A Technical Guide Describing the Use of Transradial Access Technique for Endovascular Interventions

Aaron M. Fischman, MD, Nathaniel C. Swinburne, MD, and Rahul S. Patel, MD

Transradial arterial access (TRA) has been employed for transcatheter coronary procedures for more than 25 years, with numerous studies demonstrating improved patient safety as compared with transfemoral arterial access. However, TRA remains underused by the interventional radiology and vascular surgery communities. Advantages of TRA over transfemoral arterial access include easier accomplishment of postprocedure hemostasis, decreased risk of hemorrhagic complications, shorter patient recovery leading to immediate ambulation and decreased procedure-related costs, and increased patient satisfaction. In particular, TRA may be advantageous in the population of patients with obesity. The primary patient selection factor to consider before attempting TRA is whether the patient has adequate collateral perfusion to the hand; this is assessed using the Barbeau test. Limitations of TRA may include operator unfamiliarity or learning curve and unavailability of adequate length catheters. The most common complication, although still rare, is localized access site hematoma, which is often asymptomatic. Radial artery occlusion is rare and rarely symptomatic owing to collateral perfusion to the hand. Theoretical increased risk of cerebral embolism during TRA may be minimized by preferentially accessing the left wrist during below-diaphragm procedures, which limits transcatheter manipulation of the aortic arch. Transulnar artery access is under investigation for use in patients who cannot undergo TRA. Providing patients the option of TRA can lead to improved outcomes, potentially increasing safety and patient satisfaction while decreasing procedure costs.

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Background

Use of the radial artery as the primary access vessel into the arterial system for transcatheter diagnosis and intervention is not a new concept. The first series describing diagnostic angiography of the coronary circulation using transradial arterial access (TRA) was published in 1989 by Lucien Campeau at the Montreal Heart Institute. Campeau suggested percutaneous radial access as a safer alternative to percutaneous and “cutdown” brachial or axillary access.

His series of 100 patients demonstrated an 88% technical success rate and a 6% asymptomatic radial artery occlusion rate, which was a significant improvement over brachial or axillary upper arm access. Shortly thereafter, in 1992, Kiemeneij performed the first successful transradial coronary angioplasty procedure and then, in 1993, the TR coronary stent placement via the radial artery. Since then, the use of this technique has grown significantly worldwide.

Despite this growth, TRA is estimated to account for only 10% of percutaneous coronary interventions (PCIs) worldwide. There are some areas in Canada and Europe that perform approximately 95% of PCIs via the TR approach. In the United States, TRA is estimated to have grown from 1.2% of all PCI procedures in 2007 to slightly more than 16% in 2012. Its usage is largely absent within the interventional radiology and vascular
surgery communities, however. The brachial artery continues to be the most common upper extremity artery used for noncoronary interventions. Reasons for underuse of TRA outside the cardiac catheterization laboratory may include a lack of appropriate training, equipment limitations such as inappropriate catheter length and shape, and the initial learning curve.

This review describes the technique of TRA for noncoronary interventions, including below-diaphragm interventions such as hepatic embolization, and the issues surrounding its usage.

Advantages of the Transradial Approach

There are several obvious advantages of TRA over transfemoral arterial access (TFA). First, the radial artery is more superficial than the femoral artery, and there are no surrounding critical structures that are susceptible to injury. In addition, inadvertent injury to the artery itself, such as dissection or thrombosis, is significantly less detrimental to the patient because of the dual blood supply to the hand. The radial artery is also readily compressible, which decreases the incidence of postprocedural bleeding complications during PCI and, in some studies, decreased cardiac mortality. Hemostasis can be achieved without the introduction of a foreign body, such as a vascular closure device, which is a common practice in many interventional suites that use TFA.

Patient comfort issues are also of paramount importance, especially in the current climate in which patients choose among many treatment options. Following TRA, patients are able to ambulate immediately, sit up in bed, and are discharged home faster. In a randomized trial, Cooper et al demonstrated a strong patient preference, improved quality-of-life metrics, and decreased hospital costs for TRA over TFA during cardiac catheterization. The specific advantages of immediate ambulation and decreased incidence of back pain are of particular importance during hepatic embolization, which is performed in a patient population that frequently experiences nausea and vomiting.

