Distal Transradial Access for Percutaneous Coronary Intervention: Advantages, Disadvantages, Opportunities, and Challenges Postprint

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Abstract

As a novel access route for percutaneous coronary intervention, distal radial artery access has gained increasingly widespread clinical application in recent years. Compared with conventional radial artery access, distal radial artery access demonstrates distinct advantages in enhancing patient and operator comfort, reducing complication rates, and minimizing forearm arterial injury; however, it also exhibits certain limitations, including lower puncture success rates, a steeper learning curve, more pronounced puncture site pain, and higher incidence of radial artery spasm. Currently, distal radial artery access may also serve as an approach for acute coronary syndrome and complex coronary percutaneous coronary intervention, though its suitability for large-scale promotion and application remains to be further validated. This article primarily summarizes and analyzes the advantages, disadvantages, opportunities, and challenges associated with distal radial artery access in percutaneous coronary intervention, aiming to provide a reference for its scientific and rational clinical application.

Full Text

Preamble

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Medical Center, Houston, USA; and the University of Texas Medical Branch, and holds a US medical license. He was the first in China to introduce excimer laser therapy for complex coronary artery disease and pioneered percutaneous aortic valve intervention. Dr. Liu is a Fellow of the European Society of Cardiology, Fellow of the American College of Cardiology, Member of the Coronary Artery Disease and Atherosclerosis Group of the Chinese Medical Association Cardiovascular Branch, Director of the Beijing Medical Association Cardiovascular Branch, Vice Chairman of its Youth Committee, Member of the Structural Group of the Chinese Medical Doctor Association Cardiovascular Branch, and Director of the Beijing Physiological Society.

Title: Percutaneous Coronary Intervention via Distal Transradial Approach: Strengths, Weaknesses, Opportunities and Challenges

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Abstract: As a new approach for percutaneous coronary intervention (PCI), the distal transradial approach (dTRA) has gained increasing clinical application in recent years. Compared with the traditional transradial artery approach (TRA), dTRA offers significant advantages in improving patient and operator comfort, reducing complication rates, and minimizing forearm arterial injury. However, dTRA also has certain limitations, including lower puncture success rates, longer learning curves, more pronounced puncture site pain, and higher incidence of radial artery spasm. Currently, dTRA can also serve as an access route for acute coronary syndrome and complex coronary PCI, but its suitability for widespread promotion and application requires further validation. This article summarizes and analyzes the strengths, weaknesses, opportunities, and challenges of dTRA in PCI to provide a reference for its scientific and rational clinical application.

Keywords: Coronary disease; Coronary artery disease; Percutaneous coronary intervention; Radial artery; Distal radial artery; SWOT analysis

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Introduction

In 1993, Kiemeneij first reported percutaneous coronary intervention (PCI) via the transradial artery approach (TRA) [1-2]. Today, TRA has become the pre-

ferred access route for PCI. Compared with the transfemoral approach, TRA offers advantages including a shorter learning curve, lower procedural complication rates, and better patient experience [3]. However, radial artery occlusion (RAO) remains one of its main complications. Due to dual blood supply from the palmar arches, RAO after TRA PCI rarely manifests clinically, making its true incidence difficult to estimate. The incidence varies significantly among patients with different coronary lesions and procedural characteristics, anticoagulation regimens, and hemostasis strategies. Studies have shown that RAO occurs in approximately 8% of patients within 24 hours after TRA PCI and in about 6% within one week [4].

To further reduce RAO incidence, Kiemeneij pioneered exploration of left hand snuffbox radial artery access for PCI, publishing his findings on safety and feasibility in *EuroIntervention* in 2017 [5]. Since then, the distal transradial approach (dTRA) has gradually gained clinical traction as a novel PCI access route [6-10]. Compared with TRA, dTRA offers multiple advantages but also has certain limitations. This article summarizes the strengths, weaknesses, opportunities, and challenges of dTRA to provide guidance for its more scientific and effective clinical application.

1. Strengths of dTRA

1.1 Enhanced Patient Comfort

Coronary angiography and/or PCI via TRA requires patients to maintain a palm-up position for extended periods, often causing upper arm and shoulder discomfort during lengthy procedures. To maintain this position, a wide operating table is needed for support, increasing the risk of upper limb suspension and inadequate support in obese patients. When using left TRA, operators often position the patient's left forearm on their abdomen to avoid leaning over the patient, but this palm-up placement exacerbates hand and upper arm discomfort. dTRA can mitigate these issues: with right dTRA, the patient's right forearm rests naturally with the palm facing sideways, eliminating the need to maintain an upward palm position; with left dTRA, the left forearm can be naturally bent and placed on the abdomen with the palm facing toward the navel, facilitating prolonged position maintenance and better tolerance of lengthy procedures.

