Received: 6 December 2019 | Accepted: 12 December 2019
DOI: 10.1002/ccd.28672

CLINICAL DECISION MAKING

WILEY

SCAI expert consensus statement update on best practices for transradial angiography and intervention

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Abstract

Transradial angiography and intervention continues to become increasingly common as an access site for coronary procedures. Since the first "Best Practices" paper in 2013, ongoing trials have shed further light onto the safest and most efficient methods to perform these procedures. Specifically, this document comments on the use of ultrasound to facilitate radial access, the role of ulnar artery access, the utility of non-invasive testing of collateral flow, strategies to prevent radial artery occlusion, radial access for primary PCI and topics that require further study.

1 | INTRODUCTION

In 2013, the Society for Cardiovascular Angiography and Interventions (SCAI) published an expert consensus statement on "Best Practice for Transradial Angiography and Intervention".[1] Since the publication of that document, the body of evidence for both the technical aspects of the transradial procedures and their application has considerably increased. Notably, the prior document outlined areas needing further research, and many of these areas have been subject of either randomized or observational studies in the last several years. To summarize the available contemporary data and provide consensus on how these data should be applied in clinical practice, SCAI convened a panel of experts to update the "Best Practice for Transradial Angiography and Intervention."

2 | METHODS

This document has been developed according to SCAI Publications Committee policies for writing group composition, disclosure and management of relationships with industry (RWI), internal and external review, and organizational approval. The writing group has been organized to ensure diversity of perspectives and demographics, multi-stakeholder representation, and appropriate balance of RWI. Relevant author disclosures are included in Table S1. Before appointment, members of the writing group were asked to disclose all relevant financial relationships with industry (>$25,000) from the 12 months prior to their nomination. A majority of the writing group disclosed no relevant financial relationships. Disclosures were periodically reviewed during document development and updated as needed. SCAI policy requires that writing group members with a current financial interest are recused from participating in discussions or voting on relevant recommendations. The work of the writing committee was supported exclusively by SCAI, a nonprofit medical specialty society, without commercial support. Writing group members contributed to this effort on a volunteer basis and did not receive payment from SCAI.

Literature searches were performed by group members designated to lead each section and initial section drafts were authored by the section leads. The authors prioritized randomized clinical trials or large observational studies to formulate recommendations. As this work is an update to a prior document, the writing group solicited publications from the past 5 years for topics previously covered. Search terms for the various sections are included in Table S2. Recommendations were discussed by the full writing group on a series of teleconferences until all group members agreed on the text and qualifying remarks. All recommendations are supported by a short summary of the evidence or specific rationale.

The draft manuscript was peer reviewed in June 2019 and the document was revised to address pertinent comments. The writing group unanimously approved the final version of the document. The SCAI Publications Committee and Executive Committee endorsed the document as official society guidance in November 2019.

SCAI consensus statements are primarily intended to help clinicians make decisions about treatment alternatives. Clinicians also must consider the clinical presentation, setting, and preferences of individual patients to make judgments about the optimal approach.

3 | ULTRASOUND GUIDANCE FOR ARTERIAL ACCESS

3.1 | Recommendations

1. Operators should develop proficiency with ultrasound guidance to facilitate forearm vascular access.
2. Real-time ultrasound guidance should be available and used when difficulty with radial access is encountered or expected.

Inability to cannulate the radial artery is the predominant (57%) failure mode for transradial procedures.[2] While the radial artery is superficial and generally easily palpated, it is relatively small (2.2–2.6 mm diameter), approaching the discrimination threshold of human sensation. Radial arteries may be calcified, diminutive, or have proximal anatomic variants that complicate vascular access. The use of two-dimensional ultrasound can be useful for preprocedure planning and assessment of radial artery size and anomalies,[3] and for real-time access guidance. Ultrasound can image the radial artery location, radial veins, needle tip, and wire, confirming arterial puncture and intraluminal wire position before sheath insertion. Operator expertise with a probe and needle angulation is necessary for successful ultrasound imaging, with initial experience best obtained with routine use on normal arteries rather than on the most challenging ones.

