How to Improve the Success Rate of Distal Radial Artery Puncture, "A Winding Path to Seclusion" : Experience Summary Based on Over Two Thousand Cases (Postprint)

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Date: 2022-12-23T00:00:00+00:00

Abstract

Distal transradial access for coronary interventional procedures has emerged as a research focus in the field of vascular access. Compared with conventional radial artery access, it offers advantages of enhanced patient comfort and fewer vascular access-related complications; however, due to the tortuosity and relatively small caliber of the distal radial artery, puncture entails a significant learning curve. Drawing upon our institution' s experience, we describe the common causes of distal radial artery puncture failure and corresponding management strategies, aiming to assist interventional physicians in reducing puncture time, improving success rates, and facilitating the clinical adoption of distal transradial access in interventional practice.

Full Text

Preamble

Title: How to Improve the Success Rate of Distal Radial Artery Puncture, "A Winding Path to the Secluded" : Experience from Over 2,000 Cases

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Abstract: Transradial coronary interventional diagnosis and treatment via the distal radial artery approach has become a research hotspot in the field of vascular access. Compared with the conventional radial artery approach, it offers advantages of greater patient comfort and fewer vascular access-related complications. However, due to the tortuous and relatively small caliber of the distal radial artery, a significant learning curve exists for puncture technique. Based on our center’ s experience, we describe the common causes of distal radial artery puncture failure and corresponding management strategies to help interventional cardiologists reduce puncture time, improve success rates, and promote broader clinical application of the distal radial artery approach.

Keywords: Distal radial artery; Intervention; Coronary artery disease

1. Challenges in Distal Radial Artery Access Puncture

The radial artery originates from the brachial artery and descends along the radial aspect of the forearm. At the level of the radial styloid process, it gives off the superficial palmar branch before turning toward the dorsal hand, then passes through the space between the first and second metacarpal bones to form the deep palmar arch with the distal ulnar artery. The distal radial artery represents the continuation of the radial artery at the wrist, coursing through a triangular region on the dorsal hand known as the anatomical snuffbox. This triangle is bounded laterally by the tendons of the abductor pollicis longus and extensor pollicis brevis, medially by the extensor pollicis longus tendon, inferiorly by the radial styloid process, and its floor is formed by the bony platform created by the trapezium and scaphoid bones. In this location, the distal radial artery is more superficial and its pulse is easily palpable. However, because this access site is more distal than the conventional radial artery approach, the vessel is relatively smaller and more tortuous, increasing the difficulty of puncture and cannulation and creating a pronounced “learning curve” [5].

In large domestic coronary interventional centers with high procedural volumes, a “fast-paced” environment is common. Throughout the history of interventional cardiology, emerging technologies have consistently generated waves of enthusiasm. Nevertheless, it is undeniable that the existence of a learning curve means that beginners will require more puncture time and face higher failure rates, which can be discouraging. Previous studies have reported distal radial artery puncture success rates ranging from 70% to 100%, showing considerable variation [6]. Although most current studies suggest that puncture success rates for distal radial artery access are similar to those for conventional radial access [7-9], early randomized controlled trials reported significantly lower success rates for distal radial artery puncture compared with conventional radial access (70% vs. 100%) [10]. Despite its many advantages, the ability of operators to overcome the learning curve quickly, reduce puncture time, and increase procedural success represents a critical factor determining whether distal radial artery access can be widely adopted.

2. Distal Radial Artery Puncture Kits

Several radial artery puncture kits are commonly used in China. Puncture needles can be categorized based on whether they include a cannula: bare steel needles or cannula needles. Needle sizes range from 22G to 20G (outer diameter 0.71-0.91 mm), with matching guidewires of 0.018-0.025 inches (0.46-0.63 mm) [4]. Our center routinely uses the Terumo cannula needle (Terumo, Introducer kit II, 20G needle + 0.025-inch guidewire) for conventional radial artery puncture, and we therefore prefer using cannula needles for distal radial artery puncture as well. Cannula needles offer particular advantages during distal radial artery puncture: when guidewire advancement is difficult, contrast injection through the cannula can clarify the vascular anatomy and help identify the cause of guidewire resistance, often resolving many difficult advancement issues. However, cannula needles also have disadvantages in distal radial artery puncture. Due to the superficial location of the vessel in some patients, blood return may be visible even when the cannula has not fully entered the vessel, leading to puncture failure. Some domestic centers routinely use bare steel needles with high success rates. In practice, needle selection typically depends on the operator' s prior experience and habits, and neither approach is universally superior.