1.2 Enhanced Operator Comfort

During coronary angiography and/or PCI, operators typically work from the patient's right side. With right TRA, there is little difference in operator experience between dTRA and TRA. However, with left TRA, the difference is significant: to maintain a stable palm-up position, operators must lean, bend, or even lie across the patient, increasing fatigue, particularly with obese patients or shorter operators. Studies have shown that prolonged PCI requiring sustained bending increases lumbar disc pressure and radiation exposure, affecting operator health [11-12].

1.3 Enhanced Compression Comfort at Puncture Site

Compression hemostasis duration significantly impacts patient comfort after coronary angiography and/or PCI. After TRA angiography, compression typically lasts about 6 hours, potentially longer in hypertensive patients, those with coagulation abnormalities, or those sensitive to antiplatelet agents. To reduce bleeding and hematoma complications, patients must minimize wrist movement, increasing discomfort. dTRA markedly shortens compression time and improves comfort: Kiemeneij's early study [5] found that after dTRA angiography and/or PCI, compression bandaging for 30 minutes followed by light dressing for 3 hours allowed complete removal; clinical practice shows that 2-hour compression after dTRA does not increase bleeding complications. Compared with TRA, dTRA significantly reduces compression time and improves patient comfort while facilitating easier nursing care. Studies show high patient satisfaction with dTRA [6], with most patients reporting minimal puncture site pain [11].

1.4 Reduced Complication Rates

RAO is common after TRA coronary angiography and/or PCI, with incidence increasing significantly with longer procedure and compression times. Studies report RAO rates of 1-10%, with even higher rates in patients undergoing repeated TRA procedures [13]. Because dTRA punctures more distal vessels with dual blood supply from deep and superficial palmar arches and richer collateral circulation, it reduces forearm radial artery injury and markedly decreases postprocedural RAO. Kiemeneij's study [5] found no forearm RAO in 70 patients undergoing left dTRA angiography. Lee et al. [6] reported no forearm RAO on one-month ultrasound follow-up in 191 patients after left dTRA angiography. Ziakas et al. [9] found no RAO on 24-hour ultrasound in 49 patients after right dTRA PCI.

Coomes et al. [14] systematically analyzed 19 dTRA studies, finding a 2.4% overall complication rate, with bleeding and hematoma being the most common (18.2% incidence), while RAO occurred in only 1.7%. In a single-center randomized controlled trial, Tsigkas et al. [15] found that among patients completing post-PCI radial ultrasound (404/518 in dTRA group vs. 392/524 in TRA group), dTRA significantly reduced RAO (3.7% vs. 7.9%, P=0.014). Mizuguchi et al. [16] found larger radial artery diameter [(2.9$±0.5)*vs.*(2.7±$0.5) mm, P<0.001] and cross-sectional area [(6.5$±2.4)*vs.*(5.6±2.0)$mm\^{}\{2\}$, P<0.001] after dTRA versus TRA. In a prospective, comparative, longitudinal, randomized study of 282 patients, proximal radial artery occlusion (PRAO) rates at 24 hours were 8.4% in the TRA group vs. 0.7% in the dTRA group [OR=12.8, 95%CI (1.6, 100.0), P=0.002], and at 30 days were 5.6% vs. 0.7% [OR=8.2, 95%CI (1.0, 67.2), P=0.019] [17]. The lower PRAO rate with dTRA likely relates to multiple palmar arterial collateral supply and maintained radial artery perfusion during distal compression.

Elderly and obese patients are prone to hematoma from inaccurate compres-

sion after TRA, with severe upper arm hematoma potentially causing nerve compression and compartment syndrome. The distal radial artery is thinner and has bony support beneath the puncture site, facilitating better compression hemostasis and reducing hematoma risk. Koutouzis et al. [10] found significantly shorter mean hemostasis time with dTRA versus TRA angiography [(568$\pm$462)*vs.*(841$\pm$574) s, P=0.002], which is important for reducing post-procedural complications. While severe dTRA-related complications are rare [8-9, 18], some studies report local hematoma <2 cm in 7.4% [6] and forearm swelling/ecchymosis in 4.9% [7].

1.5 Reduced Forearm Arterial Injury

Since forearm arteries are primary sites for arteriovenous fistula creation in hemodialysis, TRA carries significant risk of arterial injury. dTRA minimizes forearm arterial damage and is preferred for patients with renal insufficiency requiring dialysis. Additionally, as forearm arteries may serve as coronary artery bypass graft conduits, patients undergoing CABG require intact forearm arteries with minimal injury, making dTRA particularly advantageous. Furthermore, dTRA provides additional access options for repeat PCI.

