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Core Curriculum

Best Practices for Transradial Angiography and Intervention: A Consensus Statement From the Society for Cardiovascular Angiography and Intervention's Transradial Working Group

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INTRODUCTION

The radial approach to angiography and intervention has emerged internationally as the preferred alternative to the traditional femoral approach [1]. Multiple observational and randomized trials performed to date have shown an association between radial access and reduced risk for bleeding and vascular complications [2]. Other studies have shown an association between radial approach and reduced costs [3], increased patient satisfaction [4,5], and reduced mortality in high-risk patient subgroups like those with ST-segment elevation myocardial infarction (STEMI) [6]. Disadvantages include increased radiation exposure to the operator during the learning curve, limitation of guide catheter size in some patients, and radial artery occlusion. The increased understanding of the potentially favorable risk:benefit ratio of transradial procedures has led to a near 10-fold increase in the adoption of radial access in the United States between 2007 and 2011 [7]. Concomitant with this surge in radial approach has been a proliferation of studies that have examined various technical aspects and outcomes from transradial procedures. Transradial angiography and intervention was once largely guided by anecdote and case series reports, but now there is a solid evidence base to guide some aspects of radial practice. The purpose of this document is to provide consensus opinion on what is considered "best practice" for facets of radial procedures where there is supportive evidence in order to maximize the benefits, standardize certain practices to minimize complications, and summarize areas that need further study.

METHODS

Society for Cardiovascular Angiography and Intervention Radial Committee

The Society for Cardiovascular Angiography and Intervention (SCAI) has formed a committee of members to focus specifically on radial procedures. Membership is open to any member of SCAI. The committee is tasked with planning and executing radial training programs and generating SCAI-approved statements that relate to transradial practice.

Selection of Topics

The SCAI Radial Committee decided upon topics selected for the present "best practices" statement by consensus. The decision was guided by patient-level and operator-level outcomes as well as the amount and quality of evidence to guide a specific practice. Randomized clinical trial data was considered to be the highest level of evidence followed by observational studies that reported adjusted outcomes. No formal grading of evidence was undertaken. The topics for inclusion were then selected from candidate topics by committee consensus. Three topics emerged as the focus of the statement: (1) monitoring for and reducing the risk of radial artery occlusion, (2) reducing patient and operator radiation exposure during radial procedures, and (3) transitioning to transradial for primary PCI. Three other topics, felt to be important, but in need of further study, are also discussed: (1) the role of preprocedure testing for dual circulation, (2) the optimal antithrombotic strategy for transradial PCI, and (3) the elements of a successful transradial training program. The Radial Committee discussed the evidence supporting practices for each topic and final recommendations were formulated through consensus. If randomized trials or observational studies were not available, recommendations were formulated through consensus of the committee members.

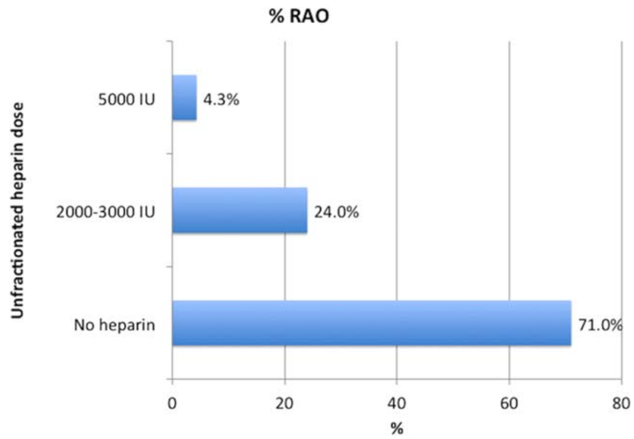

Fig. 1. Relationship between unfractionated heparin dose and radial artery occlusion. (Adapted from Spaulding et al.) (22); RAO = Radial Artery Occlusion. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