In addition to multiple small single-center studies, a 698 patient multicenter randomized trial demonstrated a reduced number of attempts (1.7 vs. 3.1, $p < .01$), improved first-pass success (65% vs. 44%, $p < .01$), and reduced time to access (88 vs. 108 s, $p < .01$) with ultrasound guidance.[4] Ultrasound was successful in rescuing failed palpation access in 80% of cases, reduced the rate of access site crossover from 5.7 to 1.4% ($p = .004$) and the number of difficult procedures (requiring 5 or more attempts) from 18.6 to 2.4% ($p < 0.001$). There was no difference in pain scores, spasm, or bleeding, indicating that ultrasound guidance improves procedural efficiency and success. The most recent meta-analysis of 12 trials of ultrasound-guided radial access in 2,432 adults in various clinical settings similarly showed an improved first-attempt success rate (risk ratio [RR] 1.35, 95% CI 1.16–1.57]) and decreased failure rate (RR 0.52, 95% CI 0.32–0.87).[5]

Ultrasound guidance can be particularly useful for patients with weak radial pulses, female gender, or peripheral vascular disease as such patients tend to have higher rates of radial access failure and access site crossover. Preprocedure ultrasound assessment can assist with selection of sheath size or alternative forearm access (i.e., ulnar) or when the radial artery is particularly small, potentially reducing the risks of radial spasm and radial artery occlusion.

4 | ULNAR ARTERY ACCESS

4.1 | Recommendations

1. Radial artery access is preferred over ulnar artery access in most situations.
2. The ulnar artery may be a reasonable alternate access site when the risks of radial access failure or complication are high (e.g., small radial diameter, calcification, tortuosity, or anatomic anomaly).
3. The ipsilateral ulnar artery may be a reasonable secondary access site after failed radial access; however, the data are limited.
4. In cases of radial artery occlusion, there are insufficient data to provide a recommendation on the use of the ipsilateral ulnar artery over alternate access sites such as the contralateral radial or femoral arteries.

The ulnar artery has emerged as an alternative access route for coronary angiography and intervention. While on average, the diameter of the ulnar artery is larger than the radial artery, potential disadvantages of ulnar access include its proximity to the ulnar nerve, deeper location, and the absence of an underlying bone to facilitate hemostasis.

4.2 | Ulnar artery versus radial artery as primary access site

Several clinical trials of cardiac catheterization and PCI via the ulnar approach have evaluated its suitability compared to the transradial approach (Table 1). Most found ulnar to be noninferior compared to radial access in terms of primary outcomes.

In the Transulnar or Transradial Instead of Coronary Transfemoral Angiographies Study (The AURA of ARTEMIS Study),[7] 902 patients were randomized in a prospective, multicenter, parallel group study in a 1:1 ratio to either radial access (n = 440) or ulnar access (n = 462). Although the study was prematurely terminated, predominantly due to a higher rate of crossover in the ulnar group, the study was performed by operators without any significant experience with ulnar access and without the use of ultrasound guidance. The ulnar approach was found to be noninferior to the transradial approach with respect to primary endpoints including MACE and vascular complications at 60 days.

A meta-analysis of five randomized controlled trials comparing transulnar to transradial access was performed involving 2,744 patients with 1,384 transulnar cases and 1,360 transradial cases included in the analysis.[11] There was similar efficacy and safety with transulnar compared to transradial access; however, there was a higher number of puncture attempts and access site crossover rates. Of note, the trials were also heterogeneous and underpowered for safety.

