# Minimalistic Approaches for Vascular Access in Minimally Invasive Transcatheter Interventions

**Ph.D. Dissertation**

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## LIST OF PUBLICATIONS (Period October 2021 – January 2023)

### Publications directly related to the subject of the dissertation

I. **Achim A,** Kákonyi K, Jambrik Z, Nagy F, Tóth J, Sasi V, Hausinger P, Nemes A, Varga A, Bertrand OF, Ruzsa Z. Distal Radial Artery Access for Coronary and Peripheral Procedures: A Multicenter Experience. J Clin Med. 2021 Dec 20;10(24):5974. doi: 10.3390/jcm10245974.

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## INTRODUCTION

The history of intravascular access is a story of persistent endeavor by clinicians to apply the newest techniques in improving the lives of their patients. These applications of new techniques have meant safer and more minimally invasive routes for entering the arterial system to perform diagnostic and interventional procedures. Over the course of the last quarter century, percutaneous vascular access via the radial artery has emerged as a standard for arterial access proliferating and contributing enormously to improvements in quality of life and decreased procedural complications and mortality rates. These advancements are a result of nonlinear incremental technical and clinical refinements that made percutaneous transradial access the standard for percutaneous coronary interventions in many countries. While the femoral artery has been the traditional default access site for most diagnostic and interventional procedures, this route has been mainly seconded by the transradial route due to better patient comfort and mobilization in the post-procedure period, reduce the risk of bleeding and vascular complications and reduce health care costs (1). Nevertheless, it must be recognized that the safety of the femoral approach has also improved by the large-scale introduction of ultrasound-guided puncture and vascular closure devices.

Interest in a transradial approach was present early in the development of the fields of interventional radiology and cardiology. For instance, in 1947, Stig Radner performed an intracranial angiography via the radial artery at Lund University, Sweden. Dr. Charles Dotter's method for nonselective coronary angiography published in 1958 was performed via radial access. The next documented successful applications of transradial access in clinical practice were in 1989 by Lucien Campeau at the Montreal Heart Institute. Prior to Campeau's 1989 report, this technique was obscure and underutilized (2).

Increasing adoption of percutaneous transradial interventions provided ample data demonstrating that the transradial approach was delivering on its promise. Papers published from 1992 to 1997 showed reduced rates of major access site bleeding resulting in less mortality, increased patient comfort, and decreased costs (3). The ACCESS study was the first randomized clinical trial showing the equipoise in clinical outcomes between radial, brachial, and femoral access with less transradial access site complications (4). The mounting evidence helped to overcome the reluctance many clinicians had to learn the newer radial approach. With increasing international adoption and cooperation with medical device companies, dedicated radial access puncture sets, sheaths, catheters, and hemostasis devices were created resulting in even better outcomes and lower threshold for clinicians to start a radial program. With the turn of the millennium came a series of randomized clinical trials further solidifying the superiority of the

transradial approach in reducing bleeding risk and mortality rates; the MORTAL, RIVAL, RIFLE STEACS, and MATRIX studies (5,6,7,8). This accumulation of evidence led the European Society of Cardiology (ESC) to declare the radial access the method of choice for coronary interventions first in 2013 and then affirmed as Class I Level B in 2015 (9). The indication was definitively strengthened in 2021 by indicating it in both acute and stable cases, according to both American and European guidelines (10, 11). The transradial approach had gone from an obscure experiment to standard of care.

Until recently, there was only one transradial access and when speaking about the technique, the term “radial puncture” was unanimously used without the need to expand further details about its location at the forearm. Terms such as “proximal radial access” or “distal radial access” appeared only later, when it was proven that the radial artery can be punctured even more distally, at the anatomical snuffbox area, on the dorsal face of the hand. Until 2007, radial access was defined as puncturing the area 2-3 cm above the wrist crease, with the hand supinated. The initial one is now defined as the conventional or proximal transradial technique (PRA). This is quite established in everyday practice and in the following introductory chapters we will discuss details about the advent of other newer distal radial access, how it appeared, what advantages and disadvantages it brings and why it is considered more minimalist than its predecessor.

The distal radial access (DRA) is a novel access which consists of puncturing and accessing the distal segment of the radial artery which is situated superficially on the dorsal side of the hand, at two levels: the anatomical snuffbox and distal of the extensor pollicis longus tendon (12). These 2 alternative puncture points are distal to the carpal anastomotic networks and the superficial palmar arch and yield the same advantages as conventional TRA with an additional potential to maintain antegrade flow in the forearm radial artery during hemostatic compression of the distal radial artery, reducing thereby the risk of retrograde thrombus formation, and forearm radial artery occlusion (RAO) (12). Other significant advantages are faster hemostasis and much better patient and operator ergonomics, especially when performing left DRA. Those significant advantages are contrasted by a slightly smaller diameter of the distal radial artery, a less predictable angulated course and a different puncture curve, potentially impacting on device selection and procedural planning. Its place in cardiovascular interventions remains to be analyzed independently, to establish in an arbitrary way if DRA represents an evolution of PRA and not just a sophisticated alternative.

