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Yale University School of Medicine
New Haven, Connecticut

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Introduction

Using Procedural Approaches to Reduce Complications Related to Percutaneous Coronary Interventions

Percutaneous coronary intervention (PCI) is one of the most commonly performed cardiac procedures. Since its introduction over two decades ago, there has been a steady evolution in both devices and pharmacotherapy. Data from large registries have confirmed that periprocedural adverse events have decreased over time.1 Trend mirrors that seen with acute coronary syndromes2 and has made bleeding complications a clinical priority.3 Several studies have shown that bleeding complications during treatment for ischemic heart disease are associated with an increased risk for death, MI, stroke, stent thrombosis, and increased costs.4-6 Studies also indicate that a large proportion of bleeding complications in patients undergoing PCI is related to the vascular access site.7-9. Therefore, strategies that address this issue may potentially reduce bleeding and vascular complications and improve PCI outcomes.

This supplement is dedicated to the transradial approach to PCI and articles contained herein review and summarize the latest data regarding bleeding complications, technical aspects of transradial PCI, and elements fundamental to a successful transradial program. The issue leads off with a personal account of starting a program focused on the transradial approach by Dr. Jennifer Tremmel. Dr. Tremmel has long been involved with women’s health issues and, given that females are at higher risk for bleeding complications,10 adopting the transradial approach seemed a natural fit. Her story of overcoming the operational challenges will serve as a template for operators considering starting their own program. In a similar vein, Dr. Mauricio Cohen provides an evidence-based summary of technical aspects that operators should keep in mind as they begin to perform transradial PCI.

One important issue that will become the focus of the cardiology literature in the future is the impact of practice patterns on healthcare costs. Dr. Ronald Caputo provides a balanced view of how transradial PCI can affect resource use, including costs and length of stay. In addition to the cost impact, the transradial approach can influence clinical outcomes. Dr. John Vavalle reviews the association between bleeding, blood transfusion, and increased mortality after percutaneous coronary intervention: Implications for contemporary practice.11 Dr. Thompson’s article provides recommendations on developing a strategy for transradial primary PCI. As the practice of PCI continues to evolve, it is incumbent on interventionalists to carefully review the evidence and apply the best practices. A body of literature now supports the role of transradial PCI in reducing bleeding and vascular complications without sacrificing procedure success. The purpose of this supplement is to provide operators with a basis for adopting transradial PCI. We hope that the articles contained in this issue are helpful to interventionalists whose collective goal is to provide the best care for their patients.

— Sunil V. Rao, MD

References

Launching a Successful Transradial Program

Jennifer A. Tremmel, MD, MS

ABSTRACT: There is an increasing interest in performing transradial (TR) procedures in the United States, but with so few experienced operators, developing a TR program often means figuring out a lot on one’s own. Certain necessary fundamentals — including a good reason for doing procedures transradially, getting adequate training, gaining the support of cath lab staff, using the right equipment, and having patience and perseverance through learning and change — improve the chances of success. In discussing each of these fundamentals, this article reviews the advantages of a radial approach compared with a femoral approach; describes ways to acquire TR training; stresses the importance of involving nurses, technicians, administrators, and colleagues in the process; encourages the use of designated radial equipment for enhancing success; and demonstrates the learning curve by describing a single operator experience during the first year of launching a TR program.

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Interest in performing diagnostic and interventional procedures via the radial artery is growing in the United States. However, transradial (TR) procedures are still infrequently performed, and there are few experienced operators, factors that can make incorporating this technique into practice appear daunting. Finding training can be difficult and may require a transcontinental flight and several days off from work. The training itself, however, is typically brief and sufficient for acquiring the confidence needed to start doing procedures independently. Still, it may not necessarily prepare one for showing technicians how to best set up the table, training nurses on radial artery and upper limb management, or writing post-procedural protocols. As such, a successful TR program requires steadfast determination and the support of staff, fellows, and colleagues.

After a year in the trenches of starting a program, I have learned some fundamentals for any operator launching a program. No formula guarantees success, and the challenges will vary based on practice type and size, the personalities and politics, and the support from senior and administrative staff. Further, only an operator who has been doing TR procedures for years can tell you what you need to maintain a program. But if you’re interested in launching a program, you need certain fundamentals to cultivate success, including a good reason for doing what you’re doing, training, the support of your cath lab staff, the right equipment, and patience and perseverance (Table 1).

A Good Reason

First and foremost, you need a good reason to do procedures transradially. While this seems obvious, its importance cannot be overemphasized. If you don’t have a reason that helps you face failures through a time of learning and change, persevere when the cath lab staff is impatiently drumming their fingers, or go to the administration requesting support, your program will fail. Fortunately, there are many good reasons to change from the groin to the wrist.

Fewer Bleeding and Vascular Complications: The most obvious reason for doing TR procedures is the lower risk of bleeding and vascular complications. Radial access reduces the relative odds of major bleeding by over 70% compared to femoral access. This equates to an absolute risk reduction of almost 2%, and anyone using the ACC-NCDR Cath PCI Registry knows that such a reduction would bring their bleeding and vascular complications to nearly zero. Some are underwhelmed by the impact of bleeding and vascular complications. They argue that such complications are inherent in what we do, that the rates are not too high, and the outcomes are rarely lethal. Indeed, the overall risk of serious bleeding and vascular complications via the femoral route is relatively low, but it is not trivial. With improvements in technical success at the coronary level, groin complications have become the most common peri-procedural complication of cardiac catheterization. And while these complications are most often annoying superficial hematomas, retroperitoneal hematomas have a mortality rate of 4-10%, and those who survive generally have extra testing with prolonged hospital stays, hypoperfusion complications, and multiple blood transfusions, all of which are associated with increased morbidity and mortality. Finally, you might not think much about a little groin bleed, but your patient does. As we all know, patients have a tendency to judge their entire cath lab experience based on what happens after their coronary procedure is completed. For better or worse, they will look at that bruise on their groin and remember the awful back pain they had while they were on bed rest for 6 hours with a nurse standing on their groin rather than idolizing the mind-blowing PCI you performed.

Additionally, it remains commonly overlooked that the single biggest sex difference in the cath lab is the higher risk of bleeding and vascular complications in women compared with men. For me, this was my reason. I wanted a way to
narrow this gap. Despite improving outcomes for women in the cath lab, this striking sex difference continues, with women experiencing 2 to 3 times the bleeding and vascular complication rate of men. At its worst, being a woman is an independent predictor of retroperitoneal bleeding, with up to 70% of retroperitoneal bleeds occurring in women. While both sexes experience lower rates of bleeding and vascular complications with the TR approach, women reap an even greater relative benefit due to their higher risk at baseline. Still, women present a particular challenge. Radial access is less likely to be successful in women, with a higher rate of needing to convert to the groin, even for experienced operators. And despite similar procedural duration and complexity, and smaller sheath sizes used, women will still have more hematomas.

**Lower Costs:** A second reason to do TR procedures is the reduced cost. As healthcare costs skyrocket, it is unusual, and quite pleasant, to be able to launch a new approach that actually costs less. Compared to a femoral approach with a vascular closure device, the cost of getting access is higher with a TR approach, but the costs of catheters, closure, and recovery are lower, resulting in an overall lower cost. If no femoral closure device is used, the cost of closure is less with the femoral approach, but the overall cost is still higher than a TR procedure. Access costs more because of the use of radial-specific hydrophilic wires and sheaths, as well as the need for a spasmolytic cocktail. Catheter cost is lower because dedicated radial catheters are able to engage both the left and the right coronary arteries, reducing the number of catheters used. Like femoral vascular closure devices, radial hemostasis devices are not necessary, but have certain convenience advantages. Bed rest duration and patient satisfaction is not clearly impacted by how the radial artery is closed, whereas these factors are significantly improved with the use of femoral vascular closure devices compared with manual compression. Still, patients will have some duration of bed rest even with a femoral closure device, no reduction in their bleeding and vascular complication rate, and approximately 5 times the closure cost of a radial hemostasis device. With patients immediately ambulatory after a TR procedure and fewer vascular complications, there is less burden on nursing staff, a reduction in pain medication use, and earlier discharge, all resulting in significantly lower recovery costs.

**More Patient Satisfaction:** Finally, there is the important reason of patient satisfaction. Of patients who have had both femoral and radial approaches, 80% are more likely to strongly prefer the TR approach, while only 2% strongly prefer the femoral approach. The preference for a radial approach is related to more favorable rankings of back and body pain, social functioning, mental health, the ability to use the bathroom, and the ability to ambulate. I would have to say that the single biggest surprise for me in starting a TR program was the extent to which patients liked this approach. Their overwhelming enthusiasm made it clear how much they disliked the recovery from a femoral

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**Table 1. Fundamentals for launching a successful transradial program**

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<thead>
<tr>
<th>Fundamentals</th>
<th>Fewer bleeding and vascular complications</th>
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<tr>
<td></td>
<td>Lower costs</td>
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<td>More patient satisfaction</td>
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<td>Training</td>
<td>Hands-on courses</td>
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<td>One-on-one teaching by local radialist</td>
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<td>Instructional videos, lectures, simulators</td>
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<td>Cath lab support</td>
<td>Involvement of cath lab staff in changes</td>
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<td>Personalized training for nurses and technologists</td>
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<td>Enlistment of colleagues and administrators</td>
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<td>Equipment</td>
<td>Hydrophilic wires and sheaths</td>
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<td>Dedicated radial catheters</td>
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<td>Minimization of radiation exposure</td>
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<tr>
<td>Patience and perseverance</td>
<td>A long learning curve</td>
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<td></td>
<td>Non-selective performance of radial cases</td>
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<td>Evoked by starting with a strong reason</td>
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**The Learning Curve**

![Graph showing progression of attempted and successful transradial procedures over one year.](image)

*Figure 1. Progression of attempted and successful transradial procedures over the course of one year. Single operator experience of 238 consecutive diagnostic and interventional procedures, 44% women and 56% men, with a mean age of 64 years. % successful is of those attempted.*
procedure. And happy patients are a good way to ensure a successful practice. Happy patients tell their friends, and their friends come in requesting it. Happy patients also tell their referring doctors, who like that you’ve made their patients happy, and send you more patients. Being able to offer a procedure that is safer, less expensive, and preferred by patients is a strong advertising point, particularly when no one else locally is doing it.

