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VIEWPOINT

Anatomic Basis and Physiological Rationale of Distal Radial Artery Access for Percutaneous Coronary and Endovascular Procedures

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ABSTRACT

Transradial access offers important advantages over transfemoral access, including overall increased procedure comfort and better outcomes. Still, complications of transradial access exist, with radial artery occlusion being the most clinically relevant one. Puncture sites in the hand allowing distal radial artery access have initially been described for anterograde angioplasty of occluded radial arteries and could represent a valuable alternative to traditional wrist puncture for radial artery catheterization. What may at first appear as a "radialist eccentricity" definitely has a sound rationale, which the authors review. Knowledge of the anatomic and physiological principles at the basis of distal radial artery access is essential to promote rigorous understanding and practice of this new opportunity for both patients and interventional specialists. (J Am Coll Cardiol Intv 2018;11:2113-9) © 2018 by the American College of Cardiology Foundation.

Transradial access (TRA) is of increasing popularity among interventional specialists and patients undergoing percutaneous coronary and peripheral diagnostic and revascularization procedures (1,2). Indeed, TRA offers important advantages over transfemoral access, including improved patient comfort, early patient ambulation, lower vascular complications, lower health care costs, and reduced adverse cardiovascular events including mortality (3-6).

Still, complications of TRA exist (7), with radial artery occlusion occurring in up to 30% of cases in a prospective vascular ultrasound study (8). Because of the dual blood supply to the hand, radial artery occlusion is generally asymptomatic and overlooked, though at times it may be associated with paresthesia, pain at the site of occlusion, loss of hand function, and distal ischemia (9). Above all, radial artery occlusion may prevent future use of the radial artery for hemodialysis fistula preparation (10), coronary artery bypass grafting (11), reconstructive surgery (12), and, most important, repeat TRA. This latter issue is especially unsettling in light of better outcomes associated with TRA (5,6).

Against this background, anatomic and physiological principles suggest distal radial artery as an innovative access for coronary and endovascular procedures.

ANATOMY OF FOREARM AND HAND CIRCULATION

In the cubital fossa, the brachial artery bifurcates into the ulnar artery and the radial artery, providing dual vascular supply to the hand (**Figure 1**).

The ulnar artery gives rise to the common interosseous artery and continues its course above the

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ABBREVIATIONS AND ACRONYMS

TRA = transradial access

ulna on the medial side of the forearm to surface in the Guyon's canal. It then gives rise to a deep branch and continues across the palm as the superficial palmar arch, which is variably completed by a branch arising from the radial artery (13,14). Anatomic variation in the origin and course of the ulnar artery is relatively infrequent.

The radial artery descends along the lateral side of the forearm above the radius toward the wrist, where it is palpable between the tendon of the flexor carpi radialis medially and the anterior border of the radius (13,14). Several variants in the origin or in the course of the radial artery have been reported to potentially affect transradial procedures (15), whereas less anatomic variation is found in the distal forearm, where cannulation is usually performed. Just distally, the radial artery gives rise to the palmar carpal branch to form a transverse anastomosis with the homologous branch arising from the ulnar artery and the superficial palmar branch, which passes through the thenar muscles, sometimes anastomosing with the end of the ulnar artery to complete the superficial palmar arch. At the wrist, the radial artery curls posterolaterally to pass on the dorsal aspect of the carpus between the tendon of the extensor pollicis longus and tendons of abductor pollicis longus and extensor pollicis brevis, crossing obliquely the scaphoid bone and the trapezium in the anatomic snuffbox, where its pulse is generally obvious (13,14). Over the trapezium, the radial artery gives rise to the dorsal carpal branch, which forms, with its ulnar homologue, the dorsal carpal arch supplying the dorsal metacarpal arteries and the radiodorsal digital artery of the thumb (13). A pulsation may also be felt in the dorsum of the hand, at the vertex of the angle between the tendon of the extensor pollicis longus and the second metacarpal bone, as the radial artery swerves medially between the heads of the first dorsal interosseous muscle into the palm, where it anastomoses with the deep branch of the ulnar artery, completing the deep palmar arch. Blood supply to the digits is mainly ensured by the interconnected palmar metacarpal arteries and common palmar digital arteries arising from the deep palmar arch and the superficial palmar arch, respectively.