2. Weaknesses of dTRA

2.1 Lower Puncture Success Rate

First, the distal radial artery has a mean diameter of 2.0-2.6 mm [19-20], with smaller vessels in women than men [21], significantly affecting puncture success. dTRA demands greater puncture technique precision and a longer learning curve than TRA. Second, vessel tortuosity is an even more important factor affecting success than vessel size. The high probability of tortuosity from distal radial to forearm arteries often prevents guidewire advancement to the proximal forearm after successful needle entry, requiring greater experience and refined technique. Tsigkas et al. [15] found lower sheath insertion success with dTRA versus TRA (78.7% vs. 94.8%, P<0.001), requiring more puncture attempts [M(Q1,Q3)=2(1,3) vs. 1(1,2), P<0.001] and longer time (120 vs. 75 s, P<0.001). Reduced puncture success prolongs procedure and radiation exposure time, with dTRA showing higher dose-area product (median 32,729 vs. 28,909 cGy/cm^3, P=0.02) [15].

2.2 Longer PCI Catheter Length Requirements

Currently, dTRA PCI uses catheters designed for TRA rather than specialized devices. Since dTRA puncture sites are more distal, catheter length may be insufficient, particularly in tall patients with long arms [8], requiring advance consideration of catheter length.

2.3 Higher Puncture Pain and Arterial Spasm Incidence

Due to superficial bony structures at the distal radial artery, dTRA puncture may contact periosteum, causing more pronounced pain. Clinical practice shows higher radial artery spasm rates with dTRA, likely related to puncture and sheath delivery pain. The DISCO RADIAL study [22] found higher spasm rates with dTRA versus TRA (2.7% vs. 5.4%, P=0.015). Spasm further narrows or occludes the already small distal radial artery, causing catheter delivery difficulty and patient discomfort.

2.4 Cosmetic Impact of Puncture Site Scarring

With increasing coronary angiography use, many young patients, especially women, consider cosmetic outcomes. The dTRA puncture site on the dorsal hand is difficult to conceal, and patients with scar-prone or slow-healing skin experience prolonged scar healing. Thus, dTRA has greater cosmetic impact than TRA, and for young patients, especially women with high cosmetic demands, TRA should be preferred without specific indications.

3. dTRA Puncture Strategies

3.1 Anatomical Localization-Based Strategy

dTRA puncture sites include the Hegu point area and anatomical snuffbox. The Hegu point lies on the dorsal hand at the midpoint of the second metacarpal bone between the first and second metacarpals, where the radial artery dorsal branch runs from dorsal to palmar. The snuffbox is a triangular depression on the radial dorsal wrist, bounded laterally by the extensor pollicis brevis and abductor pollicis longus tendons, medially by the extensor pollicis longus tendon, and proximally by the radial styloid, where the radial artery dorsal branch is palpable. Few major nerves are present, only the superficial radial nerve branch, with deep bony structures formed by the distal radius, scaphoid, trapezium, and first metacarpal base [23]. The radial artery divides into deep and superficial palmar branches in the snuffbox, anastomosing with ulnar branches to form the deep and superficial palmar arches. Due to interconnections between these arches, local arterial occlusion does not compromise blood supply. After palpating the strongest distal radial artery pulsation in the Hegu or snuffbox area with the left index and middle fingers, operators can use this point for puncture. If pulsation is difficult to feel, the vertex of the first and second metacarpal junction serves as a bony landmark, or ultrasound guidance can be used [24].

3.2 Strategy for Puncture Failure

Main causes of dTRA puncture failure include failure to enter the artery and failure to advance the guidewire. Failure to puncture relates to small distal radial artery size, while wire advancement failure is a more important cause, primarily due to radial artery tortuosity, occlusion, transition from palmar to

dorsal hand, or wire entry into the deep palmar arch ulnar side. Appropriate guidewire shaping (single or double curve at the tip) improves deliverability. A shaped needle passes more easily than a shaped wire through the introducer needle, especially with large curves. A small single curve (3-4 mm from tip, ~45° angle) offers balanced performance, requiring gentle rotation during needle advancement and delicate manipulation after vessel entry. Extreme cases may require "fly-leg" shaping similar to chronic total occlusion wires. Steel needles may be preferable to introducer needles for dTRA due to easier fixation, better wire passage, no need for transfixion, and reduced hematoma risk. Introducer needles are difficult to use for transfixion at the distal radial artery due to its superficial course over the first metacarpal. However, steel needles are thicker than introducer needles, which may be problematic for small distal radial arteries. For improved success, select suitable patients (avoid those with small, weak pulses), shape wires appropriately for tortuous arteries, use pre-procedural ultrasound to assess vessels, and consider manipulating subcutaneous tissue, rotating the wrist, or using smaller sheaths to facilitate wire passage in tortuous or stenotic vessels.