**Training**

As of now, most of the formal training is only offered on the east coast. These training courses are hands-on and last about a day, which surprisingly is fully adequate for providing the knowledge and comfort needed to get started. This is what I did, traveling from California to New York for training. Hands-on seems a preferred method, but there may be other options for people who aren’t able to travel for a course. One option is to find a local radialist and invite him or her to your hospital for a day of cases. Alternatively, you could join the radialist in his or her cath lab for the day. Due to varying state laws regarding hospital privileges, you may simply have to be an observer when visiting someone else or, if they visit you, you might not be able to see one, but can do several with an expert talking you through it. Less ideal but still-viable options include watching an instructional video, going to a lecture, or practicing on a simulator. In coming years, our large annual conferences will hopefully improve educational opportunities by holding symposia on the TR approach, demonstrating the technique during live cases, and setting up break-out sessions to ask the experts and share experiences. Back home, having a network of radialists with whom you can discuss cases will ease the transition and help you feel less alone if you run into snags.

**Fellows:** You will quickly find after your training that you are not the only one who needs to be trained. If you are at a teaching hospital, you will need to decide what to do with the fellows. One reason the femoral approach persists in this country is that it’s easy to teach and learn. The TR approach is technically challenging enough, and less forgiving of an inexperienced operator, that it may not be worth training a general fellow who will never touch a catheter after fellowship ends. On the other hand, interventional fellows are eager and capable learners, as are general fellows who want to go into interventional cardiology or who plan on being invasive cardiologists. My interventional fellows quickly became master radialists before my eyes. In addition, they helped teach the nurses and housestaff how to care for these patients after the procedure, and eventually assisted in passing on the technique to other attendings in the lab who were interested in performing it.

**Nurses and Technicians:** Your success will be significantly enhanced by also having a trained and ready staff. You will need to teach them how to set up the patient’s arm on the table, what spasmolytic cocktail to prepare, how to drive the table so that precious fluoroscopy time isn’t wasted “looking for” the arm, and how to monitor the upper extremity after the procedure. Old habits will have to be broken. When we first started, I would walk into the post-procedure area only to find my radial patients lying flat on their backs and being put on bedpans. Nurses and technicians generally need protocols, and you will need to write them (see appendices beginning on p. 9A) — how long does the TR band stay on, what do you do if there’s a hematoma, and what should the patients watch for after they go home? If feasible, take a nurse and/or technician to the training course. As nurses and technicians, they have their own way of viewing the cath lab and understanding what needs to be done to make a case successful. They will likely learn better from their own colleagues than your instruction, and they will be much more interested in what you’re trying to do if they have been personally involved in the process.

**Cath Lab Support**

If you have been trained, but haven’t involved your cath lab staff in your new project, you may be fighting an uphill battle. Change comes hard to large groups, particularly if they haven’t felt a part of the process. Because it can be difficult to train everyone at once, consider identifying a small group of skilled and enthusiastic nurses and technicians to be “champions” during this transition. Once the champions have become comfortable with the procedure, they can disseminate the method to others. In addition, within several weeks of launching the program, it’s helpful to hold an in-service for the entire cath lab to get everyone up to speed. Finally, the nursing staff in the cath lab can train the nursing staff on the wards regarding post-procedure care.

**Support of Colleagues and Administrators:** Depending on the environment in which you work, you may need to spend a fair amount of time eliciting support from your colleagues and administrators, as well. I am fortunate to work with a group of interventionalists who are genuinely supportive and thrive on innovation. They made sure the road was cleared for my success, but that will not be the case for everyone. As mentioned, change comes hard and is often perceived as threatening. Colleagues may not like that you are straying from the norm, and possibly giving yourself a competitive edge. Senior colleagues may not like that you will be able to do something they can’t. Hopefully, with open communication, the physicians you work with will see that it benefits everyone, but it may take some time and effort on your part. Support from the administration should be easier. In this era of quality assurance and quality improvement, TR procedures seem an administrator’s dream — a perfect package of fewer complications, lower costs, and higher patient satisfaction.

**Equipment**

Like everything else in interventional cardiology, the procedure will be easier with the right equipment. Gone are the
days of using femoral equipment to do TR procedures. New hydrophilic wires and sheaths, dedicated radial catheters, and TR bands have simplified the procedure and reduced difficulties that used to be encountered. In addition, various “cocktails” have been studied and enhanced.\textsuperscript{22} Even the procedure itself has improved. From their experiences, veteran operators have shown us how best to cannulate the radial artery with a minimal amount of lidocaine and a through-and-through puncture; how to more easily maneuver through vascular challenges, such as radial and subclavian loops; and how to perform graft cases with relative ease.\textsuperscript{23–25} For operators who tried doing TR procedures in the 1990s and found it too difficult and too unrewarding, consider trying again.

The progressive reduction in the size of interventional devices over time has made the majority of procedures conducive to a TR approach. In addition, increased experience and radial-specific equipment appears to have improved the procedural success considerably.\textsuperscript{2}

**Radiation Exposure.** One issue that operators will need to address is the higher risk of radiation exposure that occurs with TR procedures.\textsuperscript{26,27} There are two main reasons radiation risk is increased. First, the procedure is more challenging and therefore can take longer. Second, the operator is closer to the patient and the X-ray source during the procedure. This risk of radiation persists even for more experienced operators and when maximal shielding precautions are used.

**Patience and Perseverance**

While skills from doing femoral procedures will serve you well, TR procedures are different. Obviously access is different, but there are also new obstacles that must be maneuvered through in the radial, subclavian, and aortic arch. Likewise, engagement of the coronary arteries requires learning a modified set of movements, and it takes time to learn which catheters and guides will fit best when coming from a new location. The differences in engagement are typically more pronounced when coming from the right wrist compared to the left, but the left wrist presents its own challenges, such as how to optimally position the arm and minimize radiation exposure.

The more resources you have to learn from, the quicker the process will go, but even if you’re trying to figure out most of it on your own, with patience and perseverance you will get it.

**The Learning Curve:** There is no magic number at which one suddenly becomes a radial expert; the more you do, the better you’ll get.\textsuperscript{28} Traditionally, 100 TR cases were considered the standard for competency. That number is currently 50, although no clear guidelines have been established.

Our first year saw a steady rise in the percentage of cases that we attempted transradially, as well as the percentage of cases in which we were successful (Figure 1). While it is recommended
that operators not be selective in doing radial cases, this advice is a goal to aim for, not necessarily a way to begin. When we started, we preferred large men, and avoided unstable/acute coronary syndrome (ACS) patients, patients having planned percutaneous coronary interventions (PCI) or concomitant right heart caths, and patients with bypass grafts (Table 2). Sometimes, the procedures were going so slowly that we did some femoral cases just to move things along. But gradually, we got faster and better, and found fewer reasons to forgo a TR approach. I now do nearly 100% of my cases from the radial artery. I also do right heart catheterizations through the brachial or internal jugular vein, avoiding the groin altogether. Our complications have included only a few mild hematomas, readily treated with ElastiTape.

Once competent, being selective in choosing radial cases results in a slower rate of achieving technical excellence and an underestimation of what can be done from the radial artery. Also, it lends itself to choosing the wrong cases. Selective operators will tend to shy away from high-risk ACS patients, the elderly, and small women, while these are the very patients who have the most to gain from a TR approach due to their higher propensity for bleeding complications. Young men and the obese, the cases one might gravitate toward, will benefit as well, but not nearly as much. These are good cases when starting out, but over time, you will want to incorporate the tougher appearing cases. It turns out they’re not always as hard as you might think. For example, I remember my reluctant, but determined, progression with smaller and smaller vessels in the radial cannulation of a 38-kg woman. I decided to give it a try, but was doubtful of success. To my surprise, we had no problems, and that day I learned that you never know. Unless you’re going straight to 8 French (Fr) (7 Fr in women), or you anticipate needing an intra-aortic balloon pump or left ventricular assist device, everyone should get a try. It is interesting how success emerges. It remains a mystery to me why we couldn’t gain access on some earlier cases. We generally attributed it to spasm or that the vessel was too small, but such problems slipped away — 82% of our failures occurred in the first 6 months (Figure 2). Of all our failures, 76% were due to an inability to gain radial access, while 24% were due to an inability to advance the catheter to, or adequately engage, the coronary arteries. In the first 6 months, the majority of failures due to access were in women; perhaps our expectations contributed to this effect. In contrast, in the last 6 months, access failures were more likely to occur in men. The opposite was seen in engagement failures. Once the coronary artery is engaged, performing PCI is very similar to the femoral approach. Sometimes the guide might not seat as well, but other times, it actually seats better. In our first year, we progressively did everything from the radial artery — bifurcation lesions, chronic total occlusions, bypass grafts, rotational atherectomy, fully anticoagulated patients, and most recently, ST-elevation myocardial infarctions (STEMI). In the last 6 months, our overall procedural failure rate was 6%, compared with 32% during the first 6 months. This is consistent with data showing that with experience, procedural failure from the wrist is about 5%, compared with 2% from the groin, and after 1000 cases, procedural failure is said to stabilize at about 1%, making the approaches equally successful.

Conclusions
Launching a TR program can, particularly in the beginning, be challenging. Soon, however, you forget the tough times, and can’t even recall why they were so difficult. Reflecting on our first year, I remember a lot of firsts — we tended to celebrate every “first” that we had — first successful cannulation, first time around a subclavian loop, first rotational atherectomy, first STEMI … and now that colleagues are increasingly using the technique, we have another whole set of “firsts” to celebrate. I had a strong reason to start doing radial procedures, wanting to reduce bleeding and vascular complications in women. Having a good reason is essential to launching a successful program. A good reason will spark the urge to get training, will foster support in the cath lab, and will encourage you to learn the new equipment. Most importantly, a good reason will remind you when you’re tired and frustrated why you are doing what you are doing, and evoke the patience and perseverance you will need in order to get through.

All these fundamentals are necessary for launching a successful program. How much of each is used and how they are mixed together will depend on individual circumstances, but I am certain that together they will bring the desired results, while also forming the foundation of a program that is both long-lasting and self-perpetuating.