Patient Selection

As is the case with every procedure, patient selection is paramount. Although not every patient is ideally suited for TRA, many operators believe that approximately 90% of patients can undergo TRA for PCI using a “radial first” approach. It remains to be seen whether this high percentage translates to the noncoronary space. It has become clear that TRA is associated with a steeper learning curve as compared with TFA. When initially learning this technique, higher rates of femoral crossover are seen, particularly in patients with smaller-caliber radial arteries, anatomical variants, and aortic disease and tortuosity.

In our practice, TRA is preferred in patients with obesity because of the associated difficulty in locating the common femoral artery, as well as the difficulty in detecting and controlling postprocedural hemorrhage. In 2007, the Transradial Approach in Overweight Patients (TROP) registry demonstrated that TRA significantly reduced vascular complications in patients with obesity. A retrospective review in 2012 examining access site complications in patients with extreme obesity (body mass index ≥ 40) found a significantly decreased rate of major bleeding and access site injuries following TRA as compared with TFA. For similar reasons, TRA may be advantageous for patients who are deemed high risk for bleeding complications, such as those with thrombocytopenia, coagulation disorders, or liver dysfunction, those receiving anticoagulation, and patients of advanced age. Elderly patients often benefit from the TR approach; however, anatomical issues such as vascular tortuosity and atherosclerosis may make these cases technically more challenging. Female sex has also been shown to be a risk factor for increased bleeding during PCI. In 2007, Pristipino et al demonstrated a significantly decreased risk of major and minor bleeding in women with TRA as compared with TFA. It should be noted, however, that women tend to have smaller radial arteries than men (average diameter 2.43 ± 0.38 mm in women vs 2.69 ± 0.40 mm in men), which can present a technical challenge for TRA.

All patients being considered for TR catheterization should first be evaluated for adequate collateral perfusion to the hand via a modified Allen’s test with a pulse oximeter, also known as the Barbeau test. A pulse oximeter is placed on the patient’s thumb, the radial pulse is identified, and the waveform is analyzed. The radial artery is then compressed, and the pulse oximeter waveform is again analyzed for up to 2 minutes and graded. Ulnopalmar patency includes the following 4 types: (A) no damping of the pulse tracing immediately after compression, (B) damping of pulse tracing, (C) loss of pulse tracing followed by recovery within 2 minutes, and (D) loss of pulse tracing without recovery within 2 minutes (Fig. 1). Barbeau et al demonstrated that this technique is more sensitive than Allen’s test in determining suitable candidates for TRA by direct comparison in 1010 patients. It was also shown that only 1.5% of patients were not suitable for TRA (Barbeau type D).

It is important to note that the Barbeau D waveform is the only true contraindication to TRA, as Barbeau types A-C confirm patency of the ulnopalmar arch. Other relative contraindications for TRA include small radial artery (<2 mm) and patients with a dialysis fistula or those nearing dialysis who may depend on the radial artery for access.

Another minor drawback related to TRA is that intra-procedural cone beam computerized tomography (CT) may be technically more challenging to obtain as compared with TFA. However, cone beam CT acquisition during TRA is possible (Fig. 2), and new imaging protocols are in development to facilitate this technique.
Below-Diaphragm Interventions Using Transradial Approach

Setup and Access

For interventional procedures below the diaphragm, such as hepatic embolization, left radial artery access is preferred over right-sided access for several reasons. There is a slightly shorter distance to the target vessel from the left wrist, which can be crucial given the current limitations of catheter lengths (discussed subsequently in detail). In addition, the guiding catheter or sheath is not positioned across the great vessels during the procedure, theoretically limiting the risk of cerebral emboli or thrombus formation.