4.3 | Ulnar access after failed radial access

The use of the ipsilateral ulnar artery following failed radial access has also been investigated. Agostoni et al. collected data from five operators performing 2,403 procedures.[12] In the event of failed radial sheath insertion, an attempt to cannulate the ipsilateral ulnar artery was mandated, provided the ulnar pulse was palpable. Among the 117 patients with radial failure, 75 patients were due to lack of support or prohibitive subclavian/brachial tortuosity. Of the remaining 42 patients, ipsilateral ulnar access was attempted and successful in 36 patients (85.7%). No cases of early hand ischemia were reported.

4.4 | Ulnar access in the setting of ipsilateral radial artery occlusion

Similarly, in a single-center prospective registry of 476 consecutive patients who underwent transulnar catheterization by experienced

TABLE 1 Ulnar versus radial trials

Study	Year	Design	Sample size	Ulnar	Radial	Follow-up	Outcomes
PCVI-CUBA[6]	2006	RCT	431	216	215	30 days	No significant difference in freedom from MACE at 30 days
AURA of ARTEMIS[7]	2013	RCT	902	462	440	60 days	Ulnar approach noninferior to the transradial approach with respect to MACE and vascular complications at 60 days. However, the study was prematurely terminated, predominantly due to a higher rate of crossover in ulnar group.
Geng et al[8]	2014	RCT	535	271	264	30 days	No significant differences in the primary endpoints of the rate of successful artery cannulation and access site-related complications.
Liu et al[9]	2014	RCT	636	317	319	1 year	No significant difference in first puncture success rate, complications at the vascular access site or postprocedure complications
AJULAR[10]	2016	RCT	2,532	1,270	1,262	1 week	Ulnar noninferior to radial composite primary endpoint of MACE during hospital stay, crossover to another arterial access route, major vascular events during hospital stay (large hematoma with hemoglobin drop of ≥3 g%) or vessel occlusion rate

operators, a subgroup analysis was performed in 240 patients with documented ipsilateral radial artery occlusion.[13] There was no incidence of hand ischemia or ulnar nerve injury on Day 1 postprocedure or at 1 month follow-up. Asymptomatic ulnar artery occlusion was seen at 1 month follow-up in 3.1%.

Although these studies suggest that the transulnar approach is a safe and feasible alternative to transradial access, especially when performed by experienced operators, the majority of the studies are single center or single operator, underpowered to detect differences in major adverse cardiovascular events and lack long-term follow-up.

4.5 | Future studies

Although extrapolating data from the Radial Artery Access with Ultrasound Trial (RAUST)[4] would suggest that real-time ultrasound guidance would facilitate ulnar access, further research is needed. In addition, a study of ulnar access versus femoral access in the setting of failed radial access or radial artery occlusion (RAO) might yield useful information. However, such a study may prove challenging given the relative low rates of RAO and radial access failure.

In summary, recognizing the limitations of the available data, the ulnar artery may be considered as a secondary access site for experienced radial operators if radial access is perceived to be prohibitive. Careful attention to technique is critical in order to minimize the risk of vascular complications or ulnar nerve injury and to maximize rates of first-pass success rates.

5 | UTILITY OF NONINVASIVE ASSESSMENT OF COLLATERAL FLOW OR PALMAR ARCH PATENCY

5.1 | Recommendations

1. Transradial catheterization can be performed regardless of results of noninvasive collateral testing. Routine collateral testing should not be used as a triage tool for access site selection.
2. Collateral testing may be useful in screening for postprocedural radial artery occlusion and in assessing the adequacy of hemostasis techniques.

Prior to the modern radial artery access era, little attention was paid to testing the patency of the ulnopalmar arches in the catheterization laboratory despite extensive history of brachial artery cutdown procedures that potentially risked ischemic damage to the whole distal forearm. Complications after the radial arterial line placement are rare (2.7/10,000)[14] as the forearm is highly vascularized via the ulnopalmar arches (deep and superficial volar arches).[15] Early radial operators were cautious and initially used noninvasive techniques to examine hand circulation; however, support for such testing was limited to expert opinion and is not supported by clinical evidence.[16]