References
TREMmel

SAMPLE PROTOCOL
PROCEDURE FOR TRANSRADIAL CATHETERIZATION

STANFORD HOSPITAL and CLINICS
CATH-ANGIO LAB DEPARTMENT

I. PRE-PROCEDURE
1. Allen’s test performed by physician and confirmed by pulse oximeter on thumb
2. Remove any watches or jewelry from the wrist and shave it back and front
3. Prep groin site in case of failure by radial approach
4. Restrict IV line and blood draw to the other arm

II. EQUIPMENT & SUPPLIES
1. Custom cardiology pack
2. 6 Fr (or 5 Fr) radial access kit which contains
   a. 2.5 cm 21 G needle
   b. 5 Fr Glidesheath (6 Fr for interventions)
   c. soft-tipped straight guidewire (0.018 inch x 50 cm)
3. Arm board
4. TR band
5. Angled Glidewire available
6. Low X-ray shield between operator and X-ray source
7. Apperture drape for wrist
8. 35 cc syringe for medication
9. 0.035-inch J exchange 260-cm wire

III. MEDICATIONS & IV SOLUTIONS
1. Verapamil 2.5 mg (2.5 cc) made up in 5 cc total volume (Dilute 5 mg to 5 cc total volume)
2. Heparin 2,500 units made up in 2.5 cc
3. Nitroglycerin 100 mcg/cc
   Draw up verapamil/heparin/NTG (total drug volume of 6 cc) in 35-cc syringe
4. Usual syringes of lidocaine anesthesia
5. Versed and fentanyl for conscious sedation

IV. PROCEDURE

<table>
<thead>
<tr>
<th>Action</th>
<th>Rationale/Precautions</th>
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<tr>
<td>Place patient on monitoring equipment with pulse oximeter on thumb corresponding to radial procedure.</td>
<td>To establish baseline</td>
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<tr>
<td>Explain procedure to the patient and Medicate patient as per physician’s order.</td>
<td>For patient cooperation and to decrease anxiety, prevent vasospasm</td>
</tr>
<tr>
<td>Support arm on an armboard at about 70° to the patient.</td>
<td>Proceed with coronary angiogram.</td>
</tr>
<tr>
<td>Sheath removed and TR band applied by MD in procedure room.</td>
<td>To provide hemostasis</td>
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<tr>
<td>See TR band procedure for post-procedure patient care</td>
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V. DOCUMENTATION

Record procedure, staff, vital signs, percutaneous insertion sites, sheath and catheter sizes, hemodynamic pressures, patient condition pre-, peri-, and post-procedure, medications given, patient response to medications received and to procedure, fluoro time, type and amount of contrast used, amount of fluids patient received, condition of insertion site upon discharge, receiving RN, and unit.
TREMMELE et al.

SAMPLE PROTOCOL
TRANSRADIAL CATHETERIZATION POST-PROCEDURE CARE

STANFORD HOSPITAL and CLINICS
CATH-ANGIO LAB DEPARTMENT

I. PURPOSE
To ensure continuity and patient safety while discontinuing radial arterial sheaths with a radial compression device. To provide guidelines and competency documentation for post-procedural care of the patient recovering from transradial catheterization.

Who may perform: RNs who have passed competency

II. EQUIPMENT/SUPPLIES
A. Transradial band (TR band) with attached inflator syringe
B. Wrist support or immobilizer (optional)
C. Protective covering (Band-Aid, gauze, etc)

III. PROCEDURE

Nursing Actions | Key Points
---|---
1. Patient received in holding area Phase I of ATP with TR band in place, RN assesses TR band and underlying puncture site. | RN ensures TR band in correct position, puncture site intact and distal circulation, sensation, and movement (CSM) intact.
2. RN monitors patient in the holding area Phase I of ATP for 30 minutes prior to transfer to Phase II (ward). Total recovery time 2 hours (post-diagnostic) or 4 hours (post-interventional) plus additional 1 hour after TR band has been discontinued per MD orders. Vital signs per MD orders. | For interventional cases additional anticoagulation is used, extending recovery time. Patient may be ambulatory during recovery.
3. Assesses affected extremity upon patient arrival and every 15 minutes while TR band is in place. • Assesses for bleeding, swelling (particularly at the forearm), pulse, CSM. • Ensures Velcro strap is securely fastened. • Instructs patient not to move wrist; may use immobilizer if patient is non-compliant. | RN ensures BP is not taken on affected extremity. A loose strap may result in bleeding at the site.
4. If patient complains of pain, confirms there is no bleeding at the site, removes up to 3 ml air volume with syringe if ordered by MD. | 
5. If bleeding occurs, injects more air with the syringe until the bleeding stops. Does not exceed 18 ml. | 
6. While the TR band is on it will slowly be deflating (leaking air through valve). During final 30 minutes, releases 3 ml of air every 15 minutes. Deflates fully when time is up and checks for hemostasis. | 
7. If site rebleeds at any deflation interval, reinflates with 3 ml of air and tries deflation again in 15 minutes (does not exceed 18 ml). | 
8. Before removing TR band, confirms bleeding has stopped. | 
9. Removes TR band and applies protective covering (Band-Aid, etc) over insertion site. | 
10. Assesses site 1 hour post-TR band removal. | 
11. Discharges patient, includes in instructions to limit movement (no flexion/extension) of wrist for 24 hours. | 

IV. DOCUMENTATION
Document removal of TR band in patient’s chart.

References:
1) Associated document: Cath Angio Lab procedure for transradial catheterization.

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The Journal of Invasive Cardiology
Starting a Transradial Vascular Access Program in the Cardiac Catheterization Laboratory

Mauricio G. Cohen, MD; Carlos Alfonso, MD

ABSTRACT: Over the past 20 years, since the first reports, transradial vascular access for coronary angiography and intervention has flourished in many countries while still accounting for less than 2% of all cases performed in the United States due, in part, to difficulties in introducing change to established practice patterns. The benefits of transradial access include decreased bleeding risk, increased patient comfort, lessened post-procedure nursing workload, and decreased hospital costs. A learning curve to gain the specific set of skills for transradial access has been well described. Although published data suggest that 100–200 cases are necessary to become proficient, the learning curve is likely highly individual, and some operators may become proficient sooner. The equipment to start a transradial program is minimal and includes modified sheaths and catheters. Patients with morbid obesity, peripheral vascular disease, and anticoagulation clearly benefit from this approach. To establish a transradial program and offer the benefits of this approach to most patients, a dedicated interventionalist must incorporate peers and hospital staff to create a multidisciplinary team.

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In 1989, Lucien Campeau published his successful series of 100 coronary angiographies performed via the radial artery with minimal complications.1 Subsequently in 1993, Kiemeneij described and published the use of transradial access for percutaneous coronary interventions using 6 French (Fr) guiding catheters in a time when most interventional procedures were performed with larger 8 Fr catheters.2 Since then, transradial approach has continued to gain popularity in some regions of Europe, Canada, South America, Japan, and other sites outside the United States, where transradial access is used in more than 80% of the cases. Within the United States, however, the use of transradial vascular access is much less common. In the National Cardiovascular Data Registry (NCDR), transradial access accounted for 1.3% of all catheterization procedures with almost 90% of centers doing less than 2% of cases via the radial approach.3 The reasons transradial has not caught on in the US are unclear, but are probably related to physician and ancillary staff’s comfort with femoral access, and apprehension toward change. Additional deterrents for the use of transradial access include a higher operator radiation exposure,4,5 and the well-described learning curve. However, once the procedure is mastered, the operator and staff become extremely comfortable with the technique and radiation exposure can be substantially reduced.6,7

The purpose of our article is to provide a stepwise guide to starting a transradial vascular access program and to inform medical staff what to expect during the process. A determined operator who is familiar with the data and understands the compelling reasons for the use of transradial access can promote change and implement an institutional program. During the process, colleagues and staff members quickly realize the advantages of transradial access and the program gains widespread support within the catheterization laboratory. As an example, one operator of five performing procedures via transradial access at the University of North Carolina at Chapel Hill, increased the overall percentage of transradial cases from 2–3% per year to 11–13% per year over the course of 12 months (Figure 1).

Understanding the Need for a Change

A major step in the adoption of a new technique is understanding the limitations of local current practices. Cardiac catheterization via femoral access demands greater post-procedural nursing care, is limited by prolonged bed rest (usually about 4 hours), and delays discharge. In fact, when the procedure is performed late in the course of the day, patients are usually kept in hospital overnight for prevention of access-related bleeding.

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Figure 1. Influence of one transradial operator in group practice
A motivated operator can rapidly change the profile of a practice group. In this case, 1 of 4 operators was performing 50% of his cases via transradial access, by the end of 1 year, performing more than 100 cases during the learning process. (Cardiac Catheterization Laboratory at University of North Carolina at Chapel Hill — Data provided by the NCDR-CATH PCI registry).
Femoral access is more frequently associated with increased back pain, urinary retention, delayed ambulation, and neuropathy. To overcome some of these limitations, many operators have adopted the use of vascular closure devices, but published data have consistently shown that these devices are associated with the same or increased hemorrhagic risks in comparison with manual compression. In addition, rare complications such as infections, femoral artery stenosis, arterial laceration, uncontrolled bleeding, pseudoaneurysm, arteriovenous fistula, and device embolism and limb ischemia have all been reported with the use of vascular closure devices.11

During recent years, it has become evident that bleeding complications and transfusions are associated with increased morbidity and mortality in patients undergoing percutaneous coronary interventions (PCI) and/or treated for acute coronary syndrome (ACS).12-14 Of note, vascular access-related bleedings, including groin and retroperitoneal hematomas, account for more than 80% of all major and minor bleeds, according to a large cohort study of 10,974 patients undergoing PCI.15

The Case for Transradial Vascular Access

Transradial access poses significant benefits to patient comfort. There is no need for immobilization, back pain is substantially reduced, and the time to ambulation is decreased, letting the patient use the bathroom almost immediately after the procedure. In addition, decreased use of resources during the recovery time and early discharge result in significant cost savings.8,16,17 However, the most compelling reason for adopting transradial access is the increased patient safety that results from the substantial reduction in bleeding and vascular access complications associated with this technique. Because transradial access virtually eliminates access-related bleeding, which accounts for more than 80% of major bleeding events in PCI, the interventional cardiologist can opt for more aggressive antithrombotic regimens during PCI, and at the end of the day, leave the hospital with peace of mind, knowing that the intervened patients have a low probability of severe bleeding.

