Catheterization and Cardiovascular Interventions 00:000–000 (2011)

Core Curriculum

Transradial Arterial Access for Coronary and Peripheral Procedures: Executive Summary by the Transradial Committee of the SCAI

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In response to growing U.S. interest, the Society for Coronary Angiography and Interventions recently formed a Transradial Committee whose purpose is to examine the utility, utilization, and training considerations related to transradial access for percutaneous coronary and peripheral procedures. With international partnership, the committee has composed a comprehensive overview of this subject presented herewith.

Key words: radial artery; arterial access; vascular complications; percutaneous coronary intervention

WORLDWIDE UPTAKE OF RADIAL ACCESS

Following the first reports of radial coronary angiography by Lucian Campeau in 1989 and radial percutaneous coronary intervention (PCI) by Ferdinand Kiemeneij in 1992, there was an increase in the use of transradial access (TRA) around the world [1–3]. Interest spread slowly across Europe, Asia, and Canada, aided both by radial training and the development of dedicated radial equipment [4–7]. The proportion of radial procedures has continued to rise worldwide with radial access now replacing femoral access as the dominant access site for PCI in some countries (Table I). Worldwide, an estimated 20% of procedures are performed by this route (29% if the US is excluded from the estimate). Although, there is considerable variation across Europe and Asia/Australia, these regions have the highest uptake of radial access at ~30% and 40% of procedures, respectively. The countries with the highest rates of radial access (70–80%) are found in Norway, Malaysia, and Bulgaria. Central and South America have a lower rate of radial use, estimated at 15%, and North America has a major divergence between Canada at ~50% and the U.S. at less than 2% [8–10]. The Middle East and Africa are the only other regions with a similarly low rate of radial access.

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Conflict of interest: There is no conflict of interest for any author regarding the content of this manuscript.

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Received 10 February 2011; Revision accepted 13 February 2011

DOI 10.1002/ccd.23052
Published online in Wiley Online Library (wiley onlinelibrary.com)

TABLE I. Worldwide Transradial PCI Utilization by Country and Region

	National Database				Estimates 2009 (Industry/Personal/ Society)		Totals	
Source	PCI/year	% radial (%)	Year	Type	PCI/year	% radial (%)	PCI /year	% radial (%)
Germany					340,000	25		
France	115,000	55	2008	National				
UK	80,331	35	2008	National				
Spain					61,500	43		
Italy					132,000	25		
Poland	90,238	21.8	2008	National				
Countries (<50 K PCI/year)	16,527	15.7	2006	EAPCI/ SCAAR	66,000	37		
Europe total	719,094	47.5	2009				1,069,202	29
USA		1.7	2008/9	NCDR	998,500			
Central / South America					234,350	15		
Canada					60,000	50		
Americas total							1,194,350	7
Japan					220,900	60		
India					143,000	32		
China					75,000	25		
Other (<50 K PCI/year)					143,000	32		
Asia total							581,900	42
Africa/Middle East					245,000	1–3	245,000	1–3
Total worldwide							2,945,452	22

THE ADVANTAGES OF TRANSRADIAL CATHETERIZATION

The evolution of PCI to incorporate targeted anticoagulants and antiplatelet agents, as well as coronary stents, has led to a steady decrease in ischemic complications over time [11–13]. This, along with an improvement in procedural success, has increased the focus on nonischemic complications, particularly bleeding and vascular complications. Observational data have shown a consistent relationship between bleeding complications (including blood transfusions) and increased mortality and morbidity [14–18]. Although this relationship is less clear for vascular complications that occur without bleeding or transfusion [19], such vascular complications are associated with significant patient discomfort, increased length of stay, and costs [20–25].

Three strategies to decrease vascular complications are currently available. The first is a pharmacological strategy [13, 26–30], the second is optimizing femoral access [31–35], and the third is avoiding the femoral artery altogether. Although brachial access exists as an alternative [36–45], the radial artery has become the preferred choice for upper extremity arterial access due to its easy compressibility, distance from major veins and nerves, and companion blood flow through the ulnar artery to the palmar arch.

Use of the radial artery for diagnostic and interventional procedures has been compared with the femoral and brachial approach in both randomized trials and observational studies, and has consistently demonstrated statistically significant reductions in bleeding and access site complications [11, 46–57]. The decrease in bleeding and vascular complications is even more pronounced in women, who have a 2–3 times higher risk of femoral access complications compared with men [11, 58]. In all patients, it remains uncertain whether the use of new antithrombotic agents, such as bivalirudin may reduce the incidence of bleeding with TRA even further [59].

Reductions in complications can have downstream effects, resulting in decreased length of stay, reduced cost, and improved clinical outcomes, potentially including survival [22, 26–30, 46–57]. As the Center for Medicare and Medicaid Services considers "same-day" or outpatient PCI, the number of patients treated by this strategy is likely to increase. TRA is an attractive option for same-day/outpatient PCI, with the data supporting its safety, efficacy, and potential financial savings [60–69]. Finally, for patients who have experienced both radial and femoral access, there is a strong preference for the radial approach due to increased functioning and less discomfort [62, 63, 66]. Although femoral vascular closure devices have improved early ambulation and patient comfort, they have not demonstrated a reduction in bleeding and vascular complications [70, 71].

PATIENT SELECTION AND PREPROCEDURAL PREPARATION

Preprocedure patient evaluation is the first important step toward the completion of a successful transradial procedure. This is an especially important consideration for operators new to TRA seeking to optimize initial outcomes. Ideal patient characteristics include: (1) hemodynamic stability, (2) age <70 years, (3) no history of prior ipsilateral brachial or TR procedure, and (4) a palpably large radial artery with a strong pulse and presence of a normal Allen's test. Relative contraindications to the radial approach include an absent radial pulse, an abnormal Allen's test, a severe vasospastic condition (such as Raynaud's), either a planned or present arteriovenous shunt for dialysis, and the potential use of the radial artery as a conduit for aortocoronary bypass. Myocardial biopsy procedures may also be a relative contraindication given the need for heparin with TRA to mitigate the risk of radial artery occlusion (RAO).