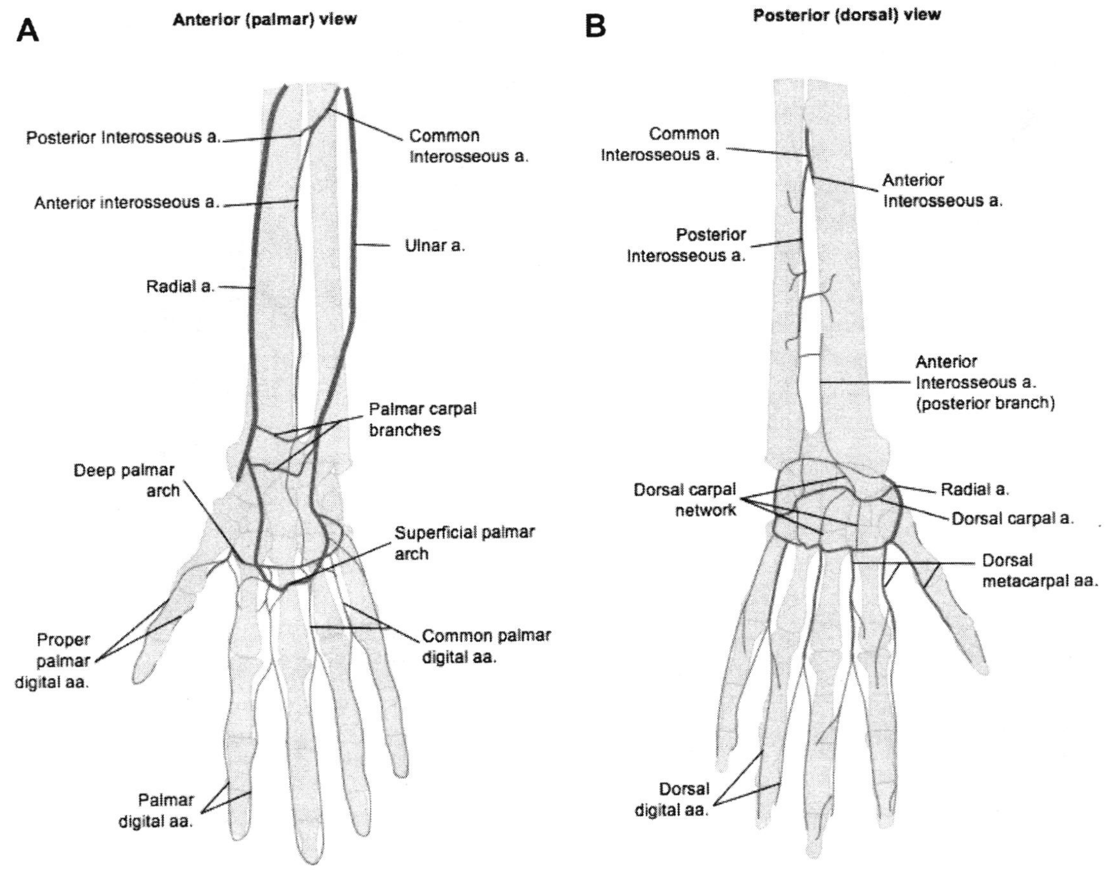
Overall, the rich anastomotic and collateral network between the radial and ulnar arteries should ensure preserved blood supply to the fingers despite transitory or persistent radial artery occlusion.