A recent meta-analysis including more than 2,400 patients enrolled in 23 trials demonstrated that transradial access was associated with a significant 73% reduction in major bleeding, and a 30% trend toward a reduction in the incidence of death, myocardial infarction, or stroke in comparison with femoral access.18 Indeed, the PCI operator would be hard-pressed to overlook radial access in light of these safety endpoints. In a large Canadian registry, the need for transfusing patients undergoing PCI was reduced by 50% with the use of transradial access and resulted in a significant mortality reduction at 30 days (OR: 0.71; 95% CI 0.61 – 0.82) and 1 year (OR: 0.83; 95% CI 0.71 – 0.98), in comparison with femoral access.19

From the technical standpoint, the superficial location of the radial artery makes it an ideal target for percutaneous arterial access (Table 1). The flat bony prominence of the radius facilitates the ease of compression and absence of ischemia when compared to other vascular access sites. The absence of major adjacent nerve complications ensures no neurologic sequelae. The puncture is not over the joint, which means that motion does not increase the risk of bleeding. The lack of major adjacent nerve complications means that there is no need for immobilization, and the small size of the puncture site means that it can be easily closed with a compression device.

Table 1. Anatomic factors and clinical correlates of transradial vascular access

<table>
<thead>
<tr>
<th>Anatomic Features</th>
<th>Clinical Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat bony prominence of the radius</td>
<td>Ease of compression</td>
</tr>
<tr>
<td>Collateralization of the radial artery</td>
<td>Absence of ischemia</td>
</tr>
<tr>
<td>Puncture not over joint</td>
<td>Motion does not increase risk of bleeding</td>
</tr>
<tr>
<td>No major adjacent nerve</td>
<td>No neurologic sequelae</td>
</tr>
</tbody>
</table>

Table 2. Advantages and disadvantages of the radial approach

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased major access complications</td>
<td>Learning curve: ~100 cases</td>
</tr>
<tr>
<td>Decreased access-related bleeding</td>
<td>Access</td>
</tr>
<tr>
<td>Immediate sheath removal</td>
<td>Navigation of arm vasculature</td>
</tr>
<tr>
<td>Improved patient mobility</td>
<td>Catheter manipulation for coronary cannulation</td>
</tr>
<tr>
<td>Immediate sheath removal</td>
<td>Technical aspects</td>
</tr>
<tr>
<td>Decreased time to ambulation</td>
<td>Limited compatibility with larger devices (i.e., &gt;2 mm Rotablator burrs)</td>
</tr>
<tr>
<td>Superficial, easy hemostasis</td>
<td>Failure to reach ascending aorta</td>
</tr>
<tr>
<td>Improved patient mobility</td>
<td>Vascular anomalies (i.e., radial loops, high radial take-off in the brachial artery)</td>
</tr>
<tr>
<td>Immediate sheath removal</td>
<td>Excessive tortuosity (i.e., elderly, hypertensive patients)</td>
</tr>
<tr>
<td>Decreased post-procedural cost</td>
<td>Radial artery spasm</td>
</tr>
<tr>
<td>Early discharge</td>
<td>Increased fluoroscopy time, radiation exposure</td>
</tr>
<tr>
<td>Decreased nursing care</td>
<td></td>
</tr>
<tr>
<td>Overcome difficulties in vascular access for specific populations (i.e., morbidly obese, peripheral vascular disease, anticoagulation)</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Cooper CJ: A Physician’s Guide: Radial Approach.
Steps Toward Becoming a Radial Operator

Commitment Through the Learning Curve: Becoming a “radial operator” requires commitment and a mindset change. The first step in developing a practice is exposure to the technique that often starts during fellowship training, through courses offered by colleagues, or visits to catheterization laboratories experienced in transradial access. In addition, didactic resources available on the Internet, such as tutorials and discussion forums, can be extremely helpful during the initial process. Examples of useful Web pages:

- http://transradialworld.org/index.html

Understanding the existence and importance of the learning curve is key. Spaulding et al documented an initial access failure rate greater than 10% that decreased dramatically to about 2% after the first 80 cases. In addition, the time required for access and sheath insertion decreased from 10.2 ± 7.6 min to 2.8 ± 2.5 min and the procedure time also decreased from 25.7 ± 12.9 min to 17.4 ± 4.7 min.6

Identifying a Target Population: The initial strategy involves identifying a target population and performing diagnostic angiography only. In the beginning, procedures take more time with higher contrast use and longer radiation exposure. Therefore, it is convenient to start the experience in young and large males, with normal renal function and low chance of comorbid diabetes. Logical initial targets also include morbidly obese patients and patients with severe peripheral vascular disease (PAD), in which femoral access is associated with additional risks. On the other hand, elderly hypertensive females with small body surface area should be avoided during the initial learning curve because of a higher probability of finding smaller, tortuous vessels that pose more technical challenges.22,23 Similarly, it may be less stressful to avoid high-risk cases, and instead get familiar with transradial access in elective stable patients. In the absence of anatomic anomalies, transradial access is successful in more than 95% of the cases. Throughout the learning process, the operator should not get discouraged by the presence of technical difficulties. It is important, though, that the operator recognizes his or her own limitations. Transradial catheterization should always be performed with finesse. Wires and catheters should advance without difficulty. If resistance is found, a limited angiography through an 18-gauge angiocath placed in the radial artery, or through the sheath or a catheter, will aid in defining the presence of anomalous anatomy or unusual tortuosity and will help in deciding the best technical options. Anatomic variations are associated with increased procedural failure and can be found in 14% to 23% of cases. Variations include tortuous radial configurations, stenoses, hypoplasia, radioulnar loops, aberrant right subclavian artery (arteria lusoria), and abnormal origin of radial artery.23,24 The operator should be aware of the several techniques described to negotiate tortuous vessels and radioulnar loops with hydrophilic-coated guidewires and catheters.22,25 Patients should not experience pain during the procedure. In the presence of forearm pain, the operator should suspect, recognize, and manage local complications such as refractory spasm, forearm hematoma, and vessel perforation.27,28

Expanding to Higher-Risk and Technically Challenging Cases: At the steep part of the learning curve, the operator is already familiar with the equipment and technique, is able to approach more technically demanding cases, use a single catheter to cannulate both coronary arteries, and perform interventional procedures in high-risk populations.29-31 The operator’s mindset has already changed and every patient becomes a “transradial candidate” unless proven otherwise. Patients on oral anticoagulation who need a precise puncture become a target population. With use of transradial catheterization, anticoagulated patients with atrial fibrillation, mechanical valves or prothrombotic conditions do not need to be admitted beforehand and be bridged to heparin or receive fresh frozen plasma. The typical scenario is the anticoagulated patient presenting with an acute coronary syndrome needing urgent catheterization. Transradial access is extremely helpful in these cases as hemostasis can be easily achieved upon completion of the case.32,33 Elderly patients also benefit from transradial access due to the lower incidence of vascular complications.34 Transradial catheterization and PCI is also feasible in the setting of ST-elevation acute myocardial infarction without significant delays in door-to-balloon times and is associated with lower rates of bleeding and vascular complications.30,31,35

Table 3. Sheath removal protocol

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial sheath is always removed in the catheterization lab</td>
<td></td>
</tr>
<tr>
<td>Place arterial hemostasis device (e.g., TR band)</td>
<td></td>
</tr>
<tr>
<td>Inflate to occlude flow</td>
<td></td>
</tr>
<tr>
<td>Deflate until slight bleed-back</td>
<td></td>
</tr>
<tr>
<td>Inflate with an additional 1 cc to 2 cc of air for hemostasis</td>
<td></td>
</tr>
<tr>
<td>Immobilize wrist</td>
<td></td>
</tr>
<tr>
<td>Leave emostatic band in place for approximately 2 hours</td>
<td></td>
</tr>
<tr>
<td>Release pressure in stepwise fashion (deflate 5 cc every 15 minutes)</td>
<td></td>
</tr>
<tr>
<td>Check arterial perfusion regularly with pulse oximeter</td>
<td></td>
</tr>
<tr>
<td>Remove hemostatic band</td>
<td></td>
</tr>
<tr>
<td>Place a normal-sized bandage over the access site</td>
<td></td>
</tr>
</tbody>
</table>

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The need for simultaneous right heart catheterization or the presence of aorto-coronary bypass-grafts should not be viewed as contraindications for transradial access. Right heart catheterization can be performed through one of the large veins located in the antecubital fossa. In our institution, a nurse usually obtains venous access with an 18-gauge catheter, which is subsequently exchanged for a 5 Fr sheath using a short 0.021-inch wire, and then a 5 Fr 120-cm balloon-tipped catheter is advanced into the superior vena cava with use of a 0.025-inch guidewire. Then, the wire is retrieved, the balloon inflated and the catheter advanced into the pulmonary artery.36,37 In patients with prior coronary artery bypass grafting (CABG), radial access facilitates cannulation of the ipsilateral internal mammary artery (IMA) and allows selective engagement of aorto-coronary bypasses. Before the procedure, the patient’s type and number of grafts must be carefully evaluated in order to select the best access strategy (left versus right radial artery) and the appropriate catheter curves. A thorough review on transradial catheterization in patients with prior CABG is available in the literature.38

As experience accumulates, the operator will face more challenging cases with tortuous anatomy, expand to non-coronary interventions,39,40 and be exposed to unforeseen difficulties or complications, such as hematoma, vascular perforations, post-procedural loss of radial pulse, and abscess development at the puncture site.41-45

Changing the Institutional Culture — Implementing the Program

When a motivated operator decides to setup a transradial program, a number of changes need to occur at the institutional level. It is important to realize that the program’s success will largely be dictated by how effectively the catheterization laboratory and staff members (nurses, technologists, administrators) become incorporated into the endeavor of creating a truly multidisciplinary program. The appropriate equipment needs to be readily available, and the staff must be trained in pre-procedure set-up and preparation, procedural expectations, and post-procedure patient care.

**Equipment:** Even though there is relatively little additional or specialized equipment needed for transradial catheterization, there are products that greatly facilitate vascular access. With time, the operator will identify and stock the equipment that he or she feels most comfortable with. At our institution, we use short (10 cm) hydrophilic-coated sheaths compatible with a 0.021-inch wire. Hydrophilic sheaths have been shown to be associated with less patient discomfort, local pain, and easy removal.46 Commercially available transradial access kits usually include a 25 mm 24-gauge micro-puncture needle, very useful to effectively stick the radial artery.

