreme pain with passive movement of the forearm and hemodynamic changes should be promptly recognized with immediate action and surgical consultation. Surgical fasciotomy is the definitive treatment for compartment syndrome.

Hand compartment syndrome without involvement of the forearm is an exceptionally rare phenomenon with unclear etiology that has been described in a single case report [44].

Miscellaneous Vascular Complications

Dissection

Radial artery dissection is an uncommon complication, with the majority of cases occurring with hydrophilic guidewires negotiating through difficult anatomy such as curvatures and loops. It is important to understand that TRA-related dissections are retrograde and the dissection flap is unlikely to propagate. The operator should attempt to cross the dissection plane with a soft 0.014 inch wire to limit further dissection. Once the lesion is traversed, advancement of a catheter over the dissection plane will likely seal the dissection, and the case should proceed without expectation of any clinical manifestation of the dissection.

Pseudoaneurysm

TRA-related pseudoaneurysms are very rare occurrences due to the small vessel calibers (Fig. 6.4). Pseudoaneurysms commonly present days to weeks following the procedure and can present as a painful pulsating localized swelling. The majority of pseudoaneurysms resolve spontaneously. Ultrasound-guided compression, thrombin injections, or surgical ligation can be performed depending on the size and severity of symptoms.

AV Fistula

AV fistulas resulting from TRA are exceptionally rare occurrences, with most AV fistulas being clinically asymptomatic and managed conservatively. Placement of a covered stent has been described for large and symptomatic AV fistulas [45].

Radial Arteritis

After TRA procedures, soreness and mild pain at the access site and forearm is common. When a patient has post-procedure forearm pain that is out of proportion of what is expected with normal post-procedure pulses and an unremarkable ultrasonographic evaluation, a diagnosis of radial arteritis is made. The vast majority of

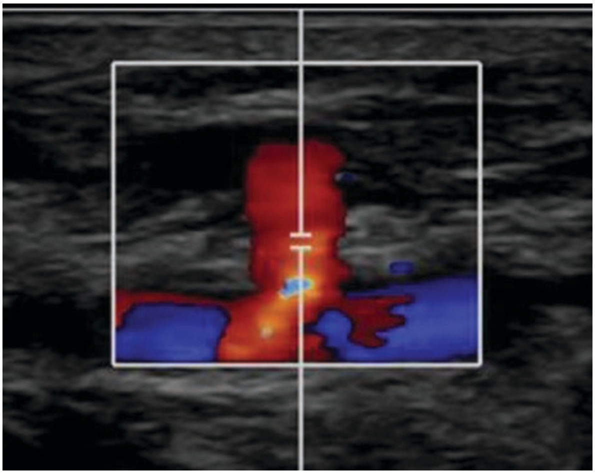

Fig. 6.4 Duplex ultrasound demonstrating a radial pseudoaneurysm after transradial catheterization in the longitudinal view

cases resolve with the use of NSAIDs, with few requiring treatment with oral steroids.

Neurologic Complications

Risk of Stroke

As the TRA involves catheters and wires traversing across the origins of the great vessels, there is a theoretical risk of periprocedural stroke. When performing subdiaphragmatic TRA procedures, the left radial approach is the strongly preferred side as it minimizes aortic arch manipulation and passage adjacent to the great vessels. As the TRA is routinely used for patients with atherosclerosis, it is important to understand this potential risk.

Although cardiology literature has explored the risk of stroke from the right radial approach, which involves aortic arch manipulation across the great vessels, multivariate analysis of observational data and large-scale meta-analyses have not demonstrated an increased risk of stroke with the TRA [46]. The incidence of cerebral embolization when using the left TRA for subdiaphragmatic procedures is exceptionally rare and is limited to case reports [47].

With the left TRA approach, caution should be used when passing the origin of the left vertebral and left subclavian arteries. With the increased scope and complexity of procedures that can be performed via the TRA, a variety of catheters and microcatheters have been designed to be used at specific stages of a procedure. As the number of catheter exchanges increases, it becomes increasingly important to flush every catheter to prevent air emboli. Operators should take special precaution when removing a catheter that may have residual embolic material or debris. In order to prevent the catheter from inadvertently cannulating the left vertebral artery and releasing embolic material, the operator should remove the catheter over a wire.