The aims of this doctoral thesis are postulated point-by-point at the end of the introductory part, after a brief analysis of this novel technique that will expose the current state of this vascular access and what scientific contribution this multi-leveled research brings to this particular field in interventional cardiology.

# THE RATIONALE OF DISTAL RADIAL ACCESS

## The advent of the distal radial access

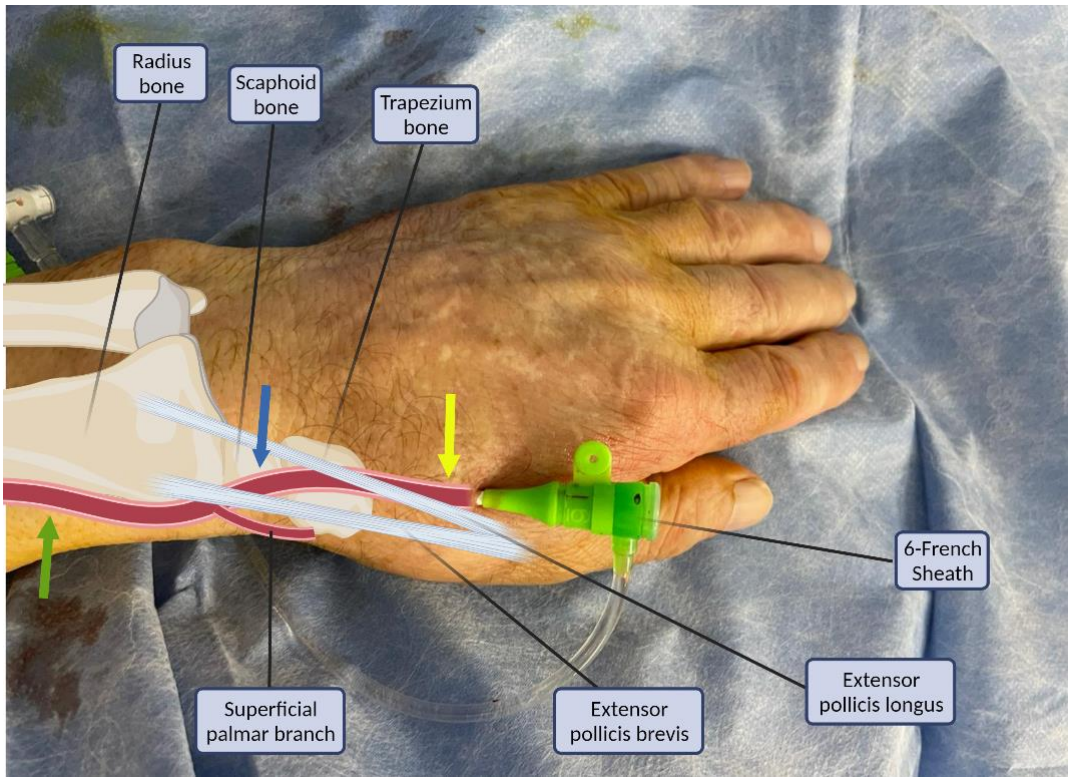
In the 70s, the access to the radial artery via the anatomical snuffbox (fovea radialis) has been described as an alternative access point for blood pressure monitoring in children and adults (13), but it took several decades until the DRA started to be used for coronary angiogram and interventions. That was the first robust publication mentioning the possibility of puncturing the radial artery in another location (13). For transcatheter interventions, it was firstly described as a way of accessing and recanalizing the occluded proximal radial artery segment (14). This particularly unique potential of DRA will be studied and discussed for the first time by a pilot study published by our institution.

The first success rate of DRA was reported by Kiemeneij et al in 2017, which was 89% in a cohort consisting of 70 patients (15). Other studies followed, reporting safety and feasibility with this technique with good clinical outcomes and low complication rate, mostly non-significant hematomas. Among the first randomized trials was the DAPRAO trial, a small but well-conducted trial in Mexico that mainly showed lower rates of RAO in a small cohort and more importantly, opened doors to other, more powerful trials (16). Until then, only observational studies were reported and the anatomic basis and physiological rationale of DRA for percutaneous coronary and endovascular procedures was first described in a viewpoint review by Sgueglia et al, stating that “DRA for percutaneous coronary and peripheral diagnostic and revascularization procedures has a sound rationale and does not appear a <radialist eccentricity>” (17). At that time, however, the phenomenon happened more on social media and DRA was selectively adopted on some patients and only by some operators. The technique needed maturation.