RECOMMENDATIONS

Monitoring for and Reducing the Risk of Radial Artery Occlusion

1. Patients undergoing transradial procedures should have radial artery patency assessed before discharge and at the first postprocedure visit
2. Adequate anticoagulation should be administered to patients undergoing diagnostic transradial procedures. The recommended regimen is intra-arterial or intravenous unfractionated heparin at a dose of at least 50 u/kg or 5,000 units in patients without contraindications to unfractionated heparin (Fig. 1). Patients with heparin-induced thrombocytopenia

TABLE I. Strategies Associated With a Reduced Risk for Radial Artery Occlusion

Reduces risk	May reduce risk	No effect or increases risk
Anticoagulation[a]	Enoxaparin[b]	Sheath length
Patent (nonocclusive) hemostasis	Hydrophilic sheaths	Sheathless guide catheters
Sheath diameter less than radial artery diameter	Routine use of drugs to reduce radial artery spasm	
Avoiding repeated access of the radial artery	Limiting the duration of radial artery compression	

[a]Agents include unfractionated heparin 70 units/kg up to 5000 units and bivalirudin 0.75 mg/kg bolus followed by 1.75 mg/kg/hr infusion during procedure.
[b]Studied dose is 60 mg given through the radial arterial sheath.
Adapted from Rao SV. Observations from a transradial registry: Our remedies oft in ourselves do lie. JAMA 2012;5:44–46.

TABLE II. Steps in the Patent Hemostasis Process After Transradial Procedures

Step 1: Withdraw the arterial sheath 2–3 cm.
Step 2: Apply the hemostatic compression device, 2 to 3 mm proximal to the skin entry site, and tighten it or inflate it, then remove the sheath.
Step 3: Decrease the pressure of the hemostatic compression device to the point of mild pulsatile bleeding at the skin entry site. After 2 to 3 cycles of pulsatile bleeding, retighten the hemostatic compression device gradually to eliminate this pulsatile bleeding.
Step 4: Evaluate radial artery patency by using the reverse Barbeau's test:
Place the plethysmographic sensor on the index finger of the involved upper extremity with the observation of pulsatile waveforms
Compress the Ulnar artery at the level of the wrist, and observe the behavior of the waveform.
Absence of plethysmographic waveform is indicative of interruption of radial artery flow.
If this occurs, the hemostatic compression pressure should be lowered to the point where plethysmographic waveform returns. This is evidence of antegrade radial artery flow.

with or without thrombosis should receive intravenous bivalirudin 0.75 mg/kg bolus for diagnostic cases; for PCI, this bolus dose of bivalirudin should be followed by an infusion of 1.75 mg/kg/hr.
3. Transradial procedures should be performed using the lowest profile system available to successfully complete the procedure and obtain optimal angiography.
4. Patent hemostasis technique should be used in all patients who undergo transradial procedures

An important limitation of transradial catheterization and intervention is radial artery occlusion (RAO). A recent international survey of transradial practice showed that only half of physicians performing transradial catheterization routinely check for radial artery patency before discharge [8]. Although most radial occlusions may be asymptomatic, there are several reasons to preserve radial patency. First, not all RAO is asymptomatic and cases of hand ischemia have been reported [9]. Second, RAO that persists makes repeat procedures through the ipsilateral radial artery either impossible or more complex requiring angioplasty of the occluded radial artery. Finally, maintaining radial artery patency is also important in case the artery is needed as a conduit for intra-arterial pressure monitoring, coronary artery bypass surgery, or hemodialysis access. Based on these considerations, it is recommended that all patients who undergo transradial procedures be monitored for RAO before discharge as well as during the initial post-procedure follow-up visit. This can be either be done using ultrasound or by using the "reverse" Barbeau test (Table II). In addition, it is recommended that strategies to minimize RAO be used by operators in all patients undergoing transradial procedures. Table I lists the evidence-based practices that are either proven to reduce RAO risk or are likely to reduce RAO risk. The most important practice that reduces the risk of RAO is nonocclusive or "patent" hemostasis (Table II).