3. Causes of Puncture Failure and Management Strategies

Most studies define successful distal radial artery puncture as the ability to successfully insert an arterial sheath. For operators proficient in radial artery puncture techniques, puncturing the distal radial artery itself is not particularly difficult. Although the distal radial artery is relatively small, most reports indicate that routine interventional procedures can be safely completed using standard 6F and 7F arterial sheaths [11, 12]. Our center routinely uses the Terumo 6F standard sheath and the Apt Medical 7F thin-walled sheath (Apt Medical Braidin® 7F thin-walled sheath) to complete standard interventional procedures. Therefore, the most critical factor causing distal radial artery puncture failure is guidewire insertion failure, which aligns with reports from international studies [1, 13]. Since 2019, our center has successfully performed over 2,000 coronary interventional procedures via distal radial artery access, with a puncture success rate of approximately 95% and sheath insertion success rate of approximately 93%. Right distal radial artery access was the first choice in 99% of patients, with failed cases converted to conventional radial artery access. For patients with difficult puncture, we collected imaging data. The causes of puncture failure can be summarized into two main categories: patient-related factors and operator-related factors. Since our center primarily uses Terumo cannula needles, we will use cannula needles as examples.

3.1 Patient-Related Factors

Intrinsic vascular characteristics represent one of the main causes of guidewire insertion failure during distal radial artery puncture, which can be further divided into several scenarios:

1. **Radial artery tortuosity** is the most common clinical scenario. Standard puncture kits are equipped with straight guidewires that are relatively stiff, providing poor navigation through tortuous vessels. Forceful manipulation can easily cause radial artery perforation or dissection, forcing operators to abandon the procedure [Figure 1a: see original paper]. **Management strategy:** Shape the puncture guidewire by creating a small "J" -shaped curve at the distal 3-5 mm of the tip, and advance the guidewire with gentle rotational movements. Care must be taken during shaping to avoid excessive force that could damage the protective structure at the guidewire tip. When the tortuosity angle is too severe and a shaped guidewire cannot pass, consider using a PTCA guidewire to assist passage through the tortuous segment [14]. Lee et al. [6] also demonstrated that switching to a thinner 0.014-inch PTCA guidewire when straight guidewire advancement is difficult can improve puncture success rates. Since PTCA guidewires are thinner with less support, but the shaft has greater support than the distal segment, if sheath insertion over the PTCA guidewire is planned, it is recommended to advance the guidewire further while maintaining coaxial alignment with the vessel during sheath advancement.

2. **Physiologic transitional bend** [Figure 1b: see original paper]: The segment where the distal radial artery curves around the radial styloid process from the snuffbox region to join the conventional radial artery is called the transitional segment. This segment has a physiologic bend that can sometimes impede straight guidewire advancement. **Management strategy:** In most cases, a shaped guidewire can pass through this segment. When ineffective, a PTCA guidewire can be used to guide the cannula as far as possible beyond the physiologic transitional segment before exchanging for a straight guidewire.

3. **Radial artery stenosis, occlusion, or spasm** [FIGURE:1c, 1d]: In patients with prior radial artery procedures, radial artery occlusion should be considered when no pulse is palpable, which can be confirmed with Doppler ultrasound examination. However, due to the unique anatomy, collateral circulation from the palmar arch and interosseous artery can provide retrograde blood flow to the occluded segment. When the occluded segment is short, relying solely on palpation of the radial pulse can easily miss radial artery occlusion. **Management strategy:** For patients with prior radial artery procedures, routine preoperative radial artery ultrasound examination can identify some cases of radial artery occlusion in advance. When encountering radial artery occlusion, successful puncture of the distal radial artery may still provide an opportunity to re-

canalize the occluded radial artery and complete coronary interventional procedures via the ipsilateral approach [15-17]. For radial artery spasm, vasodilatory drugs can be administered through the cannula.

4. **Small vessel caliber**: Compared with the conventional radial artery, the distal radial artery is relatively smaller (ratio approximately 0.8:1), increasing puncture difficulty. Studies have shown that female sex, low body mass index, and smoking are independent predictors of small distal radial artery caliber [18]. For less experienced operators, preoperative ultrasound examination can be considered to select patients with relatively larger distal radial arteries for initial attempts.

3.2 Operator-Related Factors

1. **Entry into branch vessels** [Figure 1e: see original paper]: The distal radial artery has multiple branches, including the deep palmar arch, superficial palmar arch, thumb artery, and dorsal hand artery, with tortuous courses that can easily divert the guidewire into branch vessels. **Management strategy:** Under fluoroscopy, the guidewire can be seen entering different vessels without resistance; carefully adjust the guidewire advancement direction to follow the main vessel.