Different post-mortem techniques (gross dissection, latex injection, stereoscopic arteriography) have reported high anatomic variability for both palmar arches, which are usefully categorized as complete or incomplete essentially on the basis of the safety of radial artery harvest for surgery (16). Indeed, incompleteness of the superficial and deep palmar arch puts patients at increased risk for digital ischemia in case of radial artery occlusion (Figure 2). The superficial palmar arch is defined as complete when it directly supplies all digits, including the ulnar side of the thumb, and the deep palmar arch is defined as complete when the end of the radial artery is connected with the deep palmar branch of the ulnar artery. In a recent angiographic study of 234 patients undergoing transradial cardiac catheterization, the superficial palmar arch was incomplete in 46% of patients, whereas the deep palmar arch was complete in all patients (17).

PHYSIOLOGICAL RATIONALE OF DISTAL RADIAL ACCESS

As shown in Figure 3, the 2 sites at which the radial pulse can be found, in the anatomic snuffbox and in the first intermetacarpal space, represent alternative puncture points for TRA (18-22). Once it has reached the anatomic snuffbox or the dorsum of the hand, the radial artery has already given rise to some branches that, in case of vessel occlusion occurring at the distal radial artery puncture site, could avoid flow interruption in the forearm radial artery and possibly limit the reduction of blood supply to the hand. Flow interruption appears to play a central mechanism in the complex interplay of factors leading to radial artery occlusion. Indeed, in a prospective series, absence of blood flow during the hemostasis process significantly increased the risk for radial artery occlusion (23), whereas in a retrospective analysis comparing shorter and longer hemostatic compressions, interruption of flow at the time of hemostasis was the only significant predictor of radial artery occlusion (24). Accordingly, interventions directed to maintain flow in the radial artery after sheath removal, such as patent hemostasis (25), nitroglycerin administration through the sheath before its removal (26), and ipsilateral ulnar artery compression during radial artery hemostasis (27), have been shown to reduce the rate of post-catheterization radial artery occlusion. On this background, distal TRA could maintain forearm radial artery patency during hemostatic compression or in case of occlusion at the puncture site (Figure 4A, Online Video 1). Notably, histopathology of the occlusion plug retrieved from occluded radial arteries was previously described as indicative of rapidly

FIGURE 1 Anatomy of Forearm and Hand Arterial Circulation



Upper limb blood supply in anterior or palmar view **(A)** and posterior or dorsal view **(B)**.

organizing thrombus (18). Flow preservation is hence of paramount importance to avoid proximal thrombus growth and maintain forearm radial artery patency after TRA.

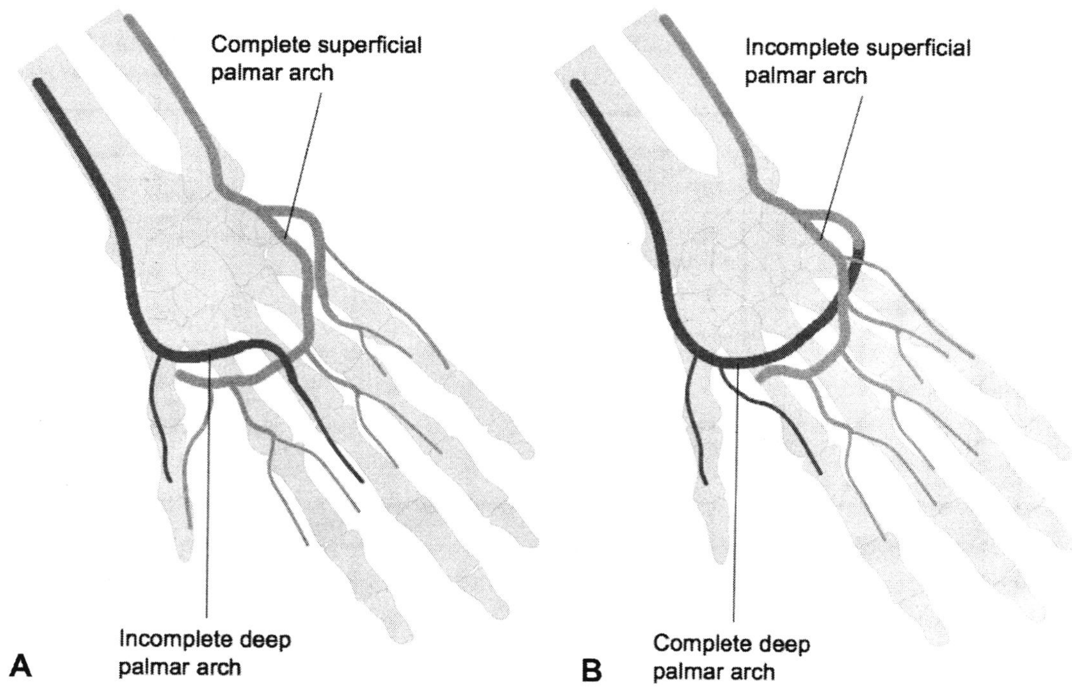
Furthermore, branches arising from the radial artery before its entry in the anatomic snuffbox make significant anastomotic connections in the wrist and hand region, hence allowing optimal distal blood flow in case of radial artery occlusion at the point of puncture, even in patients with poor radioulnar interaction (25), who may even experience ischemic hand complications (**Figures 4B and 4C**) (28–31).