Reducing Patient and Operator Radiation Exposure

1. In addition to following SCAI recommendations for minimizing radiation exposure, operators performing transradial procedures should position the patient's accessed arm next to the patient's torso
2. There is a relationship between radial proficiency and a decrease in patient and operator radiation exposure such that exposure between radial and femoral is comparable among experienced radial operators. Thus, operators should make an effort to maintain a high proportion of transradial procedures in their practice.
3. The use of extension tubing to increase the distance from the radiation source should be considered for transradial procedures.
4. Left radial approach has been associated with shorter fluoroscopy times and should be considered in patients where tortuous vascular anatomy is expected (e.g., age > 75 years, short stature)

TABLE III. Recommended Practices to Reduce Radiation Exposure During Transradial Procedures

General measures
Increase distance from image intensifier
Use low intensity fluoroscopy and low-frame rate for cine acquisitions whenever possible
Utilize standard shielding (lead gown/vest, drape, lead shield, thyroid collar)
Specific measures for transradial procedures
Use of a radial-specific radiation drape [16]
Use of a radiation board [15]
Avoid routine fluoroscopy/cineangiography of upper arm
Utilization of the left radial approach [13,17]
Under table leaded flaps

5. Operators should avoid fluoroscopically tracking the guidewire and/or catheters while traversing the arm unless resistance is felt.
6. Catheter exchanges should be performed without fluoroscopy whenever possible
7. Documentation of angioplasty balloon and stent positioning should be done using "fluoro save" if available.

A consistent finding across studies comparing radial and femoral approaches is the increased radiation exposure for the patient and operator with radial procedures [10]. In one of the largest studies on this topic that studied diagnostic catheterization procedures from multiple operators, radial access was associated with a 23% increase in radiation exposure over transfemoral procedures, a difference that was similar across operators with varying radial experience [11]. Limiting radiation exposure during transradial procedures is an important safety goal. There are few randomized trials comparing strategies to reduce radiation exposure; however, given the increasing number of operators who are adopting the radial approach (and the increasing number of patients undergoing radial procedures), the recommendations of the committee reflect a consensus and include strategies that apply to transfemoral procedures as well.

Radiation shielding for invasive cardiac procedures is covered in detail elsewhere and readers are referred to the SCAI document on radiation safety [12]; however, there are issues regarding radiation protection specific to radial procedures (Table III). Specific devices designed to reduce radiation exposure during RRA have recently been reported. Use of an extension tube between the proximal part of the coronary catheter and the manifold showed a nonsignificant trend toward lower left-arm operator exposure (28.7 ± 31.0 μSv vs. 38.4 ± 44.2 μSv, $P = 0.0739$) [14]. A transradial radiation protection board has been specifically designed to rest in a plane tangential to the cath table, between the patient's arm and side, which is associated with a significant reduction in operator radiation exposure compared with control (19.5 [10.5–35] μSV versus 28 [18–65] μSV, $P = 0.003$) [15]. Finally, a small study examining the use of a lead-free radiation shield over the right radial sheath insertion site showed a 13–34% reduction in operator radiation exposure [16]. Another issue to consider is the routine use of the left radial artery, which is associated with shorter procedure times, particularly among patients over the age of 75 years and those with short stature [17]. The most important predictor of both patient and operator radiation exposure with radial approach may be operator proficiency. Two recent studies, including a substudy from the RIVAL trial [18], have shown that increasing operator experience with radial approach is associated with decreasing patient and operator radiation exposure such that very proficient radial operators have been able to largely minimize the differences between radial and femoral access [19].

