How to tackle complications in radial procedures: Tip and tricks

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ABSTRACT

Transradial interventions (TRI) are becoming increasingly popular because of accumulating recent evidence suggesting improved survival and reduced morbidity. Complications, though rare, do occur, especially for operators on their learning curve. The complications are best prevented by utilization of proper technique. Forearm hematomas are preventable and easy to treat, but a delay in detecting and managing them can lead to disastrous consequences compartment syndrome being the most dreaded one. This review deals with tips and tricks to prevent as also treat the common and rare complications.

1. Introduction

Transradial access for percutaneous coronary interventions (PCI) has gained popularity over the last few decades due to its enhanced safety, reduced morbidity, mortality and overall reduced procedural costs.1,2 Complication rates are low with transradial procedures and a majority of them can be prevented with appropriate training, techniques and hardware selection.3 Adequate experience with transradial procedures has been shown to correlate well with reduced vascular complications and improved procedural success.3,4

Pre-procedure planning, which involves adequate assessment of forearm arteries by color doppler imaging; though not mandatory, helps quantify vessel diameters and/or forearm vascular anomalies, aiding in the selection of adequate (largest, straightest, least anomalous) vascular access (radial or ulnar), access side (right or left) and catheter dimension (5F, 6F, 7F).

Planning helps reduce radial artery spasm, minimizes sheath: artery mismatch, radial artery occlusions and prevent vascular trauma/extravasation while maneuvering through complicated cubital loops or anomalies. In appropriate case an alternate access may be chosen which may be ipsilateral ulnar or contralateral radial artery.
The complications are listed in Table 1. The commonest complication is radial artery spasm and is discussed first, following which forearm hematomas and finally rarer miscellaneous complications are presented.

2. Radial artery spasm

Radial artery spasm has been shown to be responsible for up to 38% of all transradial procedure failures. Once severe it can make catheter manipulations difficult, causing undue procedural delays & discomfort to the patients leading to crossovers and procedural failures, hence is better prevented than treated. It can potentially be avoided if the sheath diameter: internal artery diameter ratio is kept <1:1, thus emphasis on adequate catheter selection is essential.

Patients that have a short stature, small access artery diameters, low body mass indices, small wrist circumferences should be identified preoperatively as carrying a higher risk of radial artery spasm, puncture failure, and potential crossovers.

Even though the adequacy (size) of a radial artery can be appreciated by experienced operators (through simple palpation), the use of pre-procedure ultrasound of arm arteries (PPUAA) can be crucial for assessing access artery diameters and associated anomalies. Selecting the straightest and biggest artery can help avoid severe (grade 3 to 4 per Chugh’s grading of radial artery spasm) access spasm and procedure failure.

2.1. Spasmolytic agents

Spasmolytic “cocktails” used judiciously after sheath insertion, with each catheter exchange and prior to sheath removal is of paramount importance in preventing spasms.

Spasmolytics commonly used include 1–5 mg of intrarterial injection of Verapamil or Diltiazem. The use of nitroglycerine (100 mcg) alone vs verapamil (1.25 mg) with nitroglycerine showed a similar reduction in incidence of radial artery spasm when compared to placebo.

Similarly, there was no significant difference between the use of Intravenous Nitroglycerin (100 mcg) or Intravenous Nitroprusside (100 mcg) alone or in combination.

Additionally, Nicorandil and Verapamil were found to be equally effective; unlike phentolamine which was inferior in its action.

Further, if clinically severe spasm is encountered (grade 3–4), the use analgesia and sedation, apart from spasmolytic agents must be initiated (Table 2).

2.2. Hardware selection

The use of shorter, hydrophilic coated sheaths, appropriately sized pre-operatively (Table 3), are also beneficial in preventing arterial spasms again, minimizing catheter exchanges is useful in reducing the risk of development of significant spasm which can be achieved by anticipating and choosing an appropriate catheter. For example if a patient is short, usually the smallest curve should be taken; but it helps to know the aortic root diameter, which if dilated usually modifies the choice to a bigger curve. Again, in an unfolded aorta, right sided aortic arch or tortuous subclavians, a smaller catheter curve often fits better, for the left coronary artery.

2.3. What can you do when access artery spasm develops?

1. Sedation and analgesia: we commonly use small doses of injectable Midazolam in aliquots of 0.5 mg, and Fentanyl in small doses of 25 micrograms. Caution is advised for those with respiratory disorders and obstructive sleep apnea.

2. With grade 3 or significant spasm, it’s best to pause for a minute or two before proceeding.

3. Intrartrial Diltiazem or Verapamil in doses of 3–5 mg, sometimes combined with 50–100 µg of injectable nitroglycerine intra-arterially is usually enough to relieve significant spasm.