The patient's arm can be positioned in several ways. One option is to position the arm at 75º-90º, almost perpendicular to the table (Fig. 3). This allows for easier access to the vessel but makes catheter exchanges somewhat awkward and cumbersome. We prefer to position the arm at the patient's side in a similar position to that of the patient's groin. This allows for catheters or wires to be positioned over the patient's draped body similar to TFA (Figs. 4A and B). Arm positioning boards can also be used, and there are several such options available in the market today. The wrist should be slightly hyperextended, and a towel roll is used to support the wrist (Fig. 3). Prone positioning has also been described, allowing the left radial artery to be accessed and positioned in a similar fashion to those of the right common femoral artery. This
The pulse oximeter is always placed on the thumb or forefinger of the wrist being accessed. The PRE-DILATE protocol, which entails topical application of 30 mg of nitroglycerin ointment and 40 mg of lidocaine cream to the radial artery access site 30 minutes before catheterization, significantly increases radial artery cross-sectional area, with the lidocaine also serving as a local anesthetic. Our laboratory uses EMLA cream (lidocaine 2.5% and prilocaine 2.5%) in place of pure lidocaine cream.

In our laboratory, radial artery access is obtained using ultrasound guidance and the Seldinger technique with a 21-gauge echogenic-tip needle (Fig. 4C). Other laboratories use the "angiocath technique." A small intra venous catheter is advanced through both walls of the radial artery under direct palpation and slowly pulled back until blood flow is seen. A 0.018-in wire is advanced into the radial artery (Fig. 4D). If there is any resistance, the wire is pulled back and readjusted. If the wire cannot be advanced, fluoroscopy and direct visualization with contrast is performed.

A specialized radial access sheath with a hydrophilic coating is then used. The dilators on these sheaths are tapered to 0.018 in to allow for immediate sheath placement without an incision or wire exchange. The most common hydrophilic sheath used in our laboratory is the 10-cm length Glidesheath (Terumo Interventional Systems, Somerset, NJ) (Fig. 5A). Other commonly used hydrophilic radial sheaths include PreludeEASE (Merit Medical Systems, Inc, South Jordan, UT) and Flexor Radial Introducer (Cook Medical, Inc, Bloomington, IN). Rathore et al. showed that the use of hydrophilic sheaths decreases the incidence of radial artery spasm and pain during TRA. Most of the diagnostic and interventional procedures can be performed with 5- to 6-F sheaths; however, safe radial access can be performed with sheaths ranging in size from 4-7 F. The Glidesheath Slender (Terumo Interventional Systems) is a radial sheath with a very thin wall, providing a 6-F lumen while maintaining an outer diameter matching that of a 5-F sheath (Fig. 5B). In a prospective feasibility study enrolling 114 patients, Aminian et al. demonstrated greater than 99% technical success using the Glidesheath Slender with no major sheath kinking and a radial artery occlusion rate less than 1% at 30-day follow-up. Table 1 lists several radial artery access sheaths presently in the market.

After sheath placement, a medication "cocktail" is administered intra-arterially directly through the access sheath. Nitrates, calcium channel blockers, and heparin...
are typically used to prevent arterial spasm and reduce vascular tone. Although there are numerous recommendations, there is no consensus on the ideal mixture. Our laboratory uses 3000 IU of heparin, 200 mg of nitroglycerin, and 2.5 mg of verapamil. It is important to note that verapamil causes a significant burning sensation upon injection, so continual hemodilution and slow injection is recommended (Fig. 6).

Catheter Selection

In most cases, a 110-cm Jacky Radial or Sarah Radial Optitorque catheter (Fig. 7) (Terumo) and a standard 0.035-in access wire are used to navigate the subclavian region and engage the descending aorta. The catheter is then “hubbed” in the sheath, and small aliquots of contrast are used as the catheter is pulled back to engage the superior mesenteric artery and celiac artery. Other catheters that may be used for subdiaphragmatic intervention include the Merit Ultimate catheters (Merit Medical Systems, Inc, South Jordan, UT). In addition to the unique shape of these catheters, the 110-cm length makes them very useful in taller patients where 100 cm is not adequate.

One of the major limitations of TRA for hepatic embolization is the limited availability of unique shapes and lengths for engaging the mesenteric vessels. Efforts are currently underway to design new catheters for this purpose. For hepatic embolization procedures, standard-length microcatheters (130 and 150 cm) are then used to select the appropriate hepatic artery for treatment purposes. In general, 150-cm length microcatheters are recommended when using diagnostic catheters that are longer than 100 cm, particularly if Tuohy-Borst adapters are being used.
In our practice, TRA is most commonly used in transarterial chemoembolization (TACE) and transarterial radioembolization (TARE) in both the macroaggregated albumin mapping procedures and delivery of yttrium-90. In 2003, TACE using TRA was first described in Japan.\textsuperscript{18} Shiozawa et al retrospectively compared 150 TACE patients who underwent TFA and 177 patients who underwent TRA. Of the 70 patients who received both approaches, 92.9% preferred TRA. Although unpublished, our data using the TRA approach currently suggest the same trend.