The Allen's test confirms dual circulation to the hand through the palmar arch. It is performed by (1) simultaneous occlusion of the radial and ulnar arteries at the wrist level until the hand blanches, (2) release of pressure over the ulnar artery, and (3) observing the hand for reperfusion. A positive (normal) Allen's test demonstrates reperfusion of the hand within 7 sec. A negative (abnormal) Allen's test demonstrates reperfusion of the hand taking longer than 15 sec. With borderline reperfusion (between 8 and 15 sec), consideration can still be given to proceeding with TRA if there is a strong radial pulse. Alternatively, utilizing wave form plethysmography with a pulse oximeter placed on the thumb provides more sensitivity than the Allen's test and will reduce the number of patients excluded because of seemingly poor collateral flow to 1.5% [72].

Appropriate positioning of the patient often depends on whether the right or left radial artery is utilized. However, some general principles apply. The arm should be stabilized in a comfortable position on a radiolucent armboard, preferably one that swivels so that access can be gained with the arm in an abducted position. A long plexiglass board extending along the table can also be used to create a surface for the arm to rest and the operator to work. Preprocedural intravenous (IV) access is ideally gained on the contralateral arm so that it is not in the way of arterial access and drips are not impeded once a hemostatic device is placed. With arterial access in one arm and IV access in the other arm, cuff blood pressure monitoring is generally performed on the leg. The wrist should be hyperextended with a rolled towel underneath for support. This aids access by pulling the overlying skin and subcutaneous tissues taunt. A pulse oximeter is placed on the ipsilateral thumb. Following access, the arm should be placed either adjacent to the body (right TRA) or on the abdomen (left TRA) in a comfortable and stabilized position in order to reduce operator radiation exposure. Extension tubing can also be placed between the catheter and manifold to increase distance from the X-ray generator. Early in the transradial experience, it is helpful to have concurrent preparation of the groin to allow a seamless transition to femoral access in the event of TRA failure.

RADIAL VS. ULNAR APPROACH

The ulnar artery has been used successfully for cardiac catheterization and PCI [73]. Usually larger than the radial artery, the ulnar contributes more blood flow to the palmer arch [74]. Compared to the radial artery, the ulnar artery is generally not as well centered over the underlying bone, coursing slightly medially and there is more intervening tissue. This makes compression hemostasis slightly more difficult. Although in the setting of a positive reverse Allen's test ulnar access is feasible, because of the above considerations radial access is generally preferred [75].

RIGHT VS. LEFT RADIAL APPROACH

Many operators prefer the right arm approach as it provides an easier platform for access and is generally more comfortable for the patient and operator [76]. When utilizing the left radial artery, marked adduction of the arm is usually required following access in order to use right-sided table controls and maintain ergonomics for the operator during the procedure. The alternative is to set the room up as a left sided room and perform the procedure accordingly.

Other considerations impacting the choice of right or left radial access include the presence of a left internal mammary artery (IMA) graft and the possible future need for a bypass graft conduit from the nondominant hand. Short statured patients, as well as patients with significant abdominal obesity, tend to have longitudinally compressed ascending aortas, and cannulation is often easier from the left radial artery. Evaluation and treatment of infradiaphragmatic pathology is best performed from the left wrist as it provides ~10 cm of additional length. Left subclavian and left vertebral interventions are also straightforward from the left wrist. Finally, because left-sided radial procedures more closely mimic the femoral approach in terms of catheter manipulation and seating, operators, particularly those early in their learning curve, may find it easier for using more familiar femoral (Judkins) catheters.

GAINING RADIAL ARTERY ACCESS

Gaining access on the first attempt is optimal as repeated arterial trauma increases the risk for spasm.

Therefore, careful vessel palpation and planning of arteriotomy puncture are critical to successful TRA. The arteriotomy should be ~2 cm proximal to the radial styloid in order to avoid the bifurcation and diminutive distal vessel. A more proximal arteriotomy may be utilized for repeat procedures or when catheter length is an issue.

A small amount of local anesthetic (lidocaine) is utilized for cutaneous/subcutaneous anesthesia. It may be helpful to mix a small amount of nitroglycerin with the local anesthesia to promote arterial dilatation. This is usually administered prior to arterial puncture, although some operators may administer it following access and before sheath insertion in order to avoid blunting palpation of the arterial pulse. Arterial puncture can be performed with either a single anterior wall puncture using a short (1.5 cm) 21-gauge access needle and a small caliber wire (0.018"–0.025") or a double wall through-and-through puncture using an angiocath needle system. For the later technique, the angiocath is typically held at a 30–45 degree angle and once arterial blood flow is identified, the needle is advanced through the posterior wall of the artery until flow stops. The needle is then removed and the plastic cannula is slowly pulled back until an arterial backflow of blood is identified. Next, a small caliber guidewire is inserted through the plastic cannula to facilitate sheath placement. This through-and-through puncture approach may provide a higher success rate, especially for novice operators [77].

Introducing sheaths are generally 5-French or 6-French and should have a highly tapered tip and smooth transition between the introducer and sheath. Hydrophilic sheaths are utilized predominantly and may be associated with increased patient comfort, less intimal trauma, and possibly higher long-term arterial patency [63, 66, 78]. A small superficial incision may be made in the skin to ease catheter insertion. Sheath length preference (10 cm vs. 21 cm) varies among operators [79]. The smallest sheath necessary is preferable in order to reduce the risk of RAO.

Catheter advancement is typically performed with a standard 0.035" J-tipped wire. To help limit radiation exposure, the wire can be gently advanced up the arm without fluoroscopy unless resistance is met. Common causes of resistance are (1) congenital anatomic variations such as the radial artery "loop," early origin of the radial artery, or an accessory radial artery, (2) tortuosity in the axillary, subclavian, or inominate artery (especially in older hypertensive patients), and (3) arterial spasm (Fig. 1). Fluoroscopy should be utilized once the wire reaches the subclavian artery so as to avoid important branch vessels. If resistance is met with the J-wire, a second choice is a steerable 0.035" wire (e.g., Glidewire or Wholey wire). These are advanced under fluoroscopy with torquing performed as needed to avoid damage to small branch vessels. An angiogram of the arm may ultimately be necessary if the wire cannot be passed easily.