By using the left TRA with appropriate catheter technique and meticulous attention to detail when traversing the left vertebral and left subclavian arteries, the risk of clinically significant cerebral infarctions is overwhelmingly rare.

Neuromuscular Complications

It is not uncommon for patients to have minor numbness and tingling in the hands or wrists following TRA procedures, with symptoms generally resolving within a few hours. Rare case reports of complex regional pain syndromes after TRA procedures have been described, with treatment options including oral pain medication, steroid injections, antidepressants, nerve blocks, and occupational therapy depending on severity [48, 49].

There is limited data exploring the relationship between radial access-site complications and hand and limb dysfunction. The majority of reported cases of limb dysfunction are transient and resolve over time. In one study, there was diminished hand sensitivity in certain dermatomes using monofilament testing, which did not correlate with patient-reported hand symptoms [50]. In a large-scale meta-analysis, indicators of hand dysfunction including grip strength change and power loss were observed in 0.26% of cases, with the majority of symptoms resolving within 30 days [51]. This transient and rare phenomenon should be considered for individuals requiring fine-motor hand movement in the short-term after the procedure.

Device-Related Complications

Sheath Entrapment

Radial artery spasm can result in device entrapment in very extreme circumstances and has been greatly minimized with the use of hydrophilic sheaths. When faced with device entrapment, the operator should hydrate the patient, apply warm towels to the forearm, and administer antispasmodics, sedation, and pain medication. While attempting to remove the catheter, the operator should slowly retract the catheter in a cork-screw fashion. When forceful rapid retraction of catheters or sheaths is applied without success, worsening of the RAS is likely and may lead to radial artery intussusception or radial artery rupture. In these exceptional situations, radial endarterectomy with general anesthesia and regional nerve blocks will be required for removal of the entrapped device (Fig. 6.5).

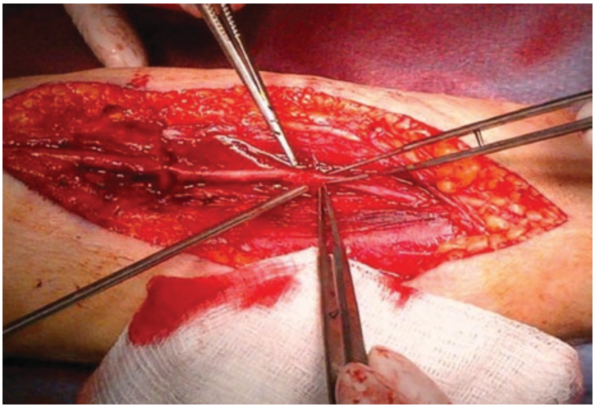

Fig. 6.5 Photograph of a radial endarterectomy procedure to remove an entrapped sheath

Catheter Granuloma

Certain sheaths have been reported to cause granulomatous skin reactions. The skin reaction follows a benign course and is usually self-limited without intervention [52].

Conclusion

The TRA has a demonstrated history of safety and patient satisfaction across heterogeneous populations in a broad range of peripheral and visceral endovascular interventions. Although clinically significant complications with the TRA are rare, it is important to recognize common pitfalls and complications unique to the TRA as it becomes more widely adopted throughout the practice of interventional radiology.

References

1. 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;60:2481–9.
2. Mehta S, Jolly S, Cairns J, et al. Effects of radial versus femoral artery access in patients with acute coronary syndromes with or without ST-segment elevation. J Am Coll Cardiol. 2012;60:2490–9.
3. Valgimigli M, Gagnor A, Calabro P, et al. Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a randomized multicenter trial. Lancet. 2015;385:2465–76.
4. Kok M, Weernick M, Von Birgelen C, et al. Patient preference for radial versus femoral vascular access for elective coronary procedures: the PREVAS study. Catheter Cardiovasc Interv. 2018;91:17–24.
5. Posham R, Biederman D, Patel R, 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;27:159–66.
6. Hess C, Peterson E, Neely M, et al. The learning curve for transradial percutaneous coronary intervention among operators in the United States: a study from the National Cardiovascular Data Registry. Circulation. 2014;129:2277–86.
7. Kiemeneij F. Prevention and management of radial artery spasm. J Invasive Cardiol. 2006;18:159–60.
8. Jolly S, Yusef S, Cairns J, et al. Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (RIVAL): a randomized, parallel group, multicentre trial. Lancet. 2011;377:1409–20.
9. Rathore S, Stables R, Pauriah M, et al. Impact of length and hydrophilic coating of the introducer sheath on radial artery spasm during transradial coronary intervention: a randomized study. JACC Cardiovasc Interv. 2010;3:475–83.