Transitioning to Transradial Primary PCI

1. Operators and sites should not start performing transradial primary PCI until they have performed at least 100 elective PCI cases with a "radial first" approach and their femoral crossover rate is $\leq 4\%$.
2. An a priori left radial approach should be strongly considered in patients undergoing transradial primary PCI who are post-CABG with a pedicle LIMA graft.
3. An a priori left radial approach should be considered in patients undergoing transradial primary PCI who are older than age 75 years or who are 5′5″ (165 cm) or shorter.
4. Bailout to either contralateral radial or femoral access is recommended if the time to obtain radial access is > 3 min, or the time from introducer sheath placement in the radial artery to engaging the infarct-related artery with the guide catheter is > 10 min (including the time to inject the non-infarct artery), or the total time from radial artery introducer sheath placement to dilating the infarct lesion is > 20 min.
5. Door-to-balloon times should be monitored closely when starting a transradial primary PCI program and cases with times that extend beyond recommended benchmarks should be reviewed to identify whether the radial approach was responsible for the delay.
6. Femoral access sites should be prepared routinely in patients with STEMI when the operator is early in their experience with transradial primary PCI or when the need for adjunctive devices like intra-aortic balloon counterpulsation is anticipated

TABLE IV. Summary of Time Metrics from Studies Comparing Transradial and Transfemoral Primary PCI

Study [Reference]	Study design	Total N (Radial N)	Crossover rate (*R* vs. *F*) %	D to B time (min) (*R* vs. *F*)	Procedure time (min) (*R* vs. *F*)
[23]	Prospective observational at 2 sites	Site A: 1069 (180) Site B: 145 (87)	2 vs. 0 4 vs. 0	Not reported	Site A: 45 vs. 43 Site B: 67 vs. 68
[24]	Prospective observational	726 (163)	1.2 vs. 0	Not reported	62 vs. 61
[25]	Retrospective observational	353 (132)	4.1 vs. 0	Not reported	43 vs. 47
[26]	Retrospective observational[a]	155 (87)	8 vs. 0	Not reported	50.4 vs. 38.8
[27]	Prospective observational	240 (124)	4.8 vs. 0	76.4 vs. 86.5	
[28]	Retrospective observational	1316 (506)			40.5 vs. 51.3
[29]	Prospective observational	1051 (571)	7.7 vs. 0.6	46 vs. 67	
[30]	Prospective observational	489 (254)	10.1 vs. 1.2	123 vs. 129	
[31]	Retrospective observational	360 (109)	0.9 vs. 0	70 vs. 72	74 vs. 76
[32]	Randomized	149 (77)	0 vs. 1.5	Not reported	44 vs. 51
[33]	Randomized (PPCI or rescue)	50 (25)	4 vs. 0	Not reported	
[34]	Randomized	370 (184)	1.6 vs. 1.1	Not reported	56.2 vs. 54.8
[35]	Randomized (PPCI or rescue)	114 (57)	12.3 vs. 1.8	Not reported	28 vs. 26
[36]	Randomized	103 (57)	1.8 vs. 0	16.2 vs. 15.4	44.1 vs. 41.2
[37]	Randomized	100 (50)	2 vs. 2	76.9 vs. 64.6	58.3 vs. 55.1
[38]	Randomized	200 (100)	4 vs. 0		37.2 vs. 35.7
[5]	Subgroup of a randomized, multicenter trial	1958 (955)	5.3 vs. 1.6		

[a]Primary or rescue PCI, age > 70.

The use of radial access for primary PCI in STEMI potentially affords the greatest opportunity to improve outcomes compared to femoral access. Patients presenting with STEMI are frequently placed on aggressive anticoagulant and anti-platelet therapies that increase their risk of vascular access site complications. The prespecified STEMI subgroup from the randomized RIVAL (RadIal V. femorAL for coronary intervention) study showed an association between radial access and reduced mortality compared with femoral access [5]. These data, along with the RIFLE-STEACS trial [20] provide evidence supporting a mortality benefit of transradial primary PCI when performed by experienced operators.

An important issue to consider in the context of transradial primary PCI is the door-to-balloon time (D2B). Transradial PCI cases may prolong this important quality metric due to difficulty in obtaining arterial access, variations in arm or chest arterial vasculature making access to the coronary arteries difficult, or variations in aortic root architecture complicating guide catheter engagement of the coronary arteries. While this concern may be well founded and fluoroscopy times are longer with the radial approach [21], a relationship between radial approach and prolonged time to reperfusion is not consistently borne out in the literature [21,22]. Based on these data, if transradial primary PCI prolongs time to reperfusion, it does not appear to be a clinically significant difference provided that the operator and center are experienced with radial approach. Indeed, the trials analyzed in both meta-analyses included very experienced radial operators and centers.