PHARMACOLOGIC THERAPY

The radial artery has a mean diameter of 2.69 ± 0.40 mm in men and 2.43 ± 0.38 mm in women (range 1.15–3.95 mm) [80], and is therefore much closer in diameter to the catheters being placed within its lumen than similar procedures accomplished through the femoral artery. Limited clearance between the catheter and vessel wall can result in a physical stimulus for arterial spasm, which will interfere with catheter manipulation. Additionally, the constrained intraluminal environment may result in reduced pericatheter blood flow raising the risk of arterial thrombosis. Pharmacologic therapy aimed at reducing both spasm and thrombosis is therefore more critical in transradial procedures compared to similar femoral procedures.

Spasmolytic Therapy

A variety of stimuli can cause the smooth muscle cells within the media of the radial artery to contract resulting in clinical spasm. Prophylactic use of pharmaceutical agents known to reduce vascular tone, such as calcium channel blockers (e.g., Verapamil 2.5 mg) and/or nitrates (e.g., Nitroglycerin 0.1–0.4 mg) are routinely utilized and are best given directly in the radial artery immediately after vascular access, although the use of topical or oral pretreatment may also be useful. In addition, diluting the spasmolytic cocktail with blood or saline can reduce burning and artery irritation.

There does not appear to be a significant difference between the different calcium channel blockers in regard to degree of arterial vasodilation, although off-target effects may be different [81]. Particular caution should be used in patients prone to hypotension related to these agents, such as those with severe aortic stenosis. Although there is no strong evidence demonstrating superiority of any one pharmacologic regimen, it has been demonstrated that lack of pretreatment is associated with symptomatic spasm in up to 30% of cases [79].

Antithrombotic Therapy

Adequate anticoagulation is necessary for transradial procedures in order to reduce the risk of RAO. Heparin is essential and can be given either intravenous or intra-arterial [82]. In addition, the effect of heparin in

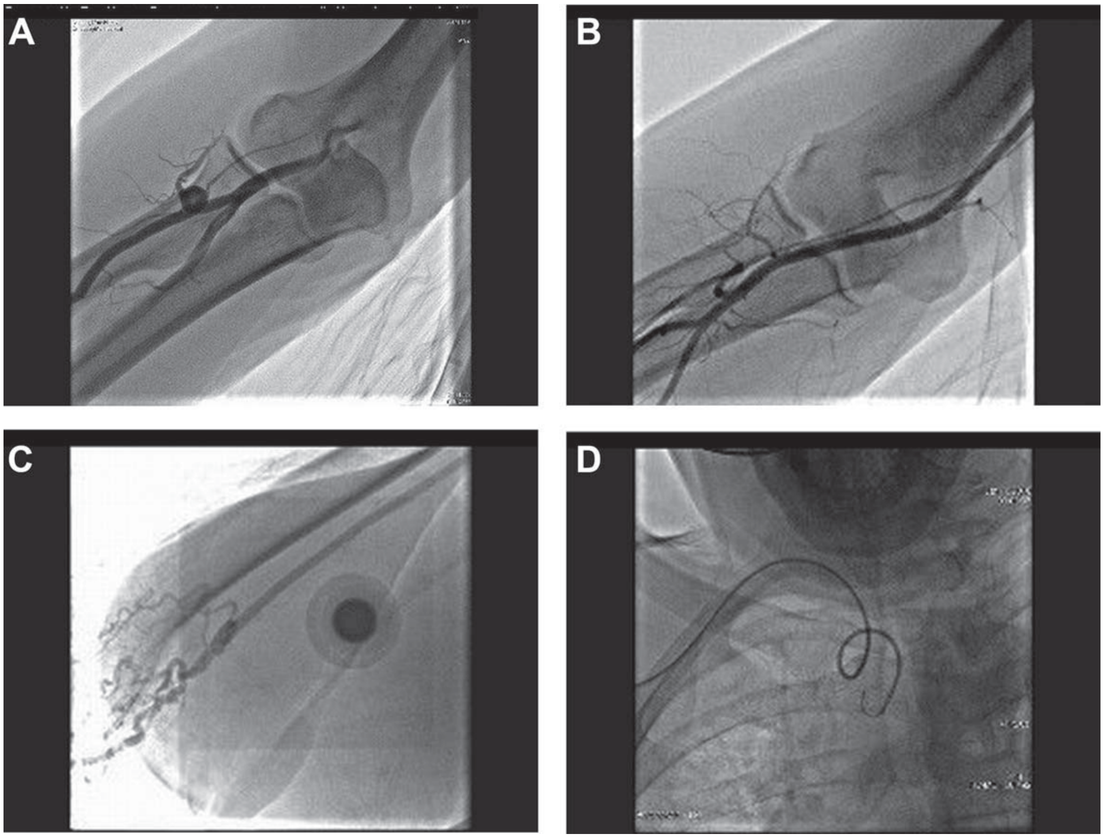

Fig. 1. (A) Anatomic variation "Radial loop." (B) Anatomic variation radial tortuosity with high take off radial artery. (C) Occluded brachial artery. (D) Subclavian/Inominate artery tortuosity.

reducing the incidence of RAO appears to be dose dependent, with a sizeable additional decrease in the incidence of RAO, by increasing the dose from 2,000 to 3,000 U to 5,000 U. Bivalirudin and the low molecular weight heparins may also be considered [83]. The appropriate timing of administration is not well defined, but since thrombosis is thought to originate from the relative stasis of blood resulting both from the radial sheath/catheter and from external arterial compression required for hemostasis following sheath removal, it is possible that anticoagulation provided any time prior to sheath removal may be effective.