## Anatomical considerations

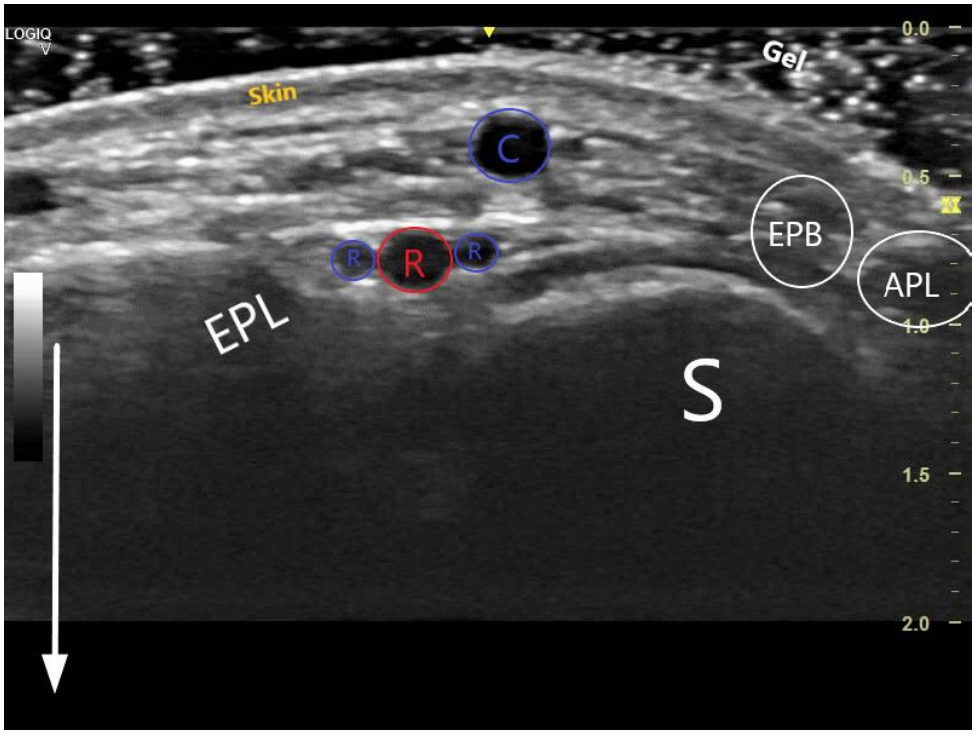
The puncture site and the anatomy of the distal radial artery and its surrounding structures are illustrated in Figure 1. The radial artery descends from the lateral side of the forearm above the radius towards the wrist, where it is perceptible between the flexor carpi radialis tendon medially and the anterior border of the radius; this is where the typical transradial access site (PRA) is located. The superficial palmar branch of the radial artery arises at the wrist, passing through the thenar muscles and anastomosing with the end of the ulnar artery to produce the superficial palmar arch. Distally, the radial artery continues posterolaterally to pass onto the dorsal part of the wrist. To complete the deep palmar arch, the radial artery anastomoses with the deep branch of the ulnar artery. The two arches are sometimes incomplete or hypoplastic (in approximately 20% of the cases).

**Figure 1**. Structures of the anatomical snuffbox in connection with the arterial sheath. Common radial puncture sites: proximal (green arrow), anatomical snuffbox (blue arrow), and distal dorsal (yellow arrow).




There are two sites where the pulse of the radial artery in the dorsum of the hand may be palpated and vascular access could be attempted. The first is the anatomical snuffbox which is a triangular depression space on the radial, dorsal aspect of the hand (Figure 1, blue arrow). The second is beyond the extensor pollicis longus, the medial border of the snuff box (Figure 1, yellow arrow). The anatomical snuffbox is a tridimensional triangle-shaped space with three borders, a floor, and a roof. The floor is a "bone base" composed of the distal radius, scaphoid, trapezium, and the base of the first metacarpal bone. The roof is superficial, composed of skin. The medial and lateral borders are bounded by tendons of the extensor pollicis longus and the extensor pollicis brevis, respectively. The proximal border is formed by the styloid process of the radius. Within this narrow triangular space, various structures are located, including the distal radial artery, a branch of the radial nerve, and the cephalic vein. All these structured are easily visualized by Doppler ultrasound, an useful tool that can help the operator visualize the needle through the skin, see where it is situated relative to these structures and make a cleaner puncture, without numerous attempts that may lead to unnecessary pain and hematoma formation (Figure 2). Last but not least, another important role of Doppler ultrasound for DRA is to estimate the diameter of the target artery. This is important because in some cases the artery cannot tolerate large catheters and the procedure can become progressively painful and lead to access cross-over.

**Figure 2.** Transversal ultraspund image at the anatomical snuffbox. The depth has been adjusted so that the structures near the transducer form the majority of the image. The white arrow demonstrates the near and the far during scanning. The 3 layers of the skin are visible, superficially is the cephalic vein (C), deeper the radial artery (red R) accompanied by 2 radial veins (blue Rs). The snuffbox is surrounded by the extensor pollicis longus (EPL), extensor pollicis brevis (EPB), abductor pollicis longus (APL), and scaphoid (S).




**The benefits**

A large body of literature has emerged describing several advantages of the novel DRA technique over the conventional radial one: minimal risk of hand ischemia due to preservation of blood flow in the forearm, faster hemostasis, reduction in nursing staff time, greater comfort for the patient and the operator, the sheath is naturally secured by the curvilinear trajectory and, finally, it preserves the proximal forearm's radial segment for future interventions or arterial graft harvesting [12,18,19]. The benefits quickly became clear and the nursing staff began to prefer it for obvious reasons: the burden of patient supervision was eased and a better throughput in the recovery room was observed. From a theoretical standpoint, DRA offers some potential advantages over conventional proximal transradial approach for physiological and anatomical reasons which are highlighted in Table 1. The most common complication after the procedure is radial artery occlusion, which has an impact because it prohibits future use of the same radial artery. The goal of all radial centers should be to reduce the rate of occlusion.