The committee considered the evidence for transradial primary PCI against the backdrop of longer times to reperfusion. Given that delayed reperfusion adversely affects patient outcomes and negatively impacts quality metrics, recommendations for transradial PCI must take into account two main factors: (1) strategies to minimize procedure times and (2) defining appropriate benchmarks for when "bailout" to the femoral approach is necessary. Further, the patients included in the RIVAL and RIFLE-STEACS trials included selected patients with STEMI and some high risk subsets like those with shock may not be suited for radial approach by operators who are not experienced with transradial primary PCI. Table IV lists access site crossover rates and procedure times from observational and randomized studies comparing radial with femoral access for primary PCI. It is challenging to determine when an operator has "sufficient" transradial experience for performing transradial primary PCI. The committee's recommendations reflect consideration of the relationship between radial experience and decreased procedure failure and procedure time [39], and relying solely on a specific volume cutoff. Importantly, the committee felt that it was mandatory to measure door-to-balloon metrics once a transradial primary PCI program is established so that any upward "creep" in D2B beyond the recommended benchmarks can be identified. Once identified, corrective action may include a requirement for more elective transradial PCI experience before continuing to perform transradial primary PCI.

TABLE V. Arguments Both For and Against Routine Clinical Testing of Collateral Hand Circulation Before Arterial Cannulation During Transradial Cardiac Catheterization

Reasons to routinely test for collateral flow	Reasons why routine testing is not necessary
Demonstrates the presence of collaterals through the palmer arch	Other routes of collateral flow also exist and may not be recognized
Radial arteries are vital if collaterals are not present	Surgical experience has shown no ischemia in patients with abnormal collaterals and radial harvest for bypass.
Radial artery occlusion in the setting of an abnormal collateral test may result in hand ischemia	There are no definitive reports of hand ischemia as a direct result of poor collateral circulation.
Hand ischemia could be a devastating complication	Ischemic symptoms are the result of distal embolization into fingertips or nerve injury and not prevented by intact radial flow.
Normal collaterals suggest the chance of ischemic hand complication is lowest	Hand ischemic complications have not been associated with the status of the collateral testing preprocedure.
Abnormal collateral testing is an indication for transfemoral approach	Net risk still favors the radial due to known risk of femoral artery complications
Attention to detail of collateral circulation is important part of procedure	Collateral testing take time and focus off of the important issue at task, evaluation of heart disease
Protection from legal suits	Claims based on radial artery complications are rare compared to femoral artery claims

AREAS NEEDING MORE RESEARCH

Role of Preprocedure Testing for Dual Circulation of the Hand

An area of controversy is the need for testing collateral circulation in the hand before performing transradial procedures. Although the clinical Allen's test relies on visual assessment of the hand, an alternative has been described using the pulse oximetry probe and plethysmography ("Barbeau" test) [40]. While the latter modification suggests a measure of objectivity, the fundamental question is whether the results of the test are predictive of hand ischemia when RAO occurs. The bulk of the literature examining this issue is in the critical care setting among patients with indwelling radial artery pressure monitoring catheters. There are several case series of patients with indwelling radial arterial lines who developed ischemic complications, but these complications had no correlation to the results of tests assessing the presence of collateral circulation before cannulation [41,42]. Case series of patients with abnormal collateral flow who have had radial artery harvesting for use as bypass grafts have reported no postoperative hand ischemia [43]. With a lack of outcome data that demonstrates the predictive value of testing for dual circulation, some radial operators have moved away from routine use of such tests [8]. Even in the setting of litigation risk, claims related to femoral artery complications overshadow claims related to radial artery complications [44]. Arguments for and against testing are shown in Table V.