2. **Excessive angle between needle and vessel** [Figure 1f: see original paper]: This is related to both vascular anatomy and the angle adopted by the operator during puncture. When the needle direction forms a large angle with the vessel course, it can create difficulty similar to vessel tortuosity. **Management strategy:** Adjust the angle of the extracorporeal cannula to achieve coaxial alignment with the vessel, then reattempt guidewire advancement.

3. **Tight contact between cannula and vessel wall** [Figure 1g: see original paper]: Advancing the cannula against the posterior vessel wall creates an artificial angulation that impedes guidewire advancement. **Management strategy:** Slightly withdraw the cannula and reattempt guidewire insertion.

4. **Incomplete cannula entry into vessel** [FIGURE:1h, 1i]: This can be divided into two situations: first, the needle hits the "bull' s-eye" but the cannula is not fully inserted; second, the needle fails to hit the "bull' s-eye," preventing guidewire entry into the vessel lumen. **Management strategy:** Use the through-and-through technique for cannula needle puncture—after obtaining blood return, advance the needle slightly further. For thin patients with vessels closely adherent to bone, the puncture distance is shorter, so the needle angle can be reduced and the cannula advanced slightly along the needle after blood return is obtained. The recommended puncture angle is approximately 30° at the snuffbox region and even smaller at the more distal "Hegu point" region [19]. If the needle fails to hit the "bull' s-eye" and the matching guidewire cannot be

introduced into the vessel, either repuncture or switch to a thinner PTCA guidewire to guide the cannula into the vessel, then exchange for the puncture guidewire.

During practical procedures, we can estimate the likely cause based on how far the guidewire advances and then formulate the next management strategy. If the guidewire has not exited the cannula, possible causes include incomplete cannula entry into the vessel or contact with the vessel wall. If the guidewire has advanced beyond the cannula, possible causes include physiologic transitional bend, radial artery tortuosity, occlusion, or entry into branch vessels [Figure 2: see original paper]. Based on our experience and that of other operators, the cannula can be advanced forward along the guidewire, and a small amount of contrast can be injected through the cannula to clarify the cause of guidewire insertion difficulty [5].

4. Application of Ultrasound in Improving Distal Radial Artery Puncture Success

High-frequency ultrasound probes can clearly identify the distal radial artery, cephalic vein, superficial branch of the radial nerve, bony structures, and tendons at different locations within the snuffbox region [20]. Previous studies have shown that ultrasound guidance can significantly improve conventional radial artery puncture success rates and has high clinical value [21], but ultrasound application in distal radial artery puncture remains limited. Norimatsu K et al. [22] used ultrasound to measure distal radial artery diameter in 142 patients undergoing coronary interventional procedures, analyzing the sheath-to-vessel diameter ratio to assess potential vascular injury from cannulation. Mori S et al. [23] compared ultrasound-guided versus conventional distal transradial access for coronary angiography and intervention, finding significantly higher puncture success rates in the ultrasound-guided group (97% vs. 87%, P=0.0384).

Radial artery occlusion is not uncommon clinically, and successful distal radial artery puncture can enable retrograde recanalization of the occluded vessel [24]. However, after radial artery occlusion, despite retrograde blood supply from the palmar arch to the distal radial artery, inadequate filling often makes the pulse non-palpable. Ultrasound guidance can identify the vascular course and facilitate successful puncture [25]. However, routine ultrasound-guided puncture has practical limitations. Because the distal radial artery courses through the snuffbox region, which is a small triangular space, ultrasound probe placement is challenging. Additionally, if the operator is not proficient with ultrasound techniques, puncture time can be significantly prolonged. Nevertheless, for patients with unclear distal radial artery pulsation or radial artery occlusion, ultrasound-guided puncture may offer high clinical value.

In summary, with the development and adoption of specialized puncture guidewires and thin-walled sheaths designed for distal radial artery access, the advancement of distal radial artery interventional techniques will accelerate.

Puncture failure is common during initial attempts at distal radial artery access. However, timely identification and summary of failure causes, particularly during the early learning phase, are crucial. Only by improving puncture success rates can interventional diagnosis and treatment via distal radial artery access truly achieve "a winding path to the secluded" !

Author Contributions: Gaojun CAI conceived the research direction, drafted and revised the manuscript, and takes overall responsibility for the article. Ganwei SHI, Feng LI, Wenhua LI, Sheliang XUE, Jianqiang XIAO, Jun GU, and Yanbin SONG collected and organized case data. Wei LU was responsible for manuscript revision. Chun GONG participated in patient management and provided case data. Liuyan ZHANG was responsible for quality control. All authors approved the final manuscript.

Conflict of Interest: The authors declare no conflict of interest.

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Note: Figure translations are in progress. See original paper for figures.