In terms of catheters, a dual catheter technique using a Judkins catheter probably provides the easiest way to start the transradial learning curve and train fellows. For the left coronary it is recommended to downsize the curve of the JL catheter from 4.0 to 3.5 and for the right coronary to use either a JR4 or JR5. Catheters should always be exchanged over a long 260-cm 0.035-inch wire, especially in patients with tortuous radial or subclavian anatomy. At our institution, we use a hydrophilic-coated stiff-shaft wire with an angled tip, which lets us negotiate tortuosity and maintain stability during catheter exchanges. The more experienced operator can tran-
Transition to a single-catheter technique to selectively engage both coronary arteries with a dedicated catheter shape, thus eliminating an exchange step and decreasing procedure and fluoroscopy time. Available shapes for the single-catheter approach include the multipurpose, Kimney, Tiger, and Jacky catheters, among others. For coronary interventions, the 3.5 extra-backup curves (EBU, XP, Voda) usually work well and provide appropriate support. Recent studies examining the physics of catheter engagement and positioning in the ascending aorta indicate that the relatively new Ikari catheters (not available in the United States) provide better and more stable support for PCI than do Judkins catheters, among others.

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Advising the patient what to expect during and after the procedure is important. Patients receive explanation regarding the differences with the femoral approach, especially that the transradial catheterization is more involved, sometimes takes longer, and that in a minority of cases, significant forearm pain may develop as a consequence of radial spasm. In fact, much of the morbidity of the transradial procedure is related to vasoconstriction induced by the introduction of a sheath or catheter into the radial artery. Independent predictors of radial spasm include the presence of radial artery anomalies, multiple catheter exchanges, pain during radial cannulation, and radial diameter after administration of vasodilatory agents. Vasoconstriction can be prevented with the use of a “spasmolytic cocktail” administered through the sidearm of the sheath immediately after obtaining radial access. We are presently using 3 mg of verapamil diluted in 10 ml of normal saline. Other agents used to prevent spasm include different combinations of lidocaine, nitroglycerin, nicardipine, papaverine, and diltiazem.

In the catheterization laboratory, it is important that both patient and operator feel comfortable. As the patient is...
placed on the catheterization table, the arm is accommodated on an arm board, and the wrist is hyperextended and draped in sterile fashion (Figure 2). The femoral site should also be prepared in case it is needed, especially during the learning curve or in case of a weak radial pulse. For the comfort of the operator, instead of a regular armboard, we recommend the use of an oversized Plexiglass rectangular board (3 feet by 4 feet) that provides support for the patient's arm and the interventional equipment as depicted in Figure 3, so the operator does not feel like he/she is "working in the air." For diagnostic catheterization, we usually administer intravenous heparin at a dose of 80 U/Kg to a maximum of 5,000 U to avoid radial artery occlusion. Additional doses of heparin or other anticoagulants can be administered if a subsequent interventional procedure is needed. Because of the possibility of vascular tortuosity at different levels in the upper extremity, we usually administer heparin after the guidewire has reached the ascending aorta and there is assurance that the procedure will be completed through the radial artery without crossover to femoral access.

**Post-procedure Care:** Once the procedure is complete, the radial sheath is pulled in the catheterization laboratory regardless of the intensity of anticoagulation or antplatelet therapy. Hemostasis can simply be achieved using a roll of gauze placed longitudinally on top of the arteriotomy site and wrapped with an elastic bandage around the wrist. Alternatively, dedicated devices, such as the RadiStop and the TR band, that apply pressure directly over the radial artery without compromising the venous circulation, may be more convenient (Figure 4). The transradial catheterization policy should be specific about the duration and intensity of compression. Prolonged occlusive compression increases the risk of radial artery occlusion, which, despite being clinically silent, limits the possibility of future transradial access. Pancholy et al have described a technique that allows "patent" hemostasis. Using pulse oximetry and plethysmography, compression over the radial artery is alleviated while applying manual pressure to the ulnar artery. Patent hemostasis is achieved when oximetry in the fingertip becomes positive and a waveform is visualized with plethysmography. With this technique, late occlusion rates are approximately 2%. In our institution, hemostasis is achieved with an inflatable balloon device that applies selective pressure on the radial artery (TR Band). Two hours after placement of the device, 5 cc of air are released every 15 minutes, until the device is completely deflated and can be removed.

**Program Expectations**

Once the program is up and running, staff and physicians will comfortably offer this vascular access approach to all patients. The radial operator will increase his referral basis, initially at the expense of patients with no alternative vascular access, morbid obesity, or those on anticoagulation therapy. However, with time, colleagues will refer patients, staff will make patients aware that this approach is offered at the institution, and the community at large will recognize the benefits of transradial access and specifically request it.

The ongoing RIVAL trial, a substudy of CURRENT-OASIS 7, will randomize a total of 2,000 patients with acute coronary syndromes to transradial versus transfemoral vascular access. Hopefully, this adequately-powered study will demonstrate the benefits of transradial access in terms of bleeding, vascular, and ischemic complications. It is anticipated that transradial access will ultimately be recommended by clinical practice guidelines and become a benchmark for quality of care.

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Transradial Arterial Access: Economic Considerations

Ronald P. Caputo, MD

ABSTRACT: The economic benefits of transradial compared to transfemoral access for percutaneous coronary procedures are derived from advantages primarily related to a lower incidence of access site complications and earlier ambulation. While multiple aspects of transradial access are associated with economic benefit, a reduced incidence of complications with transradial access appears to provide the greatest magnitude of cost reduction.

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Key Words: Transradial, vascular complication, PCI

Compared with femoral arterial access, transradial access for percutaneous cardiac procedures is associated with 1) fewer access site complications and 2) earlier ambulation.1–12 These two benefits are primarily important in achieving improved patient safety and comfort. However, they also confer an important secondary economic advantage. The purpose of this article is to examine this advantage.

Reducing Vascular Complications

It is well established that vascular access complications following catheter-based procedures result in increased procedure and hospital-related costs.13–25 Incremental costs are contributed to by 1) requirements for diagnostic vascular imaging, 2) additional laboratory costs, 3) blood transfusions, 4) vascular repair procedures, and 5) increased length of hospital stay. An example of the representative charges related to these additional tests and interventions for a hospital in the northeastern United States is elucidating (Table 1). It is important to consider that these charges do not accurately reflect cost. Additive indirect costs are related to factors such as fixed overhead, increased nursing intensity, and additional utilization of support staff, which must also be considered. Furthermore, little additional reimbursement can be expected to offset these costs.

The magnitude of the negative economic impact of a vascular access complication has been quantified. Kugelman et al reviewed data from Medicare patients undergoing PCI (n=335,477) and demonstrated adjusted incremental costs of $4278 for those experiencing a vascular complication.16 Analyzing from the Mayo Clinic PCI Registry demonstrated an incremental cost of $5883 for bleeding events.17 Regression modeling from the ACUITY trial revealed significant additional costs for minor ($2282) and major ($8658) bleeding events.18 A recent single-center multiple-regression analysis of GUSTO definition bleeding after non-urgent PCI showed a progressive increase in hospital costs with minor ($4,310), moderate ($6,980), and major ($14,006) events.21 It is therefore rational to expect a significant decrease in costs with any technique or device that reduces the incidence of vascular complications.

The avoidance of vascular complications associated with transradial access provides the greatest cost benefit related to this approach. Several studies have demonstrated that, compared with femoral arterial access, the transradial approach has been associated with a significant reduction in vascular access site bleeding complications.1–12 It is notable that this benefit was seen in even the earliest randomized experiences of Kiemeneij (0% versus 2.0%, p=0.03) and Mann (0% versus 4.0%, p<0.01) at a time when transradial technique was still being refined.12 In a large meta-analysis of 12 studies (n=3244) the incidence of vascular complications after transradial procedures was significantly lower than that seen in transfemoral cases (0.3% versus 2.8%, p<0.001).3 More recent studies confirm these initial findings and demonstrate benefit in regard to reduced access site bleeding complications. This reduction in complications extends to high risk subgroups such as women, obese patients, the elderly, acute coronary syndrome, primary PCI and rescue PCI patients.5–11 Importantly, recent data from the MORTAL study and PRESTO-ACS vascular sub-study suggest that this reduction in access site complications also results in a mortality benefit for those patients undergoing PCI by the radial rather than the femoral route.5,12

Early Patient Mobility

Early ambulation provides potential cost reduction and economic benefit through various avenues, including expedited room turnover/increased throughput (both through the catheterization laboratory and same-day/recovery unit); decreased intensity of care required by nursing and support staff; shorter length of stay; enhanced ability to perform same-day PCI; and a more rapid return to productivity for working patients.

The economic benefits of transradial PCI were first described by Kiemeneij in 1995. Transradial stenting demonstrated a 45% cost reduction compared to transfemoral stenting driven mainly by a significantly shorter length of hospital stay.12 Mann et al, in a randomized study of 142 patients, demonstrated a 15% decrease in hospital charges with transradial stenting. In this study, total charges were significantly reduced with transradial access compared to the femoral approach ($20,476 ± 811 versus $23,389 ± 1,180; p<0.01). This was related to a lower incidence of access site complications.
complications (0% versus 4%; \( p<0.01 \)), and shorter length of hospital stay (1.4 ± 0.2 versus 2.3 ± 0.4 days). A randomized single-center study by Cooper et al demonstrated a significant reduction in hospital costs for transradial versus transfemoral diagnostic catheterization ($2010 versus $2299; \( p<0.0001 \)) related to reductions in length of stay (3.6 versus 10.4 hours), pharmacy, and total costs. It is notable that a difference was demonstrated even though vascular closure devices were not used in this study, minimizing equipment costs for the transfemoral group.

Amoroso et al quantified the workload for both catheterization laboratory and recovery area nurses following 260 consecutive transradial (n=208) and transfemoral (n=52) procedures. The workload was significantly reduced for transradial procedures (TR=86 minutes versus TF=174 minutes; \( p<0.001 \)) and for transradial recovery (TR=386 minutes versus TF=720 minutes). The workload and time savings were related to less time spent for sheath removal, early patient mobility, shorter recovery time, and shorter time to ambulation. As a frame of reference, the average hourly wage plus benefits for catheterization and recovery area nurses at our institution are approximately $41.70 and $36.54, respectively. Institutional protocol mandates a 3-hour recovery time for transradial patients and a 6-hour recovery time for transfemoral patients, thereby conferring a substantial advantage for the former group in regard to reduced post-procedure nursing costs.