4. With development of grade 3 spasm, it is usually best to downsize catheters to a lower French (F) size, which for diagnostic angiogram may mean downsizing to 4F catheters.

5. It is important to use exchange length (260 cm) 0.035” or 0.038” Teflon or Terumo glide wire for exchange of catheters, because with the shorter 180 cm guide wire, the wire often comes back too far into the segment of spasm in the access artery making re-advancement of the guidewire difficult.

3. Radial artery occlusion

The incidence of Radial artery occlusion (RAO) has been reported in recent literature as between 3 and 10% of all transradial interventions (TRI).

The utilization of appropriate anticoagulation, proper sheath selection, and non-occlusive/patent hemostasis can
lower RAO rates tremendously. In the PRIMA-FACIE TRI study,\(^7\) which used best practices in TRI, RAO rates were down to <1% of all transradial procedures.

RAO can be documented by ultrasound doppler post-procedurally and on follow-up. It is essential to remember that the presence of radial artery pulse doesn’t rule out RAO, as flow would seemingly be maintained by collateral flow through the palmar arches.\(^{13}\)

We recently showed that an access artery diameter of ≥1.7 mm is associated with lesser procedural complications, failures, cross-overs and RA occlusions during TRI compared to ‘small’ access arteries defined as those with an internal diameter <1.7 mm on color doppler ultrasound in our registry.\(^{14}\)

### 3.1. Anticoagulation

Adequate anticoagulation is of paramount importance. Stella et al showed a incidence of 30% RAOs in patients who were given only 1000 U of UFH.\(^{15}\) Patients must receive at least 50 IU/Kg or 5000 U of unfractionated heparin (UFH) for all TRIs, and in the setting of Heparin Induced

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**Table 2 – Chugh’s grade of radial artery spasm.\(^6\)**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>4</td>
<td>Severe pain and spasm disallowing any catheter movement necessitating crossover</td>
</tr>
<tr>
<td>3</td>
<td>Moderate pain and spasm restricting catheter movement &amp; necessitating a pause in procedure and &gt; 2 doses of additional intra-arterial Diltiazem or Verapamil &gt; 5mg and/or &gt; 1 mg of intravenous Midazolam.</td>
</tr>
<tr>
<td>2</td>
<td>Mild pain and spasm not restricting catheter movement; no pause in procedure but &gt; 1 dose of (additional) intra-arterial Diltiazem (or Verapamil) of 5mg and/or 0.5 mg of intravenous Midazolam.</td>
</tr>
<tr>
<td>1</td>
<td>Mild pain and spasm not restricting catheter movement; no pause in procedure and only 1 dose of either or both intra-arterial Diltiazem (or Verapamil) of 5mg and/or &gt; 0.5 mg of intravenous Midazolam.</td>
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**Table 3 – Sheath Selection Protocol.\(^6\)**

![Sheath sizing chart](chart.png)
Thrombocytopenia, the use of Bivalirudin has shown promising results (0.75 mg/kg bolus followed by 1.75 mg/kg/hr infusion).

3.2. Sheath: Artery ratio

Saito et al showed that the incidence of RAO increased from 4% to 13% if the Radial Artery Internal Diameter: Sheath Outer Diameter ratio was <1.0 compared to >1.0.

Similarly, from a randomized trial using 5F/6F catheters for TRIs, it was observed that the incidence of RAO was around 1% with use of 5F but increased with larger (6F) sheaths (5.9%).

3.3. Post-procedure hemostasis

Following the PROPHET study, the concept of patent hemostasis became well known. It is now well understood that the absence of blood flow during the hemostatic process increases the risk of RAO. In the PROPHET study, the “conventional hemostasis” arm involved RA compression with a pressure band for 2 h according to usual practice and the “patent hemostasis” arm involved placement of the pressure band after plethysmography confirmed antegrade flow through the RA for the same duration. The RAO rates were almost four fold (7%) on 30 day follow-up in the Conventional arm.

In our practice, a compression bandage/TR band is made non-occlusive once the patient is shifted outside of the catheterization laboratory.

3.4. Dealing with RAO

Ischemia is very rare as the hand is well perfused with dual blood supply through the palmar arch. From our experience, when post-catheterization plethysmography shows radial artery occlusion, we use additional doses of heparin (1000 IU bolus) and compress the ulnar artery for 20 min to increase collateral flow through the radial. This strategy is often enough to counter the RAO when detected early and corrective measures are instituted promptly.

RAOs are often asymptomatic but in the setting of pain, low molecular weight heparin given for 2 days usually reduces symptoms and signs of RAO.