10. Sanmartin M, Gomez M, Ramon J, et al. Interruption of blood flow during compression and radial artery occlusion after transradial catheterization. Catheter Cardiovasc Interv. 2007;70:185–9.
11. Pancholy S, Coppola J, Patel T, et al. Prevention of radial artery occlusion- patent hemostasis evaluation trial (PROPHET study): a randomized comparison of traditional versus patency documented hemostasis after transradial catheterization. Catheter Cardiovasc Interv. 2008;72:335–40.
12. Pancholy S. Impact of two different hemostatic devices on radial artery outcomes after transradial catheterization. J Invasive Cardiol. 2009;21:101–14.
13. Cubero J, Lombardo J, Pedrosa C, et al. Radial compression guided by mean artery pressure versus standard compression with a pneumatic device (RACOMAP). Catheter Cardiovasc Interv. 2009;73:467–72.
14. Hildick-Smith D, Lowe M, Jm W, et al. Coronary angiography from the radial artery-- experience, complications and limitations. Int J Cardiol. 1998;64:231–9.
15. Sanmartin M, Cuevas D, Goicolea J, et al. Vascular complication associated with radial artery access for cardiac catheterization. Rev Esp Cardiol. 2004;57:581–4.
16. Kumar V, Balaji R, Anupam B, et al. Mid-forearm hematomas in transradial procedures. Indian Heart J. 2005;57:181.
17. Cao Z, Zhou Y, Zhao Y, et al. Transradial approach for coronary angioplasty in Chinese elderly patients. Chin Med J (Engl). 2008;121:1121–9.
18. Lim Y, Chan C, Kwok V, et al. Transradial access for coronary angiography and angioplasty: a novel approach. Singap Med J. 2003;44:563–9.
19. Saito S, Ikei H, Hosokawa G, et al. Influence of the ratio between radial artery inner diameter and sheath outer diameter on radial artery flow after transradial coronary intervention. Catheter Cardiovasc Interv. 1999;44:173–8.
20. Bazemore E, Man J. Problems and complications of the transradial for coronary interventinos: a review. J Invasive Cardiol. 2005;57:581–4.
21. Calvino-Santos R, Vasquez R, Salgado-Fernandez J, et al. Management of iatrogenic radial artery perforation. Catheter Cardiovasc Interv. 2004;61:74–8.
22. Kanei Y, Kwan T, Nakra N, et al. Transradial cardiac catheterization: a review of access site complications. Catheter Cardiovasc Interv. 2011;78:840–6.
23. Jia D, Zhou Y, Shi D, et al. Incidence and predictors of radial artery spasm during transradial coronary angiography and intervention. Chin Med J (Engl). 2010;123:843–7.
24. Loh Y, Nakao M, Tan W, et al. Factors influencing radial artery size. Asian Cardiovasc Thorac Ann. 2007;15:324–6.
25. Zhou Y, Zhao Y, Cao Z, et al. Incidence and risk factors of acute radial artery occlusion following transradial percutaneous coronary intervention. Zhonghua Yi Xue Za Zhi. 2007;87:1531–4.
26. Stella P, Kiemeneij F, Laarman G, et al. Incidence and outcome of radial artery occlusion following transradial artery coronary angioplasty. Catheter Cardiovasc Diagn. 1997;40:156–8.
27. Chen Y, Ke Z, Xiao J, et al. Subcutaneous injection of nitroglycerine at the radial artery puncture site reduces the risk of early radial artery occlusion after transradial coronary catheterization: a randomized, placebo-controlled clinical trial. Circ Cardiovasc Interv. 2018;11:e006571.
28. Pancholy S, Patel T. Effect of duration of hemostatic compression on radial artery occlusion after transradial access. Catheter Cardiovasc Interv. 2012;79:78–81.
29. Pancholy S, Bernat I, Bertrand O, et al. Prevention of radial artery occlusion after transradial catheterization: the PROPHET-II randomized trial. JACC Cardiovasc Interv. 2016;9:1992–9.
30. Nagai S, Abe S, Sato T, et al. Ultrasonic assessment of vascular complications in coronary angiography and angioplasty after transradial approach. Am J Cardiol. 1999;83:180–6.
31. Tian J, Chu Y, Sun J, et al. Ulnar artery compression: a feasible and effective approach to prevent the radial artery occlusion after coronary intervention. Chin Med J (Engl). 2015;128:795–8.
32. Madssen E, Haere P, Wiseth R. Radial artery diameter and vasodilatory properties after transradial coronary angiography. Ann Thorac Surg. 2006;82:1698–703.