As the Centers for Medicare and Medicaid Services considers the strategy of same-day or outpatient PCI, the number of patients treated by this strategy is likely to increase. Patients being considered for same-day PCI derive obvious benefit from early ambulation. This allows for an optimal time interval for evaluation of the access site. Compared to transfemoral catheterization, the transradial approach allows for both earlier ambulation and fewer access site complications. In the STRIDE study, all complications from transradial PCI occurred within 6 hours after the procedure. The incidence of access site/bleeding complications was only 2.4%, and all spontaneously resolved. Wiper et al reported zero incidence of vascular complications in a series of 442 patients treated with outpatient transradial coronary stenting. A series of 1000 patients with acute coronary syndromes treated with transfemoral coronary stenting with adjunctive abxiximab and randomized to outpatient versus overnight care demonstrated no significance in major bleeding between groups (0.8% versus 0.2%; \( p=NS \)). These studies point out the advantage of transradial PCI as an attractive access option for outpatient PCI. Cohen et al compared economic data from elective single vessel transfemoral coronary stenting with a traditional overnight hospital stay to data from 100 consecutive patients treated by transradial single vessel stenting and same-day discharge. Costs were decreased by the latter strategy by over $1000.32

Expedited ambulation has also been demonstrated with vascular closure devices. Mann and colleagues studied a consecutive series of matched patients (n=209) treated with transradial stenting versus transfemoral stenting followed by suture mediated arterial closure. Although primary success rates, length of hospital stay and percentage of patients discharged the same day were sim-

### Table 1. Sample charges related to evaluation and treatment of vascular access-site complications

<table>
<thead>
<tr>
<th>Item</th>
<th>Charge (U.S.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral vascular ultrasound</td>
<td>$243.00</td>
</tr>
<tr>
<td>CT of abdomen w/o contrast</td>
<td>$586.00</td>
</tr>
<tr>
<td>CT of pelvis w/o contrast</td>
<td>$586.00</td>
</tr>
<tr>
<td>Hemoglobin and hematocrit</td>
<td>$34.56</td>
</tr>
<tr>
<td>Hemoglobin and hematocrit x 3</td>
<td>$103.86</td>
</tr>
<tr>
<td>Type and crossmatch, etc.</td>
<td>$138.23</td>
</tr>
<tr>
<td>1 unit of PRBC/transfusion cost</td>
<td>$473.00</td>
</tr>
<tr>
<td>Thrombin injection for femoral artery pseudoaneursym</td>
<td>$667.00</td>
</tr>
<tr>
<td>Operating room charge per 30 minutes</td>
<td>$1680.00</td>
</tr>
</tbody>
</table>

### Table 2. Economic advantages of transradial versus transfemoral access for percutaneous coronary procedures

<table>
<thead>
<tr>
<th></th>
<th>Transradial Advantage</th>
<th>Transfemoral Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access-site complications</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Early mobility</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Intensity of post-procedure care</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Length of hospital stay</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Expedited throughput</td>
<td>+</td>
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</tr>
<tr>
<td>Outpatient PCI</td>
<td>+</td>
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</tr>
<tr>
<td>Early return to productivity</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Cost of vascular closure device</td>
<td>+</td>
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</tbody>
</table>
ilar between groups, costs in the transradial group were significantly lower due to fewer access site complications and lower supply costs. A similar study comparing costs for transradial access versus transfemoral access with a vascular closure device revealed significantly shorter post-procedure recovery interval (126±36 minutes versus 150±48 minutes; p<0.05) and 33% lower costs ($185 ± 52 versus $208 ± 70.4; p<0.001) with the transradial strategy.

Early ambulation and a secure access site may also allow for an earlier return to productivity. Discharge instructions at our Institution advise patients to abstain from vigorous activities and lifting objects heavier than 5 pounds for 1 week after transfemoral access, but only 4 days after transradial access. This provides obvious benefit for employed patients returning to jobs with these requirements. It is also rational to expect that those patients experiencing access site complications, significantly more frequent with transfemoral access, would be delayed in returning to work by an extended recovery.

One challenge related to transradial access stems from a relatively long learning curve, during which increased fluoroscopy times, procedure times, and decreased procedure success compared to transfemoral access can be anticipated. The economic implications are increased costs for specialized arterial access equipment (such as micropuncture kits), increased catheter usage, increased overhead related to nursing time and decreased room turnover. While these costs have not been quantified, they likely temper the economic advantages of this approach during the early adoption of the transradial technique.

References
The Association Between the Transradial Approach for Percutaneous Coronary Interventions and Bleeding

1John P. Vavalle, MD; 1,2Sunil V. Rao, MD

ABSTRACT: Bleeding complications after percutaneous coronary interventions (PCI) are a significant clinical problem associated with worse patient outcomes, including mortality. A number of studies have demonstrated that the majority of bleeding complications in patients undergoing PCI are related to access-site bleeding. Employing the transradial artery approach to PCI markedly reduces these bleeding rates. The reductions in bleeding and transfusions from employing the transradial approach may be associated with improved survival in PCI patients. Despite these data, the prevalence of transradial PCI remains low and its adoption by operators has been slow to increase. Growing data to support the superior clinical outcomes with radial artery PCI, coupled with improved awareness of this data, may lead to increases in its adoption and improved clinical outcomes and mortality after PCI.

Percutaneous coronary interventions (PCI) are an integral part of the treatment of coronary artery disease and are the most commonly performed invasive therapeutic cardiac procedures. For over two decades, the dominant site of access has been the femoral artery and remains so today.1 Despite many advantages, including a marked reduction in bleeding complications, there has been slow adoption of the transradial approach for coronary interventions since its introduction by Campeau in 1989.1,2 Currently, transradial access accounts for only 1.3% of all coronary interventions in the United States.3

With improvements in procedural technique and anticoagulation strategies, there has been a significant reduction in ischemic complications and adverse cardiac events associated with PCI.4 As a result, a growing emphasis has been placed on understanding the impact of bleeding complications on clinical outcomes and implementing ways to reduce them. Periprocedural bleeding, including minor bleeding, is associated with worse outcomes such as myocardial infarction, stroke, stent thrombosis, and death.5–8 In fact, a stepwise relationship between bleeding severity and short- and intermediate-term outcomes has been demonstrated.9

Vascular access-site complications are a major contributor to bleeding events. In a registry experience including 10,974 patients undergoing PCI, Kinnaird et al reported on the adverse outcomes associated with peri-procedural bleeding and found that the majority of bleeding events in their cohort were related to vascular access hematomas.10 Therefore, employing techniques that reduce access site bleeding complications, such as the transradial approach, can significantly reduce bleeding rates and potentially improve both short- and long-term clinical outcomes.

This review will discuss the data on the role of transradial PCI in reducing hemorrhagic complications as well as some of the challenges to adopting this technique and its impact on procedural outcomes.

Bleeding Incidence and Outcomes

Multiple studies have demonstrated that bleeding events associated with PCI are independent predictors of major adverse cardiac events and death.5,6,8–12 A 30-day analysis of the impact of major bleeding on mortality and clinical outcomes from the ACUITY (Acute Catheterization and Urgent Intervention Triage strategy) trial showed that those with major bleeding had a higher 30-day mortality (7.3% versus 1.2%, p<0.0001) than patients without major bleeding.8 In this study, major bleeding was an independent predictor of 30-day mortality with an odds ratio of 7.55 (95% CI 4.68–12.18, p<0.0001). In addition, at 30 days those with major bleeding had higher rates of composite ischemia, defined as death, MI, or unplanned revascularization for ischemia (23.1% versus 6.8%, p<0.0001), as well as stent thrombosis (3.4% versus 0.6%, p<0.0001).

In both clinical trials and registry data, access-site bleeding has repeatedly been found to be the major contributor to bleeding events. In the retrospective analysis mentioned previously by Kinnaird et al, 588 major bleeding events and 1,394 minor bleeding events were noted in the 12,029 PCIs studied.10 Of the 588 major bleeding events, 400 of them were hematomas or retroperitoneal bleeds. This represents 68% of major bleeds that are due to vascular access. Of the 1,394 minor bleeds, 834 (60%) of them were hematomas or retroperitoneal bleeds.

Rao and colleagues analyzed data from four multicenter trials of patients with ACS that included 26,452 patients and reported an association between increasing bleeding severity and a stepwise increase in 30-day and 6-month mortality.9 Not only was there an incremental increase in both 30-day and 6-month mortality with increasing bleeding severity, but procedure-related moderate and severe bleeding was associated with higher mortality rates at 30 days and 6 months compared with...
non-procedure-related moderate or severe bleeds (Table 1).

Data from the National Heart, Lung, and Blood Institute (NHLBI) Dynamic Registry evaluated the relationship between access-site hematomas requiring blood transfusions and in-hospital and 1-year mortality.26 This included data on 6,656 patients and captured 120 hematomas requiring transfusion, with an incidence of 1.8%. Ninety-seven percent of the patients with hematomas had femoral artery access. Those with hematomas requiring transfusion were more likely to be older, female, have a lower BMI, and have more comorbidities like renal, cerebrovascular, and pulmonary diseases. In-hospital mortality was approximately nine times higher in those with hematomas requiring transfusion than patients without (9.9%). After adjustment for demographic, clinical, angiographic, and procedural variables, hematomas requiring transfusion remained an independent predictor of death in-hospital and 1-year mortality.6 This included data on 6,656 patients and captured 120 hematomas requiring transfusion, with an incidence of 1.8%. Ninety-seven percent of the patients with hematomas had femoral artery access. Those with hematomas requiring transfusion were more likely to be older, female, have a lower BMI, and have more comorbidities like renal, cerebrovascular, and pulmonary diseases. In-hospital mortality was approximately nine times higher in those with hematomas requiring transfusion than patients without (9.9%). Similarly, at 1 year, mortality among those who developed a hematoma requiring transfusion was approximately 4.5 times higher than those who had not (18.8% versus 9.9%). After adjustment for demographic, clinical, angiographic, and procedural variables, hematomas requiring transfusion remained an independent predictor of death both within the hospital (OR=3.59, 95% CI 1.66–7.77) and at 1 year (HR=1.65, 95% CI 1.01–2.70).

By combining patient data from the OASIS Registry,13-15 OASIS-2 trial,16 and CURE trial,17 Eikelboom and colleagues evaluated the impact of bleeding on prognosis in 34,146 patients with acute coronary syndrome.18 At 6 months, 667 (2.0%) patients developed major bleeding. Those with major bleeding were five times more likely to die within the first 30 days (12.8% versus 2.5%, \( p<0.0001 \)) and 1.5 times more likely to die between 30 days and 6 months (4.6% versus 2.9%, \( p=0.002 \)). As in other studies, they reported a similar association between major bleeding and ischemic events such as myocardial infarction and stroke.