There are several case reports of dis-obliteration of radial artery occlusion using an angioplasty wire and balloon angioplasty.

4. Access-site bleeding

The radial artery has favorable anatomical landmarks that allow for successful hemostasis via compression, thus minimizing access site bleeding complications. As a result, TRIs have been associated with significantly lower major and minor bleeding complications (both access and non-access site).

5. Access site hematomas

Local hematomas may occur as a result of improper haemostatic device application or device failure. Compression of the radial artery, both proximal and distal to the puncture site must be performed aimed at controlling both antegrade and retrograde flow from the palmar arch collateral. Practically, this can be achieved by placing the green dot of TR band on the puncture site.

In our experience, small ecchymoses (Fig. 1) occur in approximately 5% of our cases annually, following the use of non-occlusive hemostasis. These cases are generally minor and of no clinical consequence.

6. Forearm hematomas: recognizing the common culprits

Bleeding may rarely occur from a site on the radial artery remote from the puncture site. It can occur in the setting of perforation of a small side branch of the radial artery by a guide wire.

In our experience, the incidence of this is 3 per 1000 TRIs, commonly occurring following angioplasties, but rarely following angiograms: none requiring blood transfusions or vascular surgery. Avulsion of a small radial recurrent artery arising from a radial loop rarely can also cause this manifestation. It is imperative to have a low threshold to perform a radial artery arteriogram when any resistance to guide-wire or catheter insertion is encountered.

Color-doppler ultrasound can also help localize the site of active bleeding and confirm hemostasis once successfully achieved.

Early recognition of this non-access site bleeding, remote from the access site is important as it helps tailor the hemostatic strategy appropriately. Since the bleeding may be too much by the time a swelling is visible in the forearm, it is imperative to palpate the forearm for any perceived difference in softness of the forearm by comparing with the non-access...
forearm. Immediate institution of hemostatic compression along the length of access artery helps to pre-empt the development of a forearm hematoma. This is absolutely crucial as progression of forearm hematoma to a compartment syndrome can significantly affect patient outcome and endanger survival.

Control can be accomplished by the application of an Ace bandage to the forearm. We sometimes use bandage/gauze balls along the course of the radial artery (Fig. 2) with a compression bandage applied to selectively compress the radial artery (sparing the ulnar artery) for radial access and vice-versa for ulnar access.

A sphygmomanometer cuff may also be utilized to compress the brachial artery; the strategy employed involves inflating the cuff to a pressure equal to or more than systolic and then intermittently deflating it every 2–3 min for 10–15 s, repeating this cycle till adequate hemostasis is achieved. Alternatively, the cuff can also be inflated to systolic pressure or slightly higher and then gradually deflated over a period of one to 2 h, with signs of hemostasis being observed with color doppler flow serially.

Sealing of a perforation with a long sheath is also an option, but this is rarely necessary. If a perforation does occur before doing an angioplasty, one can continue to use a guiding catheter and complete the procedure, by which time the perforation usually seals off (Fig. 3A/B).

Often, trivial forearm hematomas, if not controlled urgently and appropriately, can lead to the development of a devastating “Forearm Compartment Syndrome”. The forearm is anatomically susceptible to an increase in pressure in case of blood leak as it has very little room for expansion. In the setting of pain, pallor and/or parasthesia in a post procedure patient, there should be a low index of suspicion for this syndrome. Direct measurement of the compartment pressure is a useful confirmatory tool; it can also help guide treatment strategies (conservative vs urgent surgical fasciotomy).\(^{19}\) It cannot be stressed enough that every effort must be made to prevent this from developing.

7. Miscellaneous complications

Pseudo-aneurysm (Fig. 4A) formation may rarely occur at the radial artery access site. In the only case that we had (1/14,330 cases), compression for 20 min led to occlusion of the pseudo-aneurysm (Fig. 4B). Surgery, if required, is performed under local anesthesia and is an outpatient procedure. Radial artery avulsion due to intense spasm is extremely rare. Sterile abscess formation at the radial artery access site had been reported with the use of certain hydrophilic sheaths which are now unavailable.\(^{20}\) Radial arterio-venous fistula are extremely
rare, and was seen in only one case in our series of 14,330 cases; the patient was referred for surgery because of persistent pain, and did well post operatively.

8. Conclusion

The radial artery is an excellent access site for coronary interventions. The advantages of this approach far outweigh the infrequent complications. Further, many complications are preventable with proper training and careful technique. Should they develop they can be easily controlled with prompt recognition and immediate institution of corrective measures. Delay in instituting treatment however can have devastating effects on the hand and threaten life, especially with forearm hematomas and hence must be avoided at all costs.

Conflicts of interest

All authors have none to declare.

REFERENCES