Uterine fibroid embolization may also be safely performed using TRA. In a retrospective study examining transradial uterine fibroid embolization in 29 patients, 100% technical success was achieved using a 4-F 120-cm Glidecath (Terumo), with additional use of a microcatheter required in 12 cases for cannulation of the horizontal segment of the uterine arteries. No major or minor complications were experienced, and there were no cases of radial artery occlusion at 1-month follow-up.\textsuperscript{19}

Imaging evaluation and intervention planning now include a complete vascular evaluation with CT angiography or magnetic resonance angiography of the hepatic vasculature. The angle of the access artery (celiac or superior mesenteric) to the aorta as well as the vascular tortuosity (iliac or aortic arch) is taken into account when planning TRA or TFA. Difficult access cases can be triaged to a single technique based on the perceived difficulty of vascular access. For complex mesenteric, renal, and iliac interventions, 5- and 6-F guide catheters are used for balloon angioplasty, intravascular ultrasound, and stent placement. The Launcher coronary guide catheter (Medtronic, Inc, Minneapolis, MN) and the Runway guiding catheter (Boston Scientific Corporation, Natick, MA) are most commonly used. These are available in different catheter tip shapes and multiple lengths, including 100, 110, 118, and 125 cm.

### Radial Artery Hemostasis

Nonocclusive “patent” hemostasis is a key technique in minimizing risk of postprocedural radial artery thrombosis. The prevention of radial artery occlusion-patent hemostasis evaluation trial (PROPHET) study in 2008 demonstrated that this technique is superior to occlusive pressure in maintaining radial artery patency.\textsuperscript{20} Nonocclusive hemostasis is typically performed using a wrist band device. There are several such devices in the market today, which are listed in Table 2. The most common device used in our laboratory is the TR Band (Terumo Interventional Systems) (Fig. 8). A distal radial artery pulse should be palpable during the hemostasis period, which ranges from 30-120 minutes, depending on the complexity of the procedure performed. After a typical TACE or TARE procedure using a 5-F access sheath, the band is slowly deflated in 15 minutes after 75-90 minutes of patent hemostasis. If bleeding or “oozing” is seen from the puncture site during the removal process, the band is reinflated for 20 minutes, and the process is repeated. Once the band is successfully removed, the patient is observed for 30 minutes before discharge.

<table>
<thead>
<tr>
<th>Device Name</th>
<th>Company</th>
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<tbody>
<tr>
<td>Flexor Radial Introdoer</td>
<td>Cook Medical, Inc</td>
</tr>
<tr>
<td>RadialSource, Avanti</td>
<td>Cordis (Bridgewater Township, NJ)</td>
</tr>
<tr>
<td>PreludeEase</td>
<td>Merit Medical Systems, Inc</td>
</tr>
<tr>
<td>Adelante Radial</td>
<td>Osclor, Inc (Palm Harbor, FL)</td>
</tr>
<tr>
<td>Engage TR</td>
<td>St Jude Medical, Inc (St Paul, MN)</td>
</tr>
<tr>
<td>Glidesheath, Glidesheath</td>
<td>Terumo Interventional Systems</td>
</tr>
<tr>
<td>Slender</td>
<td>Vascular Solutions, Inc (Minneapolis, MN)</td>
</tr>
<tr>
<td>VSI Radial</td>
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**Table 2 Radial Compression Devices Approved in the United States**