A variant of the Allen's test known as the Barbeau test,[17] using combined plethysmography and pulse oximetry, became a popular method to quantify the collateral circulation in the transradial era. Subsequent reports suggested this testing was also not predictive of adverse acute or chronic outcomes, including biochemical measurements of ischemia or clinical findings (self-reported hand discomfort, maximal isometric strength of the hand and forearm muscles). Importantly, the functional patency of the ulnopalmar arches of the hand varies over time in patients who undergo radial access, with those with abnormal test results displaying improvements after transradial access.[18] Furthermore, plethysmographic testing of forearm circulation demonstrates variability even over short intervals,[19] further discrediting such collateral testing for acute access triage. The underlying digital vascular supply is robust and well preserved during occlusive radial access, irrespective of the anatomic variations and results of noninvasive patency tests.[15]

While preprocedural testing of collateral circulation has not been a useful triage tool to prevent vascular complications or guide vascular access, it may be important in optimizing patent hemostasis postprocedure or identifying vascular occlusion. Since plethysmographic testing may be used at the bedside to determine the adequacy of pressure applied by the hemostasis band, understanding the macro-effects of radial and ulnar occlusion on the immediate pulsatile findings may be useful for staff monitoring the hemostasis. Likewise, collateral testing may also help to quickly identify an acutely occluded radial artery at the time of band release, and offer the potential for acute interventions such as ulnar occlusion.[20]

6 | PREVENTION OF RADIAL ARTERY OCCLUSION: OVERVIEW OF CURRENT PRACTICES

6.1 | Updated or new recommendations

1. Administration of intravenous or intra-arterial unfractionated heparin 5,000 U or 50 U/kg *or a higher dose as a bolus* is recommended following placement of radial artery introducer sheath.
2. Concomitant ipsilateral ulnar artery compression is recommended to further maximize radial artery patency.

6.2 | Continued recommendations

1. Use of lowest profile sheath and/or catheter system required for procedural success, with attention to sheath/catheter-to-artery ratio.
2. Patent hemostasis should be the default strategy, regardless of the method or device used for compression of the arteriotomy.

Radial artery occlusion (RAO) following transradial access (TRA) occurs in 2–10% of patients.[21] The mechanism of RAO is most likely related to intimal injury followed by stasis caused by hemostatic compression, leading to transmural followed by fibrotic obliteration which renders future access to the vessel impossible and may confer additional unknown consequences.

The prior Best Practices Consensus Statement recommended the use of the smallest sheath and/or catheter possible. This document recommended administering unfractionated heparin (5,000 unit bolus or 50u/kg) through intravenous or intra-arterial methods. Recent clinical trial evidence demonstrated that higher doses of heparin may further improve radial patency rates, although its safety and added efficacy while adhering to all best practices need to be further evaluated.[22] At least 5,000 U bolus (or 50 U/kg bolus in patients at extremes of weight spectrum) should be administered following sheath insertion. Lower doses of heparin yield higher rates of RAO, and therefore should be avoided. Administration of additional vasodilators before sheath removal may improve radial artery patency.[23]

Patent hemostasis appears to have the most robust randomized evidence in multiple patient subsets, supporting this strategy's ability to reduce the incidence of RAO.[24] Despite the strength of evidence supporting the technique, the adoption of patent hemostasis into clinical practice appears to be modest.

Concomitant ipsilateral ulnar compression has been demonstrated to improve radial artery hemodynamics, increasing radial artery flow and peak flow velocity. Randomized and observational data sets have demonstrated incremental benefit with ipsilateral ulnar artery compression with respect to radial artery patency when compared to the standard patent hemostasis approach.[20,25]

Employing evidence-based techniques demonstrated to minimize RAO should be prioritized and may achieve best outcomes for patients.[26]

7 | RADIAL ACCESS FOR PRIMARY PCI FOR STEMI

7.1 | Recommendations

1. Transradial access (TRA) can be used for primary PCI to reduce vascular complications and bleeding in cardiac catheterization laboratories with appropriate training and expertise in radial access procedures.
2. Operators should become experienced with nonemergent TRA PCI prior to performing STEMI TRA PCI.
3. Appropriately defined strategies for arterial access site crossover (contralateral radial or femoral) should be in place to facilitate the decision process during emergencies in order to avoid delays in revascularization and ensure optimal outcomes.