ADDITIONAL ADVANTAGES OF DISTAL RADIAL ARTERY ACCESS

When the left side is chosen, the patient's arm hyperadduction is not limited by the need to keep it in a supine position, and consequently the operator does have not to bend over the patient. Thus, distal radial artery access offers the possibility to have the left hand close to the right groin in such a way that is comfortable for both the patient and the operator. Moreover, as right TRA is currently chosen in about 90% of cases, mainly because of the working position (32), distal radial artery access offers the opportunity to increase the rate of left TRA. This in turn would be very welcome by the vast majority of patients who are right handed and who would no longer experience restriction of use of their dominant upper limb during the hemostatic compression following sheath removal.

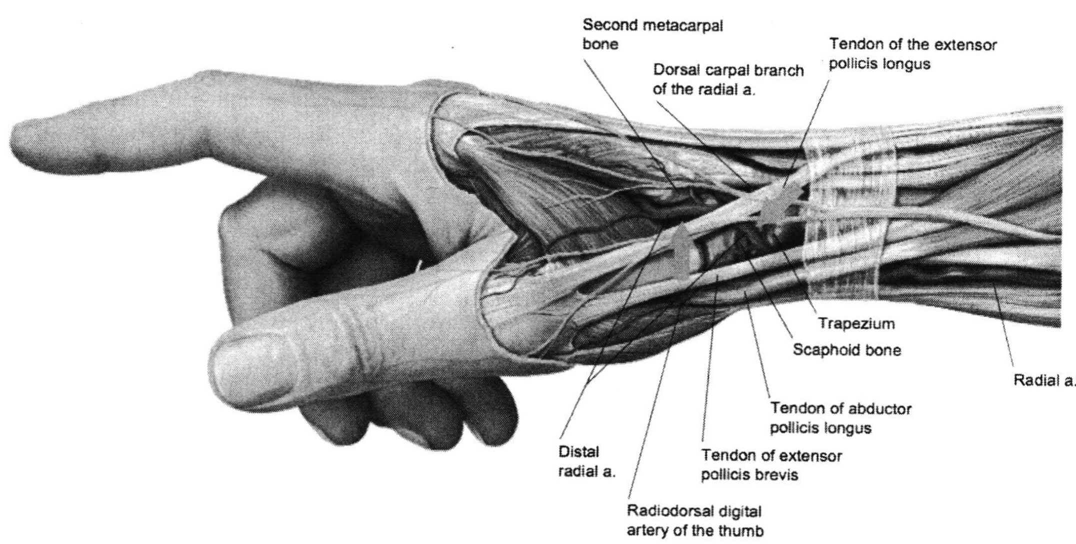
Also, because of collateral pulse transmission in case of flow interruption in the forearm radial artery, the distal radial artery may be considered an alternative puncture site when spasm occurs because of failed radial punctures at wrist level.