Retropertoneal hematomas, as a consequence of femoral artery access for PCI, have been shown to portend significant adverse events and are associated with a high mortality rate. Ellis and colleagues reported on data prospectively collected on 28,378 patients undergoing PCI.19 While the incidence of retroperitoneal hemorrhage was low in this cohort (176 patients/0.57%), subsequent outcomes in patients with retroperitoneal bleeding were substantially poor. Of those with retroperitoneal hematomas, 73.5% required blood transfusions and 10.4% of these patients died during hospitalization.

In addition to clinical and demographic predictors of retroperitoneal bleeding, femoral artery sheath placement superior to the inferior epigastric artery (\( p<0.001 \)) was associated with a higher risk of bleeding in the above study.19 This highlights the importance of appropriate technique when gaining arterial access through the femoral approach to help avoid one of its most ominous complications.

Arteriotomies located within the common femoral artery above the bifurcation but below the inferior epigastric artery reduce access-site complications, including retroperitoneal bleeding, compared with arteriotomies that are higher or lower.20 The use of fluoroscopy to identify the femoral head can help maximize the likelihood of access into the common femoral artery by placing the skin incision 1–2 cm inferior to the middle part of the femoral head.21 It is unclear how common the use of routine fluoroscopy is to guide femoral arteriotomy in clinical practice. Despite its potential beneficial effect on appropriate arteriotomy location, patient variability in vascular anatomy likely does not guarantee appropriate location even when fluoroscopy is used.

### Transradial Approach

Avoiding the femoral artery in favor of the radial artery for coronary angiography and interventions has been repeatedly shown to reduce bleeding complications. The radial artery is smaller in diameter, easily compressible, is remote from the retroperitoneal space, and does not have any adjacent major vascular structures. Early studies reported on the feasibility of this approach and began to demonstrate reductions in complications and cost.22-24 Transradial PCI was subsequently shown to be safe and effective in the high-risk setting such as acute myocardial infarction, rescue PCI, and in conjunction with glycoprotein IIb/IIIa inhibitors.25-28

More contemporary studies, as in the Prospective Registry of Vascular Access in Interventions in Lazio region (PREVAIL) have reported on the access-site specific outcomes in “real world” clinical settings.29 They evaluated 1,052 patients having any percutaneous cardiovascular procedure requiring arterial access. In that cohort, 509 had radial access with 543 having femoral access. Approximately 40% of patients in both groups had coronary angioplasty. Analysis was performed on an inten-

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### Table 1. Procedural versus non-procedural bleeding and impact on mortality

<table>
<thead>
<tr>
<th></th>
<th>No bleeding (reference)</th>
<th>Mild bleeding</th>
<th>Moderate bleeding</th>
<th>Severe bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure-related</td>
<td>1.0</td>
<td>1.3 (0.9–1.8)</td>
<td>3.7 (2.8–4.9)</td>
<td>16.5 (12.0–</td>
</tr>
<tr>
<td>bleeds 30-day</td>
<td>22.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedure-related</td>
<td>1.0</td>
<td>1.1 (0.9–1.4)</td>
<td>2.6 (2.1–3.3)</td>
<td>10.5 (8.0–13.7)</td>
</tr>
<tr>
<td>bleeds 6-month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-procedure-related</td>
<td>1.0</td>
<td>2.1 (1.6–2.6)</td>
<td>2.5 (1.7–3.5)</td>
<td>10.9 (7.1–16.7)</td>
</tr>
<tr>
<td>bleeds 30-day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-procedure-related</td>
<td>1.0</td>
<td>1.9 (1.6–2.2)</td>
<td>2.2 (1.7–2.9)</td>
<td>8.7 (6.2–12.4)</td>
</tr>
<tr>
<td>6-month mortality</td>
<td></td>
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</table>

Adapted from Rao SV, et al. AJC 2003.9
tion-to-access basis. The primary endpoint was a combined incidence of in-hospital major and minor bleeding, stroke, and access-site vascular complications. They reported that radial access was significantly associated with a reduction in the primary outcome as compared to femoral access (4.2% versus 1.96%, \( p = 0.03 \)). A combined secondary endpoint of in-hospital death and myocardial infarction or reinfarction was also lower in the radial access group (3.1% versus 0.6%, \( p = 0.005 \)). Multivariate analysis adjusting for confounders showed that intention-to-access from the radial approach was independently associated with a reduction in both the primary endpoint (OR=0.37, 95% CI 0.16–0.84) and secondary endpoint (OR=0.14, 95% CI 0.03–0.62).

Chase and colleagues reported on reductions in mortality, likely mediated through reduced transfusions, after percutaneous coronary interventions performed via the radial artery when compared with the femoral approach.\(^\text{30}\) The Mortality benefit Of Reduced Transfusion after percutaneous coronary interventions via the Arm or Leg (MORTAL) study evaluated 38,872 PCI procedures in 32,822 patients in British Columbia. In this group, femoral access was used in 79.5% of the procedures, and radial access was used in 20.5%. In the femoral group, 2.8% of the procedures were complicated by the need for peri-procedural transfusions, while in the radial group, only 1.4% of the procedures were associated with a transfusion. The transfusion rate in the radial group was essentially half that found in the femoral group with an adjusted odds ratio of 0.59 (95% CI 0.48–0.73). This reduction in the need for transfusions was associated with a significant reduction in mortality at 30 days and 1 year (Table 2). The death rates at 30 days for the transfused group versus the non-transfused group were 12.6% and 1.3%, respectively. At 1 year, the death rates were 22.9% and 3.2%. The adjusted odds ratio for death at 30 days in the transfused group versus the non-transfused group was 4.01 (95% CI 3.08–5.22) and at 1 year was 3.58 (95% CI 2.94–4.36). The number of transfusions that must be avoided to prevent one death (number needed to treat) calculated to be approximately 15 transfusions.

The data were then analyzed to compare mortality at 30 days and 1 year in the radial access group against the femoral access group. The adjusted odds ratio for 30-day mortality for transradial access versus femoral access was 0.71 (95% CI 0.61–0.82). At 1 year, the adjusted odds ratio for mortality was 0.83 (95% CI 0.71–0.98). When this comparison was made amongst the non-transfused patients, no significant difference in mortality was noted between the radial access and femoral access group, suggesting that the reductions in mortality observed with transradial access over femoral access are mediated through a decrease in bleeding and specifically in the need for transfusions.

A meta-analysis comparing radial versus femoral approach for PCI performed by Agostini and colleagues identified 12 studies that meet their criteria for inclusion.\(^\text{7}\) The primary outcomes evaluated were major adverse cardiac events (MACE), access site complications including bleeding, and procedural success. Major adverse cardiac events in the transradial and transfemoral groups were not significantly different at 2.1% and 2.4%, respectively. However, there were significantly fewer access-site complications in the transradial group (0.3%), compared to the femoral group (2.8%) with an odds ratio of 0.20 (95% CI 0.09–0.42, \( p<0.0001 \)). This, however, was observed at a cost of increased procedural failures with 7.2% reported in the transradial group and 2.4% in the femoral access group (OR=3.30, 95% CI 1.63–6.71; \( p<0.001 \)). Further analysis for secondary procedural outcomes revealed increased fluoroscopy time with the radial approach but shorter lengths of stay and total hospital charges. These latter outcomes may reflect lack of operator experience with the transradial approach and suggest that widespread exposure to transradial PCI techniques may reduce procedural failure and fluoroscopy time while still preserving the bleeding benefit.

A more recent meta-analysis by Jolly and colleagues evaluated 23 randomized trials comparing radial to femoral access and analyzed its impact on major bleeding and ischemic events.\(^\text{1}\) There was a 73% reduction in major bleeding in the radial access group (0.05% versus 2.3%, \( OR=0.27, 95\% CI 0.16–0.45 \)). Also noted was a non-statistically significant reduction in the rates of death, myocardial infarction, and stroke. Inability to cross the lesion and crossover to the other access site were both higher in the radial group as well.

The outcomes of radial and femoral approaches to PCI in 593,094 procedures reported in the National Cardiovascular

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**Table 2. The Impact of Transfusions on Mortality in Radial Versus Femoral Cases**

<table>
<thead>
<tr>
<th></th>
<th>No bleeding (reference)</th>
<th>Mild bleeding</th>
<th>Moderate bleeding</th>
<th>Severe bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=108 of 7972</td>
<td>Radial cases</td>
<td>Radial cases</td>
<td>Femoral cases</td>
<td>Femoral cases</td>
</tr>
<tr>
<td>requiring transfusion</td>
<td>requiring transfusion</td>
<td>not requiring</td>
<td>requiring transfusion</td>
<td>not requiring</td>
</tr>
<tr>
<td>1.4%</td>
<td>n=7864 of 7972</td>
<td>transfusion</td>
<td>n=859 of 30,900</td>
<td>transfusion</td>
</tr>
<tr>
<td>(98.6%)</td>
<td>(98.6%)</td>
<td>(98.6%)</td>
<td>(2.8%)</td>
<td>(97.2%)</td>
</tr>
<tr>
<td>30-day mortality</td>
<td>9/108 (8.3%)</td>
<td>69/7864 (0.9%)</td>
<td>113/859 (13.2%)</td>
<td>407/30,041 (1.4%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-year mortality</td>
<td>26/108 (24.1%)</td>
<td>198/7864 (2.5%)</td>
<td>195/859 (22.7%)</td>
<td>1018/30,0041 (3.4%)</td>
</tr>
</tbody>
</table>

Adapted from Chase AJ, et al. BMJ 2008.\(^\text{32}\)
VAVALLE and RAO

Data Registry (NCDR) from 606 centers from 2004 to 2007 was recently reported in an analysis performed by Rao and colleagues. In this large cohort, only 15 of the 7,804 (0.19%) patients who had radial access experienced vascular complications, defined as access site occlusion, peripheral embolization, arterial dissection, pseudoaneurysm, or arteriovenous fistula formation. Compared to the femoral access, radial access had a significantly lower risk of bleeding (OR=0.42, 95% CI 0.31–0.56) without any reduction in procedural success (adjusted OR=1.02, 95% CI 0.93–1.12). Despite these advantages, this study found that the use of the radial approach for PCI in this large U.S. cohort remains very uncommon, with only 1.32% of the procedures being a radial access PCI.