**Table 1.** Advantages of DRA

| Anatomical characteristics | Hemodynamic characteristics | Procedural benefits |
|---|---|---|
| Slightly smaller in diameter than the proximal radial artery | Maintenance of persistent flow though the superficial palmar arch | Better ergonomics, especially in left side access. |
| The puncture site is more superficial | Lower kinetic energy of blood flow | Easier access and posture in patients with limited hand motion ("frozen shoulder") |
| Direct contact with the scaphoid bone underneath | | Faster, easier compression and hemostasis<br>Lower rates of hematoma dissemination/ radial artery occlusion<br>Similar catheter handling as in femoral access (hands are in pronation, over the patient's pelvis)<br>Possible lower radiation in CTO procedures. |

## CURRENT LANDSCAPE IN DISTAL RADIAL ACCESS

### The technique

As shown in Figure 1, the two sites at which the radial pulse can be found are in the anatomic snuffbox and in the first intermetacarpal space (dorsum of the hand). Ultrasound is useful to determine the diameter of the distal radial artery and to select the proper sheath introducer and catheter size. The arm should be optimally positioned according to access side and operator's preference and/or experience. Asking the patient to grasp his/her thumb under the other four fingers or holding a handle favors the distal radial artery shifting to the surface. The puncture area is disinfected and covered with a sterile drape. Anesthetic agent is injected; of note, the amount should be divided in two parts and only less agent amount should be injected first, immediately under the skin as the artery is very superficial and larger amounts of anesthetics could obliterate palpation. Operator preference and/or experience help using an open needle or a catheter-covered needle. The complex three-dimensional course of the distal radial artery

turning around the base of the thumb allows different possible supero-inferior and latero-medial entry angles to achieve vascular access. A mini guidewire is carefully advanced in the vessel lumen. If resistance is felt, the guidewire should be retracted and rotated to avoid damaging small arterial branches rising between the puncture site and the forearm radial artery. Thumb adduction straightens the radial artery and may reduce the risk of the guidewire misdirection. Shaping the mini guidewire tip may alternatively help to overcome distal radial artery tortuosity. Mini guidewires with a floppy tip and a firm body, as well as thin-walled hydrophilic sheaths with a proper stiffness profile, would allow for seamless sheath insertion while preventing kinking. Individual preference directs the choice of a 0,025 inch or a 0.018 inch mini guidewire. Standard 5000 UI heparin was administered. Administration of a spasmolytic drug right after sheath introducer placement is beneficial to avoid spasm. A 210 cm wire is the best choice for catheter exchanges. In case of eft distal radial access, some resistance can be encountered when the tip of the wire approaches the brachial artery due to the flexed elbow, if it occurs the elbow should be stretched first and a hydrophilic wire could be used. Catheters 110 cm in length may be advantageous in tall subjects. Universal radial curves should be preferred for diagnostic angiography. Dedicated compression devices were developed or any compression bandage is enough to obtain successful hemostasis in approximately 3 hours.

**The RAO endpoint**

The reduced size of the radial artery, the fairly sizeable sheath, and the possibility of spasm with catheter passage all contribute to an environment conducive to acute thrombotic blockage of the artery in the immediate post-procedure period. This provides a distinct difficulty in terms of radial arteriotomy care because bleeding is generally easy to avoid, but RAO prevention is critical. If RAO persists, this option as an access point for future treatments is lost, and, while thankfully uncommon, hand ischemia has been observed (20). In light of the foregoing, whilst also manual pressure for femoral puncture generally necessitates occlusive pressure for a short period of time, the goal with radial procedures is to provide pressure that achieves hemostasis while avoiding occlusive pressure, which has been shown to increase the risk of RAO. 436 patients undergoing transradial operations were randomly assigned to classic or patent hemostasis in the Prevention of Radial Artery Occlusion-Patent Hemostasis Evaluation Trial (PROPHET). The sheath was removed and a compression wrist band was applied to the wrist in the conventional hemostasis arm. Two hours later, the band was unfastened. A compression band was placed and tightened in the patent hemostasis arm. A reverse Bateau test was then undertaken, and if the plethysmographic signal revealed that the radial artery was occluded, the band was eased until radial flow was restored. The compression was then kept up for another two hours. The use of patent hemostasis significantly reduced the incidence of RAO at 24 hours and 30 days (5% vs. 12%, p 0.05 and 1.8% vs.