Transradial procedures can be safely performed without discontinuing warfarin therapy, and recent data concerning the risks of bridging therapy would suggest that this might be preferable [84–86]. Whether heparin is also needed in a therapeutic orally anticoagulated patient is unknown. Since the bulk of safety data for interventions is based on heparin-like anticoagulation, some operators have added heparin to raise the ACT to a PCI-range in order to cover pathways not inhibited by warfarin. Others have successfully used only warfarin as their background antithrombin therapy, and have done PCI with only the addition of aspirin and thieopyridines.

CATHETER SELECTION

The choice of diagnostic or interventional guiding catheter is influenced by the site of arterial access. Different catheters may be considered for the right or left transradial approaches. Transradial coronary angiography can generally be performed using femoral catheter curves without difficulty; however, a shorter JL curve and longer JR curve may be required for a proper fit from the right transradial approach. The use of TRA, especially right TRA, provides the special opportunity to utilize a "universal catheter," that is, a catheter that can be used for left and right coronary arteriography, and left ventriculography. This concept originated with the Sones catheter and the brachial cut-down approach. Some of the currently available universal catheter shapes for TR diagnostic and/or interventional cases include the Kimny (Boston Scientific, Natick, MA) Optitorque Tiger and Jacky (Terumo, Sommerset, NJ), Sones (Cordis, Warren, NJ), Barbeau, MAC 30/30

TABLE II. Catheter Shapes for Transradial Diagnostic and/or Interventional Procedures

Diagnostic (Universal)	Diagnostic (LCA, RCA)	Guide (Universal)	Guide (LCA)	Guide (RCA)
Kinmy	JL 3.5, JR 4.0	Kimny	IKARI left	IKARI right
Tiger		MAC 30/30	LARA	MRESS
Jacky		Barbeau	MRADIAL	RRAD
Sones		PAPA	Easy Radial left	Easy Radial right
MAC 30/30				

(Medtronic, Minneapolis, MN), and PAPA (Medtronic) (Table II).

A benefit of using a universal catheter for coronary angiography is the "one-pass" technique, resulting in less instrumentation and presumably less spasm, shorter procedure durations, and lower material costs. Catheter exchanges cause transient, but measurable, functional alterations in both radial and brachial arteries with a direct relationship between catheter exchanges and arterial dysfunction [87]. Universal catheters may also shorten fluoroscopy times for diagnostic coronary angiography, compared to a multicatheter approach. In time-sensitive procedures such as ST elevation myocardial infarction (STEMI) patients, starting with a universal guide catheter may decrease time to reperfusion. Success rates for the available universal catheters for diagnostic coronary angiography have been reported to be 96–98% [88–90].

The main drawback of a universal catheter is the associated learning curve. Variability in aortocoronary relationships can make coaxial engagement with universal catheters difficult, increasing the chance of coronary ostial trauma compared to a multicatheter technique [88–91]. Universal catheter shapes may also result in "deep seating" of the catheter especially in right coronary arteries with an inferior aortocoronary take-off or when the catheter is abruptly removed from the left coronary artery without initial downward pressure and torque, similar to the action of Amplatz catheters from the femoral approach. Side-holes near the distal tip may increase the safety of these catheters by decreasing the probability of intimal dissections caused by forceful injection of contrast through a noncoaxially engaged catheter.

Certain techniques may allow the operator to successfully use universal catheters despite anatomic variations. A deep breath hold can often help align the catheter. In cases of subclavian/inominate artery tortuosity it may be beneficial to leave a 0.035" guidewire in the catheter while torquing the catheter into place. Right coronary arteries with an inferior take-off from the aorta often pose a problem due to the tendency to engage the conus branch. This may also be alleviated by straightening the shaft of the catheter by introducing a 0.035" guidewire in the catheter and engaging the right coronary artery.

When these catheters are used for left ventriculography with power injection, a lower PSI ($\leq$350) is recommended as the presence of a single side-hole does not significantly reduce the force of flow through the distal tip that could result in serious trauma to the left ventricle (Fig. 2).

For PCI, universal catheter use is less prevalent due to the need for coaxiality and proper guiding catheter support. Although there is a longer learning curve associated with some of the older available universal guide catheters, the newer shapes successfully coaxially engage the right coronary artery greater than 90% of the time and the left coronary artery ~80% of the time, and for an experienced radial operator, the learning curve appears to be less than 10 cases [90].

PCI

TRA has been demonstrated to be an effective method of access for PCI in nearly every clinical/anatomical indication and with most available devices. Although radial artery size generally limits the arterial sheath to 6-French, the increased inner diameter of 5-French and 6-French guiding catheters combined with the decreased profile of balloons and stents has allowed for bifurcation procedures, thrombus aspiration, chronic total occlusion procedures, ostial lesions, rotational atherectomy (with up to 1.5-mm diameter burr size), embolic protection, and so forth [92–95]. In addition, a certain percentage of women and men can take larger diameter sheaths (7-French and 8-French), if needed [96]. Recently a "sheathless technique" with 7-French and 8-French guiding catheters has been described to provide adequate support and a large lumen platform for complex procedures from the radial approach [97].

PRIMARY PCI

Patients presenting with acute STEMI not only benefit from the utilization of aggressive anticoagulant and antiplatelet agents, but also demonstrate higher rates of bleeding complications compared to low risk patients. TRA is therefore an attractive approach for primary PCI [89, 98–104], and the results of a large multicenter study to validate the assertion that TRA will reduce