33. Burstein J, Giderewicz D, Hutchinson S, et al. Impact of radial artery cannulation for coronary angiography and angioplasty on radial artery function. Am J Cardiol. 2007;99:457–9.
34. Charalambous M, Constantinides S, Talias M, et al. Repeated transradial catherization: feasibility, efficacy, and safety. Tex Heart Inst J. 2014;41:575–8.
35. Caputo R, Simons A, Giambartolomei A, et al. Safety and efficacy of repeat transradial access for cardiac catheterization procedures. Catheter Cardiovasc Interv. 2001;54:188–90.
36. Yoo B, Lee S, Ko J, et al. Procedural outcomes of repeated transradial coronary procedure. Catheter Cardiovasc Interv. 2003;58:301–4.
37. Valsecchi O, Vassileva A. Radial artery: how many times? Indian Heart J. 2010;62:226–9.
38. Chen S, Brunet M, Sur S, et al. Feasibility of repeat transradial access for neuroendovascular procedures. J Neurointerv Surg. 2019. https://doi.org/10.1136/neurointsurg-2019-015438.
39. Ghuran A, Dixon G, Holmberg S, et al. Transradial coronary intervention without prescreening for a dual palmar blood supply. Int J Cardiol. 2007;121:320–2.
40. De Bucourt M, Teichgraber U. Digital ischemia and consecutive amputation after emergency transradial cardiac catheter examination. Cardiovasc Intervent Radiol. 2012;35:1242–4.
41. Chatterjee A, White J, Leesar M. Management of radial artery perforation during transradial catheterization using a polytetrafluoroethylene-covered coronary stent. Cardiovasc Revasc Med. 2017;18:133–5.
42. Agostoni P, Biondi-Zoccai G, de Benedictis M, et al. Radial versus femoral approach for percutaneous coronary diagnostic and interventional procedures; systematic overview and meta-analysis of randomized trials. J Am Coll Cardiol. 2004;44:349–56.
43. Tizon-Marcos H, Barbeau G. Incidence of compartment syndrome of the arm in a large series of transradial approach for coronary procedures. J Interv Cardiol. 2008;21:380–4.
44. Jue J, Karam J, Mejia A, et al. Compartment syndrome of the hand: a rare sequela of transradial cardiac catheterization. Tex Heart Inst J. 2017;44:73–6.
45. Summaria F, Romagnoli E, Preziosi P. Percutaneous antegrade transarterial treatment of iatrogenic radial arteriovenous fistula. J Cardiovasc Med. 2012;13:50–2.
46. Patel V, Brayton K, Kumbhani D, et al. Meta-analysis of stroke after transradial versus transfemoral artery catheterization. Int J Cardiol. 2013;168:5234–8.
47. Al-Hakim R, Gandhi R, Benenati J. Incident of stroke after transradial arterial access for subdiaphragmatic intervention. J Vasc Interv Radiol. 2017;28:1287–8.
48. Padadimos T, Hofmann J. Radial artery thrombosis, palmar arch systolic blood velocities, and chronic regional pain syndrome following transradial cardiac catheterization. Catheter Cardiovasc Interv. 2002;57:537–40.
49. Sasano N, Tsuda T, Sasano H, et al. A case of complex regional pain syndrome type II after transradial coronary intervention. J Anesth. 2004;18:310–2.
50. Van der Heijden D, Leeuwen M, Ritt M, et al. Hand sensibility after transradial arterial access: an observational study in patients with and without radial artery occlusion. J Vasc Interv Radiol. 2019;30:1832–9.
51. Haq M, Rashid M, Kwok C, et al. Hand dysfunction after transradial artery catheterization for coronary procedures. World J Cardiol. 2017;9:609–19.
52. Zellner C, Ports T, Yeghiazarians Y, et al. Sterile radial artery granuloma after transradial procedures:a unique and avoidable complication. Catheter Cardiovasc Interv. 2010;76:673–6.