7%, p 0.05, respectively). There was no evidence of excessive bleeding in the patent hemostasis arm (21). Several other factors have been linked to RAO, including the usage of patent hemostasis, decreased sheath size, anticoagulation, and antispasm regimens. Dahm et colleagues randomized 171 patients presenting for transradial percutaneous coronary intervention (PCI) to procedures conducted with SF or 6F guiding catheter systems in terms of sheath size. The success rate of the procedure was comparable between groups (5F vs. 6F, 95.4% vs. 92.9%, p = NS), however the incidence of RAO after 30 days was considerably greater in the 6F group (5.9% vs. 1.1%, p = 0.05) (22). After these studies, the Novel Angioplasty Using the Coronary Accessor Thal (NAUSICA) trial results were published. In this study, 160 patients were randomly assigned to transradial PCI using 4F versus 6F devices. Although the primary end point was not significantly reduced in the 4F group (0% vs. 4%, p = 0.08), there was a tendency toward better results: the 4F group had significantly shorter hemostasis duration and vascular complication rates (4F vs. 6F; hemostasis time 237 vs. 320 min, p = 0.007; access complications 0% vs. 6%, p = 0.02) (23).

Anticoagulation should potentially be advantageous in RAO since it is a thrombotic condition and this was proven in observational studies. Rates of RAO were as high as 71% in patients who had no anticoagulation during transradial interventions in a pioneering study by Spaulding et al, but this rate was lowered to 24% and 4.3% in patients who were given 2,000 to 3,000 and 5,000 units of heparin, respectively (p 0.05) (24). In contrast, randomized controlled trials have yet to determine the appropriate anticoagulant dose. While there is a wealth of evidence to support the use of intraprocedural anticoagulation in RAO prophylaxis, the efficacy of postprocedural anticoagulation has received less attention. RAO rates were comparable in trials comparing 2,000 units to 5,000 units of heparin, as well as 5,000 units to weight-based dosage (50 units/kg). Similarly, it has not been demonstrated that the manner of heparin administration (ie, intravenous versus intra-arterial through the sheath) affects RAO risk. For all transradial interventions, current guidelines propose heparin dosages of 50 units/kg or 5,000 units. The use of vasodilators may also be beneficial in lowering the risk of RAO (9). Dharma et al randomized 1,706 patients to 500 micrograms (mcg) intra-arterial nitroglycerin versus placebo at the end of a transradial intervention and discovered that rates of RAO diagnosed with routine duplex on post-procedure day 1 were reduced by more than 25% (8.3% vs. 11.7%, p = 0.006) (25). The effect of other commonly used antispasmodic regimens on RAO incidence is not well understood. Most people who develop RAO are asymptomatic and, as a result, do not require treatment. In reality, subsequent imaging will reveal that a significant number (>50%) of occluded radials have recanalized. Lavi et al found that roughly 33% of individuals with early RAO had patent radial arteries as measured by color Doppler ultrasonography at 1 month in the PRACTICAL-2 randomized study (26). Endovascular therapy and anticoagulation have both been utilized successfully in symptomatic patients.

Neither technique can be consistently endorsed at this time due to a lack of reasonable evidence. In the author's experience, anti-inflammatory medications alleviate the discomfort associated with symptomatic RAO and may aid in symptom remission. For RAO discovered very early in the post-procedural period (eg, within a few hours), 1 hour of ipsilateral ulnar compression has been demonstrated to be safe and successful in restoring flow, probably by diverting flow and raising pressure toward the occluded radial. However, further clinical evidence and testing is needed to corroborate these findings.

## AIMS

1. To explore the safety and feasibility of DRA in different clinical scenarios: acute coronary syndrome, chronic coronary syndromes (elective cases), dual radial access for chronic total occlusion interventions, radial access for structural interventions, and radial access for peripheral interventions.
2. To define the role of ultrasound in performing DRA.
3. To discuss procedural insights and technical aspects of DRA from the perspective of the enrolled cohorts.
4. To find new roles of DRA: from the correlation of radial artery calcification with other cardiovascular factors to new opportunities to recanalize RAO.

## METHODS

### Patient population

Between 2019 and 2022, a total of 1450 patients were recruited prospectively in a large, multileveled database. This registry generated 5 major studies:

1. DRA in coronary and peripheral procedures
2. DRA vs PRA for CTO PCI procedures
3. Distal radial balloon aortic valvuloplasty: the DR-BAV pilot study
4. Transcatether aortic valve implantation: DRA as secondary access
5. DRA for chronic RAO recanalization: a pilot study

This thesis presents the findings of these five studies.

All patients received DRA at the Division of Cardiology, Second Department of Internal Medicine, University of Szeged Hospital, Szeged, Hungary. In this center, as per 2019 there was a switch

from proximal radial access to distal radial ultrasound-guided access. The cohort comprised of all comers. In some sub-studies, control populations were recruited from 2 other institutions in Hungary ( Bács-Kiskun County Hospital, Kecskemet and Cardiac and Vascular Center, Semmelweis University, Budapest).