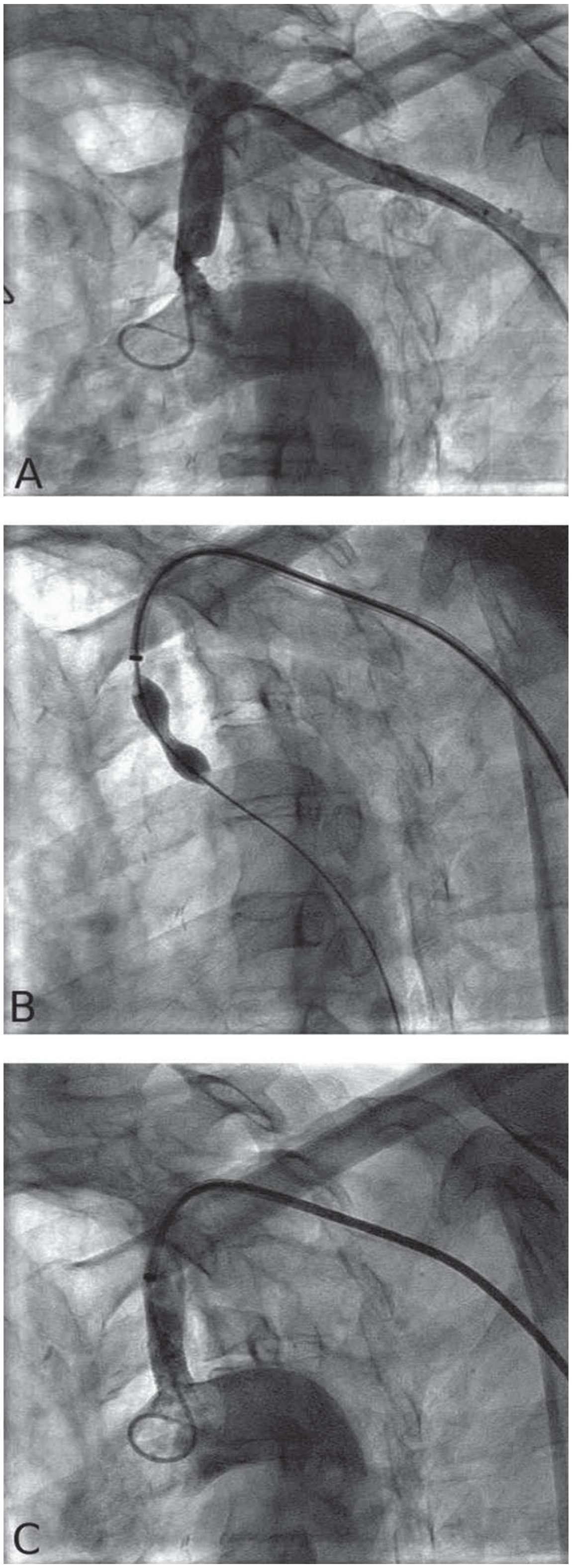

Fig. 2. (A) Left subclavian artery stenosis. (B) Stent deployment left subclavian artery. (C) Left subclavian poststent deployment.

bleeding and improve patient outcomes are forthcoming (RIVAL study).

Certain considerations of primary PCI using TRA should be noted. With TRA, there can be higher procedural failure with the need to cross-over to femoral access (~5% rate), which could negatively impact door to balloon times. Although most series report no delay in time to reperfusion with TRA versus femoral access, others do report delays, one as long as 11 min. In the absence of data from large randomized trials, the clinical impact of any small delay in reperfusion cannot be measured against the benefit of any decrease in bleeding. Because delays appear to be more common with less experienced radial operators, it is suggested that primary PCI via the radial artery be attempted only once the operator is fully facile with complex PCI from this approach. Concurrent preparation of the groin is generally recommended for primary PCI cases planned through the radial artery, so that delay can be minimized if cross-over becomes necessary and the groin is ready to receive large caliber hemodynamic support systems (e.g., intra-aortic balloon pump), should they become necessary. Finally, femoral access may need to be favored in hemodynamically unstable patients, who may not tolerate the spasmolytic cocktail used in TRA.

VEIN GRAFT ANGIOGRAPHY

TRA for angiography and intervention in patients with previous coronary artery bypass grafting (CABG) requires special consideration. In general, the difficulty for operators will surround achieving successful graft cannulation with adequate support. As with the femoral approach, special catheter shapes may be needed for successful engagement, although universal catheters can often be used. Another consideration is the side of entry. The prevalence of left IMA grafts generally requires utilization of left radial artery access. A patient with a previous radial harvest and an ipsilateral intact IMA graft would require contralateral radial access or a femoral approach. Bilateral IMA grafts may also present a challenge from a single radial artery access site. Specific patient selection and catheter selection recommendations have recently been summarized [94, 105–107].

Although TRA for CABG patients may not be recommended for the beginning operator, it can safely be integrated into routine practice as experience increases and TRA appears to result in high success rates, comparable procedure times, and lower vascular complication rates compared to the transfemoral approach.

SHEATH REMOVAL AND RECOVERY

Transient local discomfort during radial sheath removal was historically a consistent finding in a proportion of patients. With the development of hydrophilic sheath coatings, the traction force required for sheath removal has been reduced, and reported pain scores have been markedly lowered, such that significant pain on sheath removal is now an infrequent finding [63, 66].

Regardless of the agent used for anticoagulation, or whether there is concurrent use of intravenous or oral antiplatelet agents, there is no role for measurement of clotting profiles prior to sheath removal. Arterial control is easily maintained by applying external compression. Leaving a sheath in place to await return of clotting times to lower values only exposes the patient to the hazards of ischemia and thrombosis related to prolonged sheath dwell times. As a general rule, the vascular sheath should be removed at the completion of the procedure without delay. Despite the method of compression, the concept of nonocclusive hemostasis is recommended whereby radial artery compression pressure is adjusted to result in both hemostasis and maintained arterial flow. Generally compression is applied for 60–120 min with gradual release of pressure during this time (up to 4 hr if glycoprotein IIb/IIIa inhibitors are used). This method appears to be related to improved long-term radial artery patency [108].

RIGHT HEART CATHETERIZATION

Reports outlining the concurrent use of both arterial and venous access via the arm surfaced in the last decade from several different groups [109–111] with subsequent reports suggesting that this approach may be more efficient than the traditional groin approach [112, 113].