Conclusions
Periprocedural bleeding remains a significant complication after PCI. Multiple studies have shown that the most common site of bleeding in patients undergoing PCI is related to the vascular access site and that bleeding is associated with worse short- and long-term outcomes. The transradial approach to PCI has been repeatedly shown to reduce bleeding and improve clinical outcomes and mortality. Despite this, the transition to this approach, especially within the United States, remains slow with a very low percentage of PCIs being performed via the radial artery. This is likely related to lack of exposure to transradial PCI during fellowship training and operator discomfort with transradial techniques. If these hurdles can be overcome and the use of the transradial approach increases, the available data suggest that outcomes after PCI can be significantly improved.

References
Transradial Approach for Percutaneous Intervention in Acute Myocardial Infarction

Craig A. Thompson, MD, MMSc

ABSTRACT: Transradial intervention (TRI) approach has emerged as an alternative and competitive method compared with transfemoral intervention (TFI) approach for percutaneous coronary intervention (PCI) in simple to complex coronary disease. TRI, when performed by operators experienced with this technique, appears to have comparable efficacy and procedural resource utilization compared with TFI. However, vascular access complications, specifically major and minor bleeding, can be reduced with TRI. Patients with acute myocardial infarction (AMI) are at the highest risk for periprocedural bleeding for a variety of reasons, and may derive the greatest benefit from TRI. This review article will discuss potential advantages for TRI in the setting of AMI, barriers, and development of a TRI AMI program.

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Key Words: Transradial, radial, vascular, intervention, myocardial infarction, stent

Transradial intervention (TRI) approach for percutaneous coronary intervention (PCI) has emerged as an alternative to transfemoral intervention (TFI) in many settings and serves as a default access strategy for operators experienced in this technique. The radial artery is the preferred approach arm, compared with the brachial artery because, in most patients, the hand can remain perfused in the case of radial artery occlusion via the ulnar artery and a patent palmar vascular arch. This is not the circumstance with brachial access; the brachial artery serves as an end blood supply to the forearm and hand via the radial and ulnar arteries and its occlusion can be devastating. In addition, vascular compression and hemostasis are more consistent in the radial distribution and wrist compared with the upper arm post-PCI.

TRI can be used successfully in many complex coronary lesion subsets, including left main disease, bifurcations, multivessel disease, chronic total occlusion, thrombotic, and calcified lesions.1–11 The efficacy of TRI seems comparable to TFI when used by experienced operators. The learning curve includes proper patient selection, radial access assessment, troubleshooting arm vessel anomalies,12 guidewire selection and engagement, augmentation of guide support, and adjunctive device selection. With TRI specific experience, the operator can eff-ectively utilize this approach in most patients if desired, and maintain the femoral approach as a crossover technique as needed. In this setting, efficacy appears comparable between TRI and TFI. Although vascular complications exist with both approaches, the mechanism of the complications often differs between the radial and femoral routes. TRI in the appropriate settings seems to reduce major and minor bleeding.13–19

Bleeding and Adverse Events in Myocardial Infarction

Periprocedural blood loss, as defined by TIMI and GUSTO criteria, as well as blood transfusion are associated with higher rates of death and recurrent ischemia in the short- and long-term in patients with AMI and acute coronary syndrome.20,21 Elderly patients, women, and patients with very high or very low body surface area have higher rates of vascular adverse events post-PCI as well.22–28 It is noteworthy that patients with myocardial infarction are at the highest risk for bleeding for multiple reasons, but particularly related to anticoagulant/antiplatelet/thrombolytic status and the emergent nature of their procedures. It is also troublesome that bleeding complications in this patient subset are much more likely to be associated with repeat ischemia as well as short- and long-term adverse cardiac events, including mortality.

Major and minor bleeding, which can be particularly life threatening in the clinical setting of AMI or acute coronary syndrome are lower with TRI. Bleeding events do still occur and remain associated with poorer outcome and therefore cannot be trivialized even with TRI approach.25 but TRI appears to have a different vascular adverse event profile compared with TFI in terms of the nature and frequency of events. Radial artery occlusion (RAO) is found in -5% of cases during the post-TRI follow-up period,26 and a much higher percentage of patients may experience long-standing impairment of radial artery vasomotor tone of uncertain significance.

It is not currently clear if newer coated sheath designs, improved compression techniques, and increased operator experience have contributed to a reduction in RAO over time. In addition, radial artery access with inadequate compression technique is prone to pseudoaneursym formation, as is the femoral artery, but with much lower apparent frequency.27 Finally, a critical ischemic limb complication involving a dominant hand may be a catastrophic life event for a patient, though these complications in the lower extremity can be equally serious and impairing.

It is unclear if systematic utilization of TRI for myocardial infarction can compress morbidity and mortality in this
clinical patient subset by virtue of reduction in vascular complications, but preliminary data are encouraging.

Transradial PCI in Acute Myocardial Infarction

Ochiai and colleagues performed an observational pilot investigation to determine if risk stratified AMI patients could experience reduced bleeding complications and earlier mobilization with TRI and primary stenting. Twenty-seven patients with Killip class I or II and positive Allen’s test were treated by operators with more than 30 cases of elective TRI experience. Successful stent delivery was achieved in all patients and successful stenting with normalized outflow in 97% of patients. No major vascular complications occurred in this experience. Philippe et al. observed similar results in their experience of 119 consecutive patients with AMI having primary PCI via radial (64 patients) or femoral (55 patients) approach with adjunctive abciximab. Hospital length of stay was higher in the TFI group compared with TRI (5.9 versus 4.5 days, respectively, p=0.05). There were no vascular complications in the TRI group, but 3 (5.5%) in the TFI group (p=0.04). They did observe longer radiation exposure times in the TRI cohort. Cruden and associates expanded on these registry observations in 287 patients having rescue PCI in patients with unsuccessful thrombolysis for AMI. In this retrospective analysis, procedural success was similar for TRI and TFI (98% versus 93%, p=0.3). However, vascular complications (0% versus 13%, p=0.01) and length of stay (7.0 versus 7.9 days, p=0.005) favored TRI over TFI.

Saito and colleagues, in the TEMPURA clinical trial, randomized 149 patients with AMI <12 hours from onset to TRI (n=77) or TFI (n=72). Procedural success (96.1% TRI versus 97.1% TFI, p=NS) and adverse cardiac events (5.2% TRI versus 8.3% TFI, p=NS) were similar between these groups. Severe bleeding was seen in 3% patients with TFI and none with TRI. In the RADIAL AMI pilot trial, Cantor and colleagues randomized 50 patients having primary or rescue PCI to TRI or TFI approaches. No major bleeding or transfusion was required in either group. Procedure time slightly favored TFI over TRI (this is in contrast with slightly better TRI procedure times in the Saito series). Final TIMI flow, contrast, and fluoroscopy time were similar for TRI and TFI.

It should be noted that patients in all of these investigations were well selected. Many patients with severe cardiogenic shock, hemodynamic instability, and/or tenuous or nonpalpable radial pulse were often not included. Furthermore, and very importantly, the operators in all these studies had significant TRI experience in the elective setting of 30 to 100 (and often more) cases.

The Transradial Acute Myocardial Infarction Program

No formalized guidelines exist regarding development of TRI AMI program, but it is reasonable to assume that this should be an outgrowth of standard elective TRI. Leading to AMI applications for TRI, the operator and support staff should have experience managing well selected, non-complex patients in the elective setting to develop skill and experience with this method. This elective experience should be extended to more complex scenarios including 5/6 Fr bifurcation techniques, calcification, and vascular/coronary tortuosity. The operator can then become more accustomed to technique modification and device choices that are suited for these situations in a more controlled environment before encountering these circumstances in patients who are less stable and when time to perfusion is critical. The number of cases to achieve these competencies will be variable by operator and program, but it should be recognized that a minimum of 30 to 100 TRI cases per operator is supported by the citations from this manuscript (and the majority of operators in these cited reports likely had more TRI experience).

Room preparation and patient setup are keys in AMI TRI. Arm boards for the access site should be placed close to femoral position to mimic the TFI approach. Many operators shift a standard femoral window drape so the right femoral window is over the right radial (for right TRI) and the left femoral window is overlying the right femoral artery (for femoral crossover or IABP/hemodynamic support device placement). This method works well for non-obese patients. An alternate method is to use towel drapes for the desired radial access site and standard femoral window drape for the legs. Although the preparation time is slightly prolonged to prepare provisional femoral access, it is typically justified to minimize this activity when femoral access is needed during the case. This delay may be offset by the ability to access the radial without needing fluorescent guidance (i.e., while the staff is completing room setup).

Whatever the preparation choices for the program, this should be standardized to truncate door-to-balloon time. Trans-radial sheaths, access kits, and diagnostic and interventional catheters should be immediately available. When setup is standardized and gear is immediately available, room-to-coronary engagement time should be comparable to transfemoral technique, and therefore reduce barriers for TRI approach on the basis of perceived prolongation of procedure and/or door-to-balloon time.

Diagnostic angiography should be performed in the non-infarct vascular distribution, followed by angiography with a guide catheter for the infarct-related distribution (XB, EBU, or equivalents for the left coronary, Judkins right 4, Amplatz left 1 for the right coronary, or per operator practice or discretion). Another potential advantage to TRI for primary PCI is that dedicated radial guide catheters that are designed for both the RCA and LCA can be used (e.g., Kimny). Guide catheter anchoring support, deep seating, or other augmentation may be utilized as needed. Thrombectomy, PTCA, or direct stenting can then be performed and PCI completed in usual fashion. Vascular hemo-stasis can be achieved in typical transradial fashion using a variety of specialized radial closure devices.

The specifics of radial PCI technique are beyond the scope
of this manuscript; however, active guide catheter support augmentation may be particularly important in myocardial infarction. First, guide catheter selection is incredibly important. If the guide catheter is a poor fit for support, it should be exchanged for a better choice. Often, forcing a poor guide catheter choice for complex anatomy is associated with increased procedural difficulty. Second, multiple wires (often three or more) to enhance coaxial orientation and modify vascular architecture and support can be beneficial when device delivery is difficult. Finally, a wire and monorail balloon in a sidebranch (sidebranch anchor balloon technique) can be used to improve device delivery. Other methods for anchoring and guide augmentation exist, but the aforementioned techniques should be standard for the transradial interventionalist.

Conclusion
In conclusion, TRI can be an effective alternative approach to TFI in patients with myocardial infarction. This technique can be accomplished safely and effectively in the hands of an experienced operator and staff. Patient and room preparation and operator experience with elective complex transradial intervention are the starting basis for developing a transradial acute myocardial infarction program. The potential benefits of this approach include reduced vascular complications in this high-risk subset, improved patient comfort, and earlier ambulation.

References