<table>
<thead>
<tr>
<th>Device Name</th>
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<tbody>
<tr>
<td>VasoStat</td>
<td>Forge Medical (Philadelphia, PA)</td>
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<tr>
<td>HemoBand</td>
<td>Hemoband Corporation (Portland, OR)</td>
</tr>
<tr>
<td>RADstat, Finale</td>
<td>Merit Medical Systems, Inc</td>
</tr>
<tr>
<td>RadiStop</td>
<td>St Jude Medical, Inc</td>
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<tr>
<td>TR Band</td>
<td>Terumo Interventional Systems</td>
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<tr>
<td>Vasc Band</td>
<td>Vascular Solutions, Inc</td>
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**Figure 8** (A) The TR Band (Terumo Interventional Systems) and (B) the “patent” hemostasis technique. (Color version of figure is available online.)
Complications

The most common, albeit rare, complication seen in our practice is a localized minor hematoma (grade 1) with mild pain at the access site. This is often self-limited and can be treated with nonsteroidal anti-inflammatory drugs if necessary. Despite proper patent hemostasis technique, radial artery thrombosis will occur in a minority of cases, which are almost always asymptomatic. Factors associated with a decreased rate of radial artery occlusion include increased heparin dose, smaller sheath size, and use of a hydrophilic sheath. Other rare complications include radial artery pseudoaneurysm, perforation, radial arteritis, severe spasm, and dissection. Digital ischemia is exceedingly rare and has been described in the literature in patients who do not have a patent ulnopalmar arch.

One concern when performing TRA instead of TFA is the theoretical risk of cerebral embolization related to arch manipulation. In addition, catheter placement from the left radial artery will lie across the left vertebral artery during subdiaphragmatic interventions. Several studies have concluded that silent brain infarcts occur at rates as high as 15%-22% after cardiac catheterization using TFA. Hamon et al performed diffusion-weighted magnetic resonance imaging on 41 consecutive patients after right-sided TRA and identified 2 procedure-related ischemic lesions (4.9%), both of which were asymptomatic. This study concluded that TRA has a lower incidence of cerebral embolization compared with TFA when intervening on the coronary circulation based on previous studies published in the interventional cardiology literature. Anecdotally, the incidence of cerebral embolization when using the left radial approach for interventions below the diaphragm is exceedingly low and theoretical at this point, with no published literature on this to date. In our single-center experience of more than 1300 TRA interventions, there were no complications related to cerebral infarction (manuscript in preparation).

Patient Preference and Cost-Effectiveness

As more interventions move from the hospital setting to outpatient offices, improved patient comfort and faster discharge times are increasingly important. This is currently the trend in busy interventional oncology practices across the United States, Canada, and Europe. In our practice, TARE is performed solely on an outpatient basis, and TACE is performed with a 23-hour observation admission and trending toward a completely outpatient procedure. Procedure cost is also an extremely important issue as we move toward the next phase of health care reform. Many studies have demonstrated decreased costs associated with TRA as compared with TFA. In peripheral interventions, TR direct procedure costs will generally be lower because of decreased use of closure devices. Additionally, indirect costs will be lower because of decreased readmission for bleeding complications. Further research is being performed in this area to investigate this concept.

In our practice, patient preference overwhelmingly favors TRA over TFA for hepatic embolization procedures, mainly owing to earlier ambulation and discharge times. We must pay attention to patient satisfaction as we build comprehensive interventional oncology practices. We believe TRA should be learned by busy operators so that we can offer this technique to our patients.

Future Directions

Inability to successfully access the radial artery does not preclude a patient from distal arm access. Many operators have used the ulnar artery as an alternative to the radial artery, especially if radial artery spasm or severe tortuosity is encountered or if the ulnar artery is dominant. De Andrade et al described their experience with translumeral access in a prospective registry of 410 patients, with a low access site complication rate of 3.9%.

Other potential applications for TRA in the future include renal artery denervation and carotid, iliac, and infrainguinal interventions. Several studies have already described some of these techniques. Cerebral angiography from the radial artery has been performed and described for more than a decade, including a large series of more than 1000 patients in Korea in 2010. More recently, complex cerebral interventions, including aneurysm coiling, have been performed using TRA. Widespread adoption in the United States is currently limited by availability of equipment required to successfully perform these cases.

Conclusion

Transradial intervention has broad applications for interventional radiology. In particular, hepatic embolization procedures are well suited for this approach. Learning and implementing transradial access technique enables operators to offer comprehensive, cost-efficient, and safe care to their patients.

References

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