Venous procedures can usually be done without a prophylactic spasmolytic, especially with the small diameter, flexible balloon tip catheters presently available on the market. If it occurs, venospasm responds poorly to calcium channel blockers, making nitrates the vasodilator of choice. Typically, a 20-g IV catheter is placed in a superficial vein by a nurse prior to the procedure. Veins are quite numerous on the forearm, and any nonvaricose vein from the wrist to the antecubital fossa can potentially be used. If superficial veins are not present, vascular ultrasound can identify deeper laying veins as they course next to arteries. The IV catheter is exchanged over a 0.018" wire for a 5-French vascular sheath to provide access for the balloon tipped heart catheter. Although larger French sizes can be used, they are generally not necessary.

Veins on the radial side of the forearm divide equally between the inner brachial vein and lateral cephalic vein, while the ulnar-sided veins tend to drain up the brachial vein into the axillary system [114]. When passing up the cephalic vein, entry into the axillary vein at the shoulder may occur at a "T junction." This may require a wire or deep breath to facilitate passage up into the subclavian vein verses returning back down the axillary vein. Otherwise, passage to the central venous system is typically unremarkable and catheters behave similarly to devices passed from the neck or subclavian vein. As the venous system is low pressure, hemostasis after the procedure is easily achieved.

Challenges of venous access generally stem from prior trauma or medical devices. Prior brachial cutdowns, radiation therapy, widespread surgical dissections for treatment of malignancies of the breast or lymphoma, or trauma, such as a fractured humerus, can result in venous injury and problems with catheter passage. Pacemaker devices and defibrillators with intravenous leads may also cause obstruction from adherent organized thrombus.

With increasing experience, the technique of venous access from the arm, can be applied to other procedures [115]. The veins can expand to take vascular sheaths much larger than one might otherwise place in a radial artery. Endomyocardial biopsy, temporary pacemakers, and access for endovascular procedures such as caval filters are feasible in selective situations [116]. Similar to the radial artery, venous procedures can also be done while patients are fully anticoagulated on warfarin.

PERIPHERAL APPLICATIONS

A few observational studies, feasibility studies, technical reports, case series, and case reports have demonstrated successful application of TRA for addressing peripheral arterial disease (PAD) including internal carotid, vertebral and basilar, subclavian and innominate, renal, iliac, celiac, mesenteric, and superficial femoral artery lesions [117–126]. Importantly, TRA provides an alternative to the femoral approach in patients with severe lower limb and/or aortoiliac vascular disease. Limitations of TRA for the treatment of PAD are mainly related to diameter and distance. Radial artery size may preclude utilization of large diameter equipment (>6-French), and limitations imposed by catheter length may make it impossible to reach arteries distal to the common and external iliacs, especially in taller patients. However, the use of left TRA and a high puncture may provide a solution in many of these cases [120, 127].

TRA for Carotid Artery Intervention

Small feasibility studies using ipsilateral and contralateral TRA for carotid artery stenting have been published [117, 121]. Generally, a 5-French Simmons-1 catheter is used to cannulate the common carotid artery (CCA) for both ipsilateral and contralateral TRA. When contralateral TRA is used, a 5-French Optitorque catheter (Terumo) may be used as an acceptable alternative. A 0.035" Amplatz super-stiff wire is then placed in the external carotid artery, or deep in the CCA away from the origin of the internal carotid artery. Optimal coaxial positioning of a 6-French or 7-French carotid sheath in the CCA is performed over this wire, and the rest of the procedure is performed in a fashion similar to the femoral approach.

TRA for Vertebrobasilar Intervention

Endovascular intervention of vertebrobasilar disease is a relatively new, but alternative modality of management [119, 128]. In performing these procedures, ipsilateral TRA may be preferred, where a 6-French IMA guiding catheter easily cannulates the ostium of the vertebral artery (VA). For addressing ostial VA stenoses, a guiding catheter with side-holes should be used. Standard coronary guidewires, balloon catheters, and coronary stents can generally be used for the intervention.

TRA for Subclavian and Inominate Artery Intervention

Endovascular treatment of subclavian and inominate artery disease has been shown to have a lower complication rate compared with surgical methods, and TRA has been successfully utilized for the treatment of these lesions [129, 130]. A 45-cm long 6-French or 7-French sheath introduced through the ipsilateral TRA is recommended with the distal tip of the sheath placed proximal to the lesion.

Renal Artery Intervention

Although renal artery intervention is typically performed from the femoral artery, TRA has been utilized as an alternative approach [125]. In fact, renal artery stenting from the radial artery can be especially helpful in cases of inferiorly directed renal arteries as the guiding catheter is more coaxial, providing more support and less trauma compared with the transfemoral approach (Fig. 3).