The indication for DRA was coronary angiography, stable coronary artery disease, acute coronary syndromes (STEMIs/NSTEMIs), chronic total occlusion PCI, complex and high risk PCI, peripheral artery disease (carotid interventions, lower limb interventions, renal and celiac trunk/mesenteric artery stenting) and structural disease (primary access for balloon aortic valvuloplasty, secondary access for transcatheter aortic valve implantation, etc.). The arterial access was mainly performed by four experienced operators and several fellows in training. The study (DRA, arterial access, patient data) complied with the Helsinki Declaration and all patients signed informed consent. The study protocol was approved by the Ethics Committee of the Affiliated Second Internal Medicine Department Hospital of Szeged University (OGYÉI/50275/2018).

The only inclusion criteria was the presence of a pulse at the anatomical snuffbox and the decision of the responsible operator to proceed with DRA. Not all patients underwent radial artery ultrasound before the procedure in order to assess vessel size and patency, only during puncture. The choice of the site of dRA (left or right) was made at operating physician discretion and patient preference after detailed evaluation of the patient's pulses, medical history, and clinical case characteristics. The preprocedural exclusion criteria were: (1) Ultrasound evidence of arterial occlusion, severe calcification, and a lumen of less than 1 mm; (2) Established cardiogenic shock; (3) Raynaud's disease in the medical history.

To standardize data collection and build a useful database, the following procedural details and access parameters were entered:

(1) Baseline patient characteristics (age, gender, height, weight, cardiovascular risk factors);

(2) Time to find the artery by Doppler USG;

(3) The total number of puncture attempts;

(4) Total access time, cannulation time, and puncture time (in seconds);

(5) Total procedure time (including fluoroscopy time);

(6) Indication for intervention, sheath size, catheter size;

(7) Procedural variables (coronary anatomy, devices, scores, intraprocedural complications)

(8) Postoperative compression time, compression type;

(9) Pain score (0–5);

(10) Radiation dose, contrast amount;

(11) Hospitalization time;

(12) Postoperative complications (listed below);

(13) Ultrasound measurement of artery diameters: distal radial artery in the anatomical snuffbox and proximal radial artery (2–3 cm of the styloid);

(14) USG-measured radial artery peak systolic velocity (PSV) (cm/s) and distal radial PSV (cm/s) by USG.

(15) Major cardiovascular events at follow-up

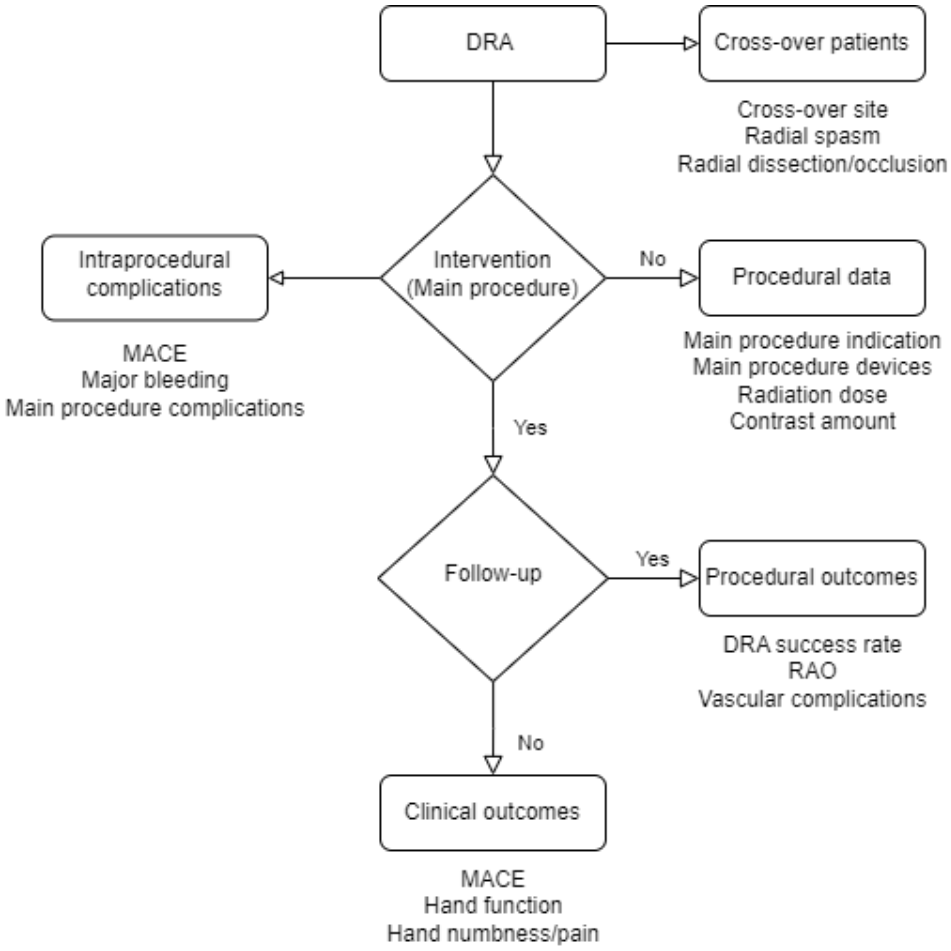
(16) Radial artery patency at follow-up

Anatomical considerations were also noted: high take-off, tortuosity, spasm, occlusion, plaque formation, calcium, brachiocephalic trunk tortuosity, and brachiocephalic trunk calcinosis.