FIGURE 2 Palmar Arch Incompleteness



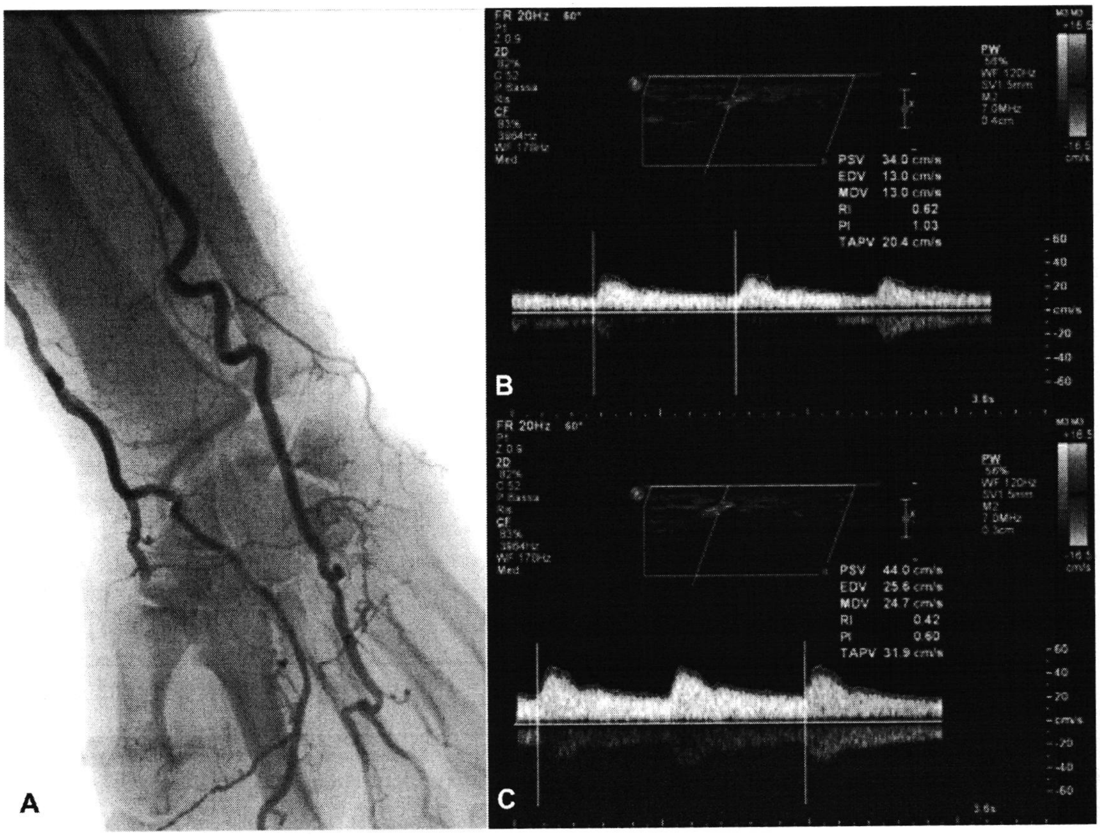
The deep palmar arch is defined as incomplete when the end of the radial artery **(violet)** is not connected with the deep palmar branch of the ulnar artery **(turquoise) (A)**. See Online Video 2. The superficial palmar arch is defined as incomplete when it does not directly supply all fingers (including the thumb) **(B)**.

FIGURE 3 Distal Transradial Access Point



Distal radial artery puncture sites **(blue arrows)** and relevant surrounding anatomic structures (Online Video 3).

FIGURE 4 Modeling of Radial Artery Occlusion



Radial artery occlusion was modeled with a hemostasis device. Digital subtraction angiographic imaging of distal radial artery occlusion within the first intermetacarpal space showing persistent blood flow in radial and ulnar arteries **(A)**. See also Online Video 1. Doppler ultrasound assessment of the radiodorsal digital artery of the thumb showing lower flow measurements when the radial artery is compressed at the wrist level **(B)** compared with a distal site **(C)**.