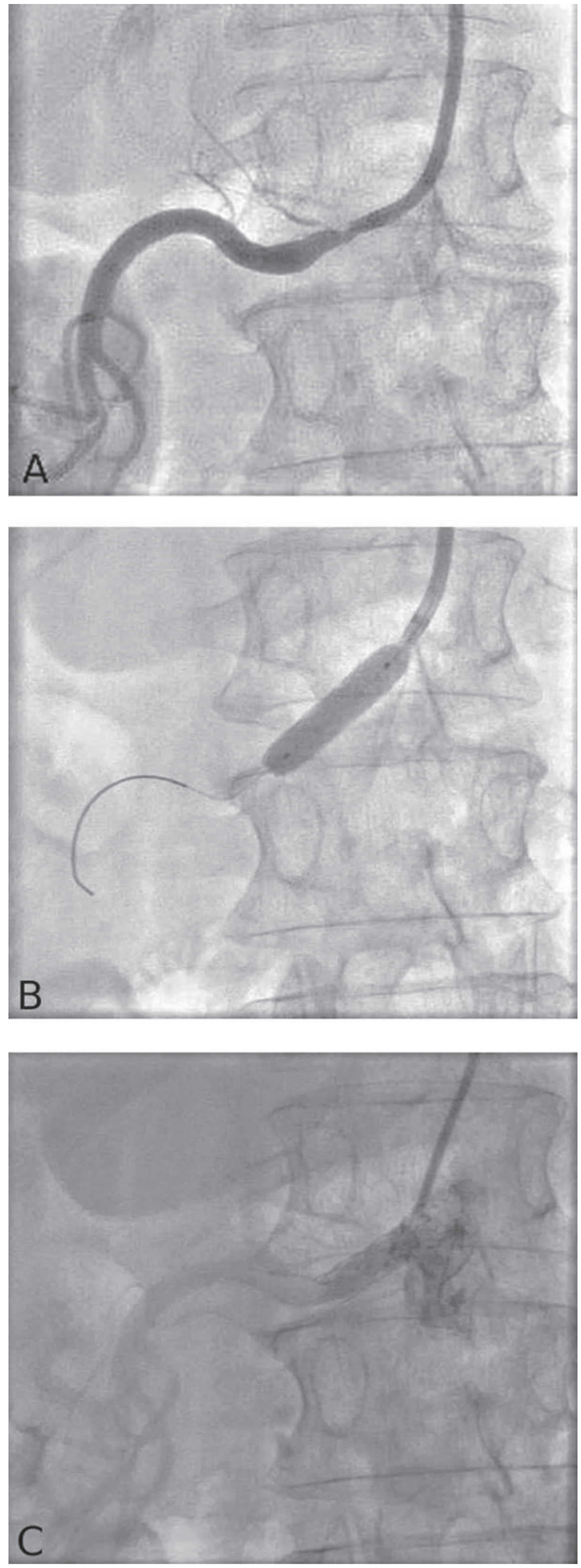

Fig. 3. (A) Right renal artery stenosis. (B) Stent deployment right renal artery. (C) Right renal artery poststent deployment.

TRA for Other Peripheral Applications

Endovascular management of celiac, mesenteric, and superficial femoral arterial systems has also been

TABLE III. Vascular Complications Associated With Transradial Catheterization

Spasm
Bleeding
Hematoma
Compartment syndrome
Perforation, laceration, dissection
Evulsion of artery
Arterio-venous fistula
Pseudo-aneurysm
Subcutaneous granulomatous reaction (hydrophilic coating)
Cutaneous infection
Subacute and delayed occlusion
Digital ischemia
Accelerated atherosclerosis
Transient vocal cord paralysis
Mediastinal hematoma
Delayed reflex sympathetic dystrophy

described [118, 120, 122–124, 126]. Similar to renal arteries, most mesenteric arteries originate from the aorta with an acute inferior angle, especially in very thin patients, giving TRA the advantage of coaxial cannulation with diagnostic or guide catheters.

RADIATION EXPOSURE

Increased operator radiation exposure with TRA has been demonstrated. This results primarily from a more proximate position to the radiation source, and is greater with right compared to left TRA [131, 132]. Medial positioning of the arm following access and attention to radiation shielding helps to mitigate this concern. Radiation exposure decreases as the operator advances along the TRA learning curve. Absolute increases in fluoroscopy time and dose area product with TRA compared to TFA are small, likely representing minimal risk to the patient (0.002% increase in lifetime cancer risk), and must be balanced against the benefits of decreased access site complications and bleeding [133, 134].

MANAGEMENT OF COMPLICATIONS

Like any other artery, puncture, sheath insertion, and catheter manipulation may still result in injury to the radial artery, and TR-specific vascular complications, such as spasm, compartment syndrome, and RAO can occur (Table III). Complications may be more frequent when anatomical variations are present [135–137].

Spasm

The radial artery is a muscular artery with an abundance of α-adrenoceptors in the adventitia, making it particularly reactive to circulating agents and local trauma. Several prophylactic techniques have been developed to reduce spasm including generous patient sedation, a spasmolytic cocktail, and use of a hydrophilic sheath of the smallest possible diameter [138–142]. Wiping and flushing catheters with solutions containing calcium channel blocker or nitrates may also help. When spasm occurs, additional spasmolytic therapy, as well as further analgesic/anxiolytic medications should be considered. Central access should always be maintained with a wire (possibly hydrophilic) so that central arterial access is not lost. The application of warm wraps is another option. Changing for a smaller diameter (4-French) system may also prove beneficial. Papaverine, a direct myorelaxant, has been used [143], and general anesthesia may be needed when other options are exhausted. Very rare cases of partial or complete radial artery evulsion have also been described when operators forcefully removed catheters or sheaths entrapped into diffuse and severe radial artery spasm. Therefore, adequate time should be given to allow the artery to relax.

Hematoma

Hematomas are generally small and easily controlled with manual pressure. A hematoma classification system has been adapted to TRA [144], which can be compared to a recent hematoma scale proposed for the femoral approach [59]. This scale includes a hematoma < 5 cm (grade I), < 10 cm (grade II), distal to the elbow (grade III), and proximal to elbow (grade IV). Hematomas grade III and IV are not directly related to the puncture site, but result from wire damage to vessels and small perforations, and may induce very unusual and very rare hematomas such as a hematoma of the pectoral muscle of the neck, or even a mediastinal hematoma [145–148].

Compartment Syndrome

Compartment syndrome is a limb-threatening emergency that can be avoided if effective preventive measures are put in place as soon as local bleeding is suspected [145, 148]. These include (1) discontinuation of intravenous anticoagulant therapy, (2) control of pain and blood pressure, and (3) use of transient external compression with a blood pressure cuff. Close monitoring of distal perfusion of the hand (plethysmography) and consultation with a vascular surgeon is also recommended so that rapid surgical intervention can be performed in the case of limb ischemia.

Radial Artery Occlusion

Although RAO is clinically insignificant in the face of a patent ulnar artery and palmar arch, it is preferably avoided. Heparin therapy is necessary with TRA to reduce the risk of RAO [149, 150]. Other factors have been implicated with RAO, including large artery-catheter mismatch, female sex, lack of pretreatment with clopidogrel, diabetes, and occlusive hemostasis [96, 108, 150], although it remains undetermined whether RAO can be definitively modulated by the type of hemostatic device used [79]. In addition, prolonged radial artery compression can be associated with persisting occlusion and delayed reflex sympathetic dystrophy [151]. RAO does not seem to be influenced by the use of heparin versus bivalirudin or intravenous versus intra-arterial routes of administration [82, 83], and its incidence decreases with time postprocedure as spontaneous recanalizaton appears to occur in ~50% of patients [150]. Successful retrograde recanalization of RAO has been described, but given the concern for possible emboli and digital ischemia this should be reserved for those patients without other adequate arterial access [152]. Antegrade recanalization should also be avoided due to these same concerns.