While STEMI management has traditionally focused on rapid reperfusion, with widespread systems of care aimed at shortening door to balloon (D2B) times in primary PCI, safety has increasingly become an important driver of outcomes. TRA has been shown to decrease access site complications in STEMI patients undergoing primary PCI.[27–29] In the prior Best Practices statement (Rao et al.), the authors put forth components of a radial primary PCI program but did not address a “preferred” access site for these cases. Since its publication, the large, multicentered, randomized, MATRIX trial demonstrated lower bleeding for STEMI patients undergoing radial access, but similar overall MACE and NACE as compared with femoral access[30] (Vranckx, EHJ 2017).

Some recent trials have demonstrated less discrepancy between access approaches especially when contemporary femoral access skills are employed. In SAFARI-STEMI (unpublished at this time), investigators attempted to compare radial with femoral access on 30-day mortality in patients with STEMI. Operators employed contemporary bleeding avoidance strategies including bivalirudin and vascular access closure devices commonly. The trial was stopped early due to futility. In the presented data, this trial showed no difference in mortality or any other clinical endpoint, which may reflect that lack of statistical power given the early stopping of the trial.

As treatment of STEMI requires high levels of systemic anticoagulation and antiplatelet therapies, the access-associated bleeding reduction benefit of TRA over femoral access appears greatest in this patient population.[31,32] This reduction even extends to patients presenting for PCI after receiving thrombolysis,[33] though TRA does not affect nonaccess site bleeding.[34]

Across multiple studies, an association between TRA and slightly longer D2B times exists, even with experienced operators,[35] and longer D2B times could potentially mitigate the safety advantage of TRA. However, the mortality benefit remains despite increased D2B times, and observational data from large registries across a large spectrum of operator experience consistently demonstrate decreased access site complications and reduced mortality with TRA.[36]

A well-defined crossover strategy should exist to minimize access-related reperfusion delay. Crossover rates from TRA are estimated at 4–10% due to inability to establish radial access, and failed radial access (due to anatomical issues or operator experience) is associated with worse overall outcomes.[37] Of note, the use of ultrasound is associated with lower TRA crossover rates, and left TRA can be considered as this may further reduce D2B times, especially in difficult patient subsets.[38,39] When conversion is necessary, either contralateral TRA or femoral arterial access are acceptable.[40] In keeping with prior documents, a 3-minute cutoff to establish access is recommended prior to crossing over to alternative sites in order to minimize potential compromise of D2B time.[1]

Prior to choosing TRA as default strategy for STEMI, operators should become facile with routine TRA across a wide clinical spectrum, and a less than 4% crossover rate is recommended, although the optimal experience level before transition to STEMI is unclear.[1,41,42]

A default strategy of TRA does not imply that there is no role for femoral access. For instance, patients presenting in cardiogenic shock and hypotension may require femoral access for mechanical circulatory support although, in these cases, TRA offers the advantage of single femoral artery access. Contemporary femoral access techniques have improved femoral arterial access safety by incorporating use of multimodality imaging including fluoroscopy and ultrasound, as well as