OUTCOMES

Preliminary outcome data on distal radial artery access are so far limited. In a series of 118 patients reported by Kiemeneij (21), 70 patients (59%) underwent left distal TRA. Puncture was not attempted, because of weak or absent pulse (23%), logistical reasons (6%), presence of an indwelling venous cannula (5%), left-handedness (3.5%), and patient preference (3.5%). Hemostasis was obtained within 3 h in all patients, and ultrasound assessment revealed 0% forearm radial artery occlusion. In this preliminary series, left distal TRA was unsuccessful in 11% of cases, and 2 patients had complications potentially related to the access site: ecchymosis of the hand (n = 1) and minor forearm bleeding (n = 1). Notably, all procedures were very well tolerated according to visual assessment scale.

Kiemeneij (21) also reported an unpublished 0% rate of forearm radial artery occlusion among 656 patients undergoing distal radial artery access at another center. Among them, a very low rate of complications potentially related to the distal radial artery access was observed: hematoma of the wrist and/or forearm (0.8%), transitory finger numbness (0.6%), radial artery dissection (0.3%), arteriovenous fistula (0.2%), and pseudoaneurysm (0.2%).

More recently, Valsecchi et al. (22) reported 90% success in a straightforward series of 52 patients undergoing distal radial artery access (79% right-side access).

On the basis of shared results, personal experience and quality control, distal radial artery access has now become the default vascular access in the first and last authors' interventional practice.

TECHNICAL ASPECTS

Following distal radial artery palpation, 1 of the 2 possible puncture sites is chosen. Distal TRA in the anatomic snuffbox may appear easier during the learning curve, although puncture in the first intermetacarpal space may provide the most optimal outcomes of distal radial artery access.

Next, optimal arm positioning represents a key step in effective distal radial puncture (Online Figures 1 and 2). To favor a shift of the distal radial artery to the surface of the fossa, the patient is asked to grasp his or her thumb under the other 4 fingers or to hold a roll of gauze, a 20-mL syringe, or the handle of a dedicated system (Online Figure 1).

After disinfection and local anesthesia, the artery is punctured according to operator preference and/or experience using a micropuncture needle or a cannula-over-needle. Because of the quantity of soft tissue, the distal radial artery may at times slip, thus requiring redirection of the needle (Online Video 2). Also, ultrasound may be particularly rewarding to assess distal radial artery location (Online Figure 2).

There is limited information on distal radial artery size (33), although a smaller diameter than at the wrist level may be expected according to the principle of conservation of energy (34). Thus, use of a small-diameter or slender introducer sheath may represent a wise first choice.

After the procedure, hemostasis may be easily achieved with a hemostasis device or a gauze plug wrapped with a tight elastic bandage (Online Figure 3, Online Video 3).

FINAL COMMENTS

Distal radial artery access for percutaneous coronary and peripheral diagnostic and revascularization procedures has a sound rationale and does not appear a "radialist eccentricity". Indeed, both anatomic and physiological principles support distal radial artery puncture in the anatomic snuffbox or in the first intermetacarpal space as a rational alternative to traditional TRA in the wrist. Expected persistence of flow in the forearm radial artery and no foreseeable causes of radial artery occlusion or hand ischemia are the most meaningful reasons to consider distal TRA. Additional advantages associated with higher comfort and potentially easier and safer periprocedural management are obviously appreciated. Preliminary data are scant, however, and outcome comparison versus conventional radial artery puncture at the wrist level is especially lacking, so accurate clinical studies to rigorously assess distal TRA and fully unveil its value and limitations are eagerly awaited. In the meantime, choice of access site should rely on the operator's personal preference.

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KEY WORDS **anatomic snuffbox, anatomy, distal radial artery, physiology, rationale, transradial access**

APPENDIX **For supplemental figures and videos, please see the online version of this paper.**