Immediate vascular complications, such as hematoma, pseudoaneurysm, arterial occlusion, ischemic injury of the hand, compartment syndrome, arteriovenous fistula, infection, or the need for vascular surgery repair, were evaluated upon hospital discharge. All patients were scheduled for a detailed clinical follow-up examination at 3, 6 and 12 months after the procedure, and all complications related to the access site (late events such as artery occlusion, hematoma, arterio-venous fistula, nerve or bone damage) were recorded during these follow-up visits.

Different subsets of patients and subpopulations were extracted from the main database and analyzed separately depending on the indication that was conferred to DRA and the specific aims and endpoints of the particular study. According to each study that was conducted, patients were follow-up differently but in general the enrollment was conducted by a protocol depicted in Figure 3.

**Figure 3**. Patient enrollment flowchart.




Main focus was the safety and the feasibility of the procedure. The puncture success rate was important as well as the cross-over rate to another access site and access site-related vascular complications. The size of the sheaths and catheters were noted as well. The performance of DRA was evaluated by the number of puncture attempts, the time for obtaining the access and the pain score collected from the patient. Outcomes were divided between procedural outcomes (RAO, success rate, safety, vascular complications, etc.) and clinical outcomes (MACE, hand function, major bleeding, etc.). Regardless of the study, the outcomes were standardized and their definitions were uniformly kept on each investigation.

**Definitions and study endpoints**

Because our study was a vascular access-related study, focused on the safety, feasibility and performance of DRA in various transcatheter interventions, 2 types of endpoints were defined. The primary outcomes of the study were the success (procedural plus clinical) and access site complications (severe arterial spasm, forearm hematoma, radial artery occlusion, bleeding, pseudoaneurysms and fistulae). Procedural success was defined as successful main procedure outcome via DRA.

The secondary endpoints included were major adverse cardiac and cerebrovascular events (MACCE) and procedural performance characteristics (volume of contrast, fluoroscopy time, radiation dose, procedure time, hospitalization time). The total procedure time referred to the time interval between the administration of the local anesthetic until the completion of the procedure. For the classification of the forearm hematomas, we used a modified version of the EASY (Early Discharge After Transradial Stenting of Coronary Arteries Study) classification (27). Large hematomas were considered ≥EASY II. Bleeding was considered significant if Bleeding Academic Research Consortium ≥2. The components of MACCE were defined as non-fatal myocardial infarction (MI), acute stent thrombosis, target lesion revascularization (TLR), stroke or transient ischemic attack, and cardiovascular mortality.

**Statistical analysis**

In the first section of our study patients were classified in five groups based on whether they had a specific transcatheter intervention and required a specific device via DRA: coronary interventions, CTO interventions, balloon aortic valvuloplasty, TAVI cases and radial occlusion recanalization cases. In the second part of the study comparisons were performed between DRA procedures and those that were performed through proximal radial access. Finally in the third part of the analyses we investigated the clinical and procedural outcomes for each group.

The current database was created using the Microsoft Excel 2019 program. Statistical analysis was performed using SPSS v26.0 software (IBM Corp., Chicago, IL, USA). Continuous variables are expressed as the mean ± standard deviation or the median with interquartile range (Q1, Q3). Categorical variables are presented as the count (percentage). The patient groups were compared using either the Mann–Whitney U test or the Kruskal–Wallis test. In case of comparison, the patients were stratified by approach (PRA vs. DRA) and compared using parametric (Student's paired t) or non-parametric (Mann-Whitney U) tests, as appropriate, for continuous variables and the Chi-squared test for categorical variables. The threshold of statistical significance was $p < 0.05$.

In the CTO group, propensity score matching was used to adjust for pre-specified baseline characteristics that were potentially confounding variables. We calculated propensity scores using logistic

regression models with all baseline variables, including patient comorbidities and lesion characteristics. The C-statistic for the model was 0.92. PRA cases were matched 1:1 with DRA cases, using the propensity score with a caliper of 0.1 of the standard deviation of the logit of the propensity score, without replacement. Standardized mean differences (SMD) were determined to compare baseline characteristics of all patients; a standardized mean difference <0.25 was considered an indicator of good balance between groups.

## RESULTS

### Coronary and peripheral procedures

During the study period 1240 consecutive patients underwent coronary procedures via DRA at 2 Hungarian centers. The clinical characteristics of the study population are shown in Table 2. The mean age of the patients (829 males (66.8%)) was 66 ± 12 years. Hypertension, diabetes, dyslipidemia, and smoking were present in 92%, 37%, 83%, and 25%, respectively. Radial access was achieved using the left (left DRA) (n = 300, 24.19%) or right arm (right DRA) (n = 940, 75.8%). The operator was allowed to decide whether to attempt puncture at snuffbox (more proximal) or distal–dorsal site (more distal) or both. Stable clinical presentation accounted for 50% of indications, and 6% of patients had a history of coronary artery bypass graft operation. In 72% of the patients, PCI was performed (n = 895). The crossover rate in patients with PCI was similar to that of those with coronary angiography alone (1.16% vs. 1.42%).