TABLE 2 Future areas of investigation

Area of investigation	Description	References
Optimal anticoagulation strategy	• The optimal antithrombotic regimen to minimize rate of RAO and bleeding complications remains undefined. • 5,000 units or 50 IU/kg of unfractionated heparin recommended previously due to high rates of RAO without or with low-dose heparin, but these studies predate the use of patent hemostasis techniques and air bladder hemostatic devices. • A recent large randomized study compared high-dose (100 IU/kg) with standard-dose (50 IU/kg) heparin for diagnostic transradial catheterization found a reduced rate of RAO (3.0% vs. 8.1%) with high-dose heparin without any increase in bleeding or compression times. However, this study did not routinely employ patent hemostasis techniques. • The available data support the use of either heparin or bivalirudin for transradial procedural anticoagulation. • · Radial procedures are increasingly performed with uninterrupted oral anticoagulation. The risks of thrombosis and bleeding and the optimal anticoagulation regimen for PCI while an oral anticoagulant is present are not defined. Warfarin alone has a higher rate of RAO than heparin in one study.	• Spaulding et al.,[43] Hahalis et al.,[22] Gargiulo et al.,[44] Pancholy et al.[45]
Distal radial access	• Distal (or dorsal) radial access in the anatomical snuffbox may: (a) improve patient and operator comfort for left radial catheterization, (b) improve perfusion during hemostatic compression or occlusion, (c) sparing of the proximal radial artery for repeated access, dialysis access, or bypass grafting, and (d) be useful for recanalization procedures for RAO. • These putative advantages are counterbalanced by several potential risks: 1) a smaller caliber artery is more likely to have spasm or occlusion, 2) increased difficulty with access, 3) standard length catheters (100 cm) may not reach the coronary circulation, and 4) hemostasis devices and techniques are less well developed and validated.	• Corcos[46]
Hand dysfunction following transradial access	• With formal and highly sensitive testing, in one study, upper extremity dysfunction or increased limb volume was found in 63.7% of patients two weeks following transradial catheterization and 66.7% at 6 months. A smaller proportion (14%) was referred to a hand surgeon or rehabilitation center. Whether such symptoms are clinically relevant or sufficient to overcome the safety benefits of transradial access is unclear. • · A systematic review of 15 studies[7] of transradial access with 3,616 patients demonstrated a low rate (0.49%) of hand dysfunction or nerve damage (0.16%). Pain was the most frequent (7.8%) risk following transradial access.	• Ayyaz Ul Haq et al.,[47] Zwaan et al.[48]
Use of radial as a future conduit	• The suitability of the radial artery as a bypass graft or dialysis conduit following transradial catheterization requires more study. A small retrospective study found a higher rate of radial graft failure (59% vs. 78%, $p = 0.035$) when the radial artery was previously utilized for angiography. • · Hemodialysis has been a relative contraindication to upper extremity (transradial/transulnar) catheterization due to the frequent failure of shunts and grafts. Whether these concerns are sufficient to overcome the demonstrated benefits of radial access remains undetermined. A small pilot study of 88 dialysis patients demonstrated a radial artery occlusion rate of 6.5% with transradial catheterization which is similar to the rate in other populations.	• Ruzieh et al.,[49] Kamiya et al.,[50] Kuno et al.[51]

micropuncture. In patients who require femoral access, use of these techniques can reduce femoral access site complications.

8 | CONCLUSION

Since the publication of the initial best practices statement, several innovations have increased our understanding of how to perform transradial procedures more safely. In this statement, the authors put forth the evidence and offer recommendations regarding the use of ultrasound, the role of ulnar access, the utility of preprocedure noninvasive testing, ongoing improvements in radial artery occlusion prevention, and benefit of transradial access for primary PCI procedures for STEMI. The authors listed several topics that require further evidence and may be part of a future document (Table 2). The aim of this document is to translate clinical trial experience into recommendations for practicing clinicians with the goal of standardizing practices around proven clinical outcomes.

ACKNOWLEDGMENTS

The writing group gratefully acknowledges the contributions of the following individuals who served as peer reviewers: Mauricio G. Cohen, MD, FSCAI; Islam Y. Elgendy, MD;

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Shroff AR, Gulati R, Drachman DE, et al. SCAI expert consensus statement update on best practices for transradial angiography and intervention. *Catheter Cardiovasc Interv*. 2019;1–8. https://doi.org/10.1002/ccd.28672