Artery Dissection or Perforation

Although fluoroscopy of the arm is unadvised in the case of easy wire passage, angiography of the arm should be performed if there is difficulty with wire or catheter advancement since failure to identify the problem may lead to vessel perforation or dissection. Radial or brachial artery dissection or perforation can produce dramatic angiographic images, but it should be remembered that they represent retrograde events [153]. Rather than aborting the procedure, it is worth trying to carefully re-cross them with a soft 0.014 angioplasty wire. If this attempt is successful, the catheter will usually seal the dissection or perforation, and there will be no clinical consequence for the patient. Aborting the procedure will leave an unsealed dissection or perforation that may be difficult to control [148].

Other Radial Complications

Complications resulting from vessel trauma like pseudo-aneurysm or arterio-venous fistula are rare, presumably due to the small caliber of the vessels. Such complications are usually managed by repeat and prolonged compression, and do not require surgical intervention. The use of a certain type of hydrophilic-coated sheath (Cook Medical, Bloomington, IN) has been associated with severe granulomatous reactions of the skin that were attributed to foreign-body reaction, but could resemble cutaneous infection [154–156]. This has not been found to occur with other hydrophilic-coated sheaths.

Procedural Failure

Procedural failure can be due to an inability to gain radial artery access or an inability to successfully engage the coronary arteries. The later may be due to anatomic variations or severe tortuosities in the radial, brachial, or subclavian arteries [135–137]. Procedural failure lessens with experience, and ultimately occurs with a frequency of less than 5% [135, 140].

TRAINING AND CREDENTIALING

In the United States, the majority of training in Interventional Cardiology occurs in Accreditation Council for Graduate Medical Education (ACGME) accredited Cardiology (level 1 and 2) and Interventional Cardiology (level 3) programs. However, current training program guidelines are vague, providing no specific recommendations regarding training for TRA [157]. The American College of Cardiology (ACC) Core Cardiology Training Symposium (COCATS) guidelines state that one needs the ability to "perform vascular access from the femoral, radial, or brachial route" [158]. Likewise, the current ACGME Program Requirements for Graduate Medical Education in Interventional Cardiology states that "Fellows must have formal instruction, clinical experience, and must demonstrate competence in the performance of...coronary interventions [via] femoral and brachial/radial cannulation of normal and abnormally located coronary ostia." Despite these requirements, there is no definition of competency with regard to TR procedures for either graduating fellows or practicing invasive/interventional cardiologists who receive postgraduate training.

The timing and approach to TR training for fellows remains undefined. Whether TR training should start early in fellowship, along with the femoral approach, or later in the fellowship after adequate femoral training, proficiency, and "comfort" are achieved is still an area of debate. Ideally, interventional fellows would graduate with equal competency in radial and femoral procedures. As practicing invasive/interventional cardiologists, then, they would then be able to choose their approach based on patient factors rather than a lack of knowledge and skill. Achieving equal competency would suggest that TR training should begin at the same time as femoral training, which is currently occurring successfully at several U.S. centers. However, the shortage of invasive/interventional cardiologists at academic centers who are able to adequately train the next generation in TR procedures remains a current barrier to fellowship training in TRA.

With the increasing interest in TRA in the United States, there is a growing demand for TR training among practicing invasive/interventional cardiologists. There are no published requirements for postgraduate TR training and generally experience is acquired through formal and informal 1–2 day programs. Formal training involves in-person interactive teaching and proctorship. Informal training involves didactic lectures, reading, instructional videos, and simulator training.

Objectives for Training

Specific objectives for transradial training include acquisition of knowledge and competence regarding:

1 Basic anatomy related to the upper extremity vasculature.
2 Patient evaluation and selection for TRA.
3 Selection of right or left TRA.
4 Patient preparation and room set-up.
5 Specific methods and equipment designed to optimize TRA.
6 Pharmacologic considerations related to TRA.
7 Obtaining radial artery access.
8 Catheter selection and manipulation from the upper extremity.
9 Basic trouble-shooting during TRA.
10 Recognizing and managing complications related to TRA.
11 Sheath removal and access site management.

The Learning Curve

The learning curve has traditionally been considered to be longer for TRA compared to the transfemoral approach. However, the data from which this conclusion was drawn studied operators learning the technique in the setting of a clinical practice rather than trainees learning multiple access approaches simultaneously within a fellowship program [159, 160].

Competency

Currently, there are no standard definitions or guidelines for competency. A scaled competency is proposed:

- Level 1 competency: Able to perform simple diagnostic cases on patients with favorable upper limb anatomy (large men).
- Level 2 competency: Able to perform simple diagnostic and interventional procedures on patients with more challenging upper limb anatomy (elective single vessel PCI; bypass grafts, small women, radial and subclavian loops).
- Level 3 competency: Able to perform complex interventional procedures even with challenging limb anatomy (CTOs, multivessel, AMI).

The number of cases required for competency will generally correlate with the experience and expertise of the operator. New fellows in training need extended exposure, as is already outlined in training program guidelines. On the other hand, an experienced invasive or interventional cardiologist can achieve basic levels of competency quite quickly.

SUMMARY

TRA for percutaneous revascularization has seen steady growth worldwide since the initial experience described by Campeau in 1989 [1]. Benefits to TRA include a lower incidence of access site and bleeding complications, higher patient satisfaction, and potentially lower overall costs compared to transfemoral access. TRA has been successfully utilized for a variety of indications including primary PCI, bypass graft angiography and PCI, and noncoronary revascularization. However, guidelines regarding training and competency are lacking, and will need to be more clearly defined as the current trend of increasing adoption continues in the United States.

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