Anesthesia considerations include: (1) after identifying the puncture site, infiltrate locally; (2) beginners should use larger anesthetic doses (5-10 ml) to reduce severe pain from inadvertent periosteal contact; (3) excessive anesthetic may mimic hematoma or interfere with assessment, requiring practice to minimize puncture attempts and anesthetic volume.

4. Opportunities and Challenges for dTRA

PCI access selection should be patient-centered, aiming to reduce complications, minimize suffering, improve comfort, and facilitate procedures. While dTRA offers many advantages over TRA, its limitations require individualized selection based on patient characteristics. Operators must accumulate experience and conduct further research to obtain more evidence for scientific and effective PCI access selection. Current studies have preliminarily confirmed dTRA's safety and reliability, and it can serve as an access route for acute coronary syndrome and complex coronary lesions. With increasing patient acceptance, dTRA will likely gain wider promotion and may become the preferred PCI access.

4.1 Widespread dTRA Application Requires Large-Scale Validation

Recent years have seen increasing clinical research on dTRA, with most studies suggesting advantages and feasibility for complex PCI, but these are primarily single-center, small-sample studies [5, 8-10, 18]. The DISCO RADIAL study [22] is an international, multicenter, randomized trial that assigned patients eligible for 6F Slender sheath PCI to dTRA (n=650) or TRA (n=657). The primary endpoint was forearm RAO incidence at discharge by vascular ultrasound; secondary endpoints included access site crossover, hemostasis time, and puncture-related complications. Results showed no significant differences in forearm RAO

(0.91% vs. 0.31%, P=0.29), overall bleeding (6.8% vs. 5.5%, P=0.33), or vascular complications (1.1% vs. 1.2%, P=0.81). dTRA had higher crossover rates (7.4% vs. 3.5%, P=0.002) but shorter median hemostasis time (53 vs. 180 min, P<0.001). While dTRA shows advantages, further multicenter, prospective, randomized studies are needed. Moreover, although dTRA reduces puncture site complications, proper RAO prevention strategies remain key to reducing RAO incidence, including appropriate sheath selection to minimize arterial wall injury, rational antithrombotic therapy, and proper hemostasis methods. Additionally, since dTRA may prolong procedure time, delayed revascularization in acute coronary syndrome patients undergoing primary PCI may offset its benefits [25].

4.2 Puncture-Related Issues

Key concerns include: (1) Blind puncture increases tendon injury risk, while transfixion not only causes periosteal irritation but also allows blood leakage from the posterior wall puncture site, increasing hematoma risk. (2) Puncture near the extensor pollicis tendon may cause inadvertent deep palmar arch branch injury. (3) Selecting the strongest pulsation point may mislead puncture site selection, affecting post-procedural compression and increasing complication risk.

4.3 Ultrasound-Guided dTRA Puncture as a Future Direction

Ultrasound-guided distal radial artery puncture can identify important anatomical landmarks, avoid adjacent structure injury, accurately locate vessels, and distinguish arteries from veins, improving success rates and reducing venous injury. Ultrasound can even identify tendons, superficial radial nerve branches, and cutaneous nerves, reducing tendon and nerve irritation/injury. It can measure vessel diameter to guide sheath size selection and determine optimal anesthetic location and dose to reduce spasm [26]. Multiple studies show ultrasound-guided TRA improves puncture success [27], reduces time, and decreases hematoma risk [28], supporting ultrasound over blind puncture. Although ultrasound-guided dTRA requires a longer learning curve, this should not hinder its clinical promotion. Hadjivassiliou et al. [29] published a detailed technical guide on ultrasound-guided dTRA puncture in the anatomical snuffbox for reference.

5. Summary and Outlook

Currently, dTRA's long-term clinical advantages over TRA remain to be established. Whether dTRA provides additional benefits on hard clinical endpoints while maintaining equivalent efficacy should be a primary future research focus. Higher crossover rates and longer procedure times are main weaknesses. Continuous improvement in puncture success and accumulating experience are crucial for widespread dTRA promotion. With growing experience and technical refinement, dTRA may become a more widely used PCI access route. However, dTRA remains dynamically evolving—where it will ultimately land can only be

revealed by the future!

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