Optimal Antithrombotic Strategy for Transradial PCI

Antithrombotic therapy is essential during PCI to reduce thrombotic complications but increases the risk for access-site and nonaccess site bleeding [45]. Both types of bleeding are associated with an increased risk for long-term mortality, but the risk appears higher with nonaccess site bleeding [46]. Several pharmacological bleeding avoidance strategies have been studied in the setting of PCI. These include appropriate dosing of antithrombin and antiplatelet agents [47], intravenous enoxaparin [48], and bivalirudin [49]. Although both observational and randomized studies have shown that these therapies reduce the risk of bleeding compared with heparin with or without glycoprotein IIb/IIIa inhibitors, the majority of the patients in these studies underwent transfemoral PCI. Since radial access virtually eliminates the risk of access-site bleeding compared with femoral access, it is tempting to assume that more potent antithrombotic therapies can be used during transradial PCI. Whether this maximizes both safety and efficacy is unclear due to the absence of large-scale studies involving both radial access and different anticoagulant strategies. Moreover, there are no randomized studies specifically comparing different antithrombotic combinations and different vascular access strategies. Such trials are currently ongoing (clinicaltrials.gov identifiers NCT 01398254, NCT 01433627, NCT 01084993) and will inform the optimal antithrombotic strategy for transradial PCI.

Elements of a Successful Transradial Training Program

As practicing invasive/interventional cardiologists in the United States increasingly take interest in performing transradial procedures, there is a growing need for efficient, high-quality, and personalized transradial training programs that educate the entire catheterization laboratory team. Although there is an association

TABLE VI. Proposed Curriculum Content of Structured Basic and Advanced Transradial Training Courses

Basic training course
Basic anatomy related to the upper extremity vasculature
Patient evaluation and selection
Patient preparation and room set-up, minimizing radiation
Obtaining radial artery access
Pharmacologic considerations (minimizing spasm and radial artery occlusion)
Catheter manipulation through the upper extremity
Catheters and guides for transradial procedures
Basic trouble-shooting during TRA
Recognizing and managing complications related to TRA
Right Heart Catheterization from the arm
Sheath removal and access site management
Advanced (master's) training course
Reiteration/refinement of basic techniques
Transradial procedures in high-risk subsets (LM, CTO, etc.)
Maneuvering through the most difficult anatomy
When and how to establish a transradial STEMI program
Performing sheathless procedures
Same-day PCI
Recent advances in the field

between the volume of radial procedures performed and reductions in procedure time [39], the shape and slope of the radial "learning curve" is less clear. A study performed among Canadian operators indicated that a case volume of 50 transradial PCIs was sufficient to demonstrate a plateau in procedure metrics such as procedure time, fluoroscopy time, and procedure success [50]. Whether these data are applicable to other countries where total PCI volumes may be less or more, or to all operators across whom technical proficiency may vary is unknown. It is likely that the learning curve may be higher (100–150 procedures) for some operators. Given the association between volume and outcomes, it is likely that the relationship between radial volume and proficiency is a continuum.

There are no formal guidelines for the number of radial cases a trainee should complete during general or interventional cardiology fellowship training, nor are there guidelines on a minimum number of transradial PCIs that operators should perform to maintain proficiency. The COCATS guidelines for training in diagnostic and interventional catheterization currently state that "exposure" to radial, femoral, and brachial access is necessary [51]. Table VI lists proposed curriculum content of structured basic and advanced transradial training courses. The effectiveness of existing training programs at encouraging and sustaining an attendee's radial practice is unknown. It is likely also important to have specific training for nurses and technicians. The role of simulators in radial training remains to be elucidated, as does the role of proctoring programs where a radial expert spends 1–2 days at a center to facilitate radial cases. Future research should focus on which formats are most effective at not only imparting knowledge regarding radial procedures but also practical clinical skills that focus on diagnostic angiography, PCI, and recognition and management of complications.

CONCLUSIONS

As the adoption of radial approach continues to increase worldwide, it is important to develop and expand the evidence base that underlies its use. The present document outlines evidence-based best practices as they relate to three important aspects of transradial procedures and summarizes areas needing further study. Although the recommendations made in this document are based on the highest level of evidence available, they are ultimately a result of expert consensus. As such, they should be revised as the literature continues to evolve.

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