**Table 2**. Baseline characteristics of all 1240 patients.

| Demographic features | Mean±SD (range)/ N (%) |
|---|---|
| Age (years) | 66.4 ± 12 (25-92) |
| Gender: female/male, % (n) | 33.14% (411) / 66.85% (829) |
| Height (cm) | 173 ± 8 |
| Weight (kg) | 78 ± 17 |
| **Risk Factors** | |
| Renal failure | 196 (15.8%) |
| Diabetes Mellitus | 463 (37.33%) |
| Hypertension | 1152 (92.9%) |
| Smoking | 311 (25.08%) |
| Family History | 255 (20.5%) |
| Dyslipidemia | 1035 (83.46%) |
| Previous MI | 295 (23.79%) |
| Previous CABG | 80 (6.45%) |
| Previous PCI | 199 (16.04%) |
| **Indication for Catheterization** | |
| Stable Angina Pectoris | 627 (50.56%) |
| Unstable Angina | 60 (4.83%) |
| NSTEMI | 82 (6.53%) |
| STEMI | 46 (3.7%) |
| Heart Failure | 16 (1.29%) |
| Severe Aortic Stenosis | 25 (2.01%) |
| Cardiac Arrest | 7 (0.56%) |
| Peripheral Interventions | 322 (25.72%) |

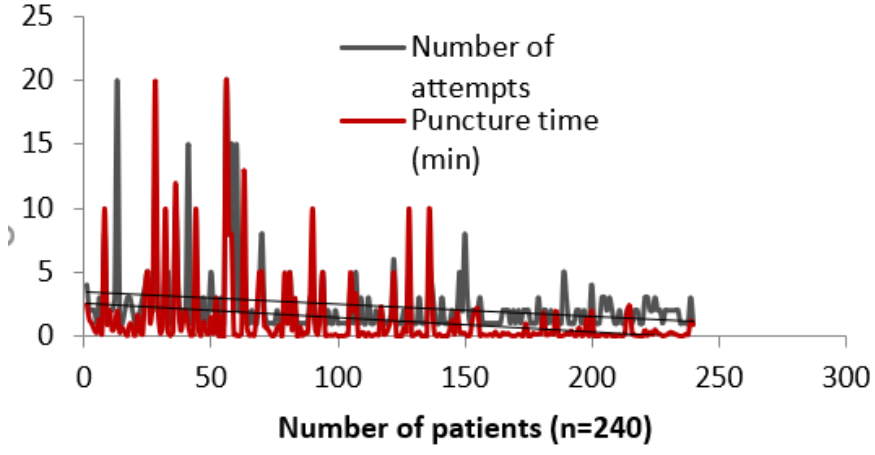
Most of the cases were performed through the right radial artery (n = 1108, 89.35%). SB was predominant (n = 1046, 84.35%). Access was obtained within 1.26 ± 1.1 min. The general procedural characteristics are summarized in Table 3. Moreover, two of the three main outcomes of our study interest can be yielded from this collection of data. The overall technical success rate, which was described as a successful DRA sheath insertion, was achieved in 1208 (97.4%) patients. It was slightly higher at the right DRA than the left DRA (97.65% vs. 96.51%, respectively, $p < 0.05$). Of note, among the total patients, only 32 cases (2.58%) required crossover to another access site. The most common crossover was from initial (failed) right DRA to left DRA. In 66 patients (5.32%), the preprocedural USG revealed the total occlusion of the artery. In this situation, as a first attempt, the contralateral artery had been punctured. These cases were not considered crossover situations because the initial access site defined by USG did not change. The overall femoral access of all patients during this period (not just those included in the registry) was 4.4%—this means that DRA has managed to perform in almost all types of interventions.

**Table 3**. Procedural data for DRA-related cases.

| Procedural characteristics | Values |
|---|---|
| Coronary angiography only | 272 (21.9%) |
| Coronary angiography and PCI | 966 (77.9%) |
| Right distal transradial access | 1108 (89.35%) |
| Right DRA success rate | 1082 (97.65%) |
| Left distal transradial access | 172 (13.87%) |
| Left DRA success rate | 166 (96.51%) |
| Number of puncture attempts | 2.28 ± 0.67 |
| Artery puncture time, min | 1.26 ± 1.1 |
| Tortuosity (loop) | 14 (5.9%) |
| Pain score (0-5) | 2.7 ± 0.8 |
| Sheath size (5F) | 852 (68.7%) |
| Sheath size (6F) | 269 (21.6%) |
| Sheath size (7F) | 11 (0.88%) |
| Sheath size (8.5F) | 4 (0.32%) |
| Procedural duration (min) | 42.12 ± 10.1 |
| Fluoroscopy time (min) | 14.6 ± 10.2 |
| Radiation dose (/mGy) | 733.99 ± 542.23 |
| **Postoperative complications** (total) | 13 (1.04%) |
| Major bleeding | 0 (0%) |
| Vasospasm | 6 (0.48%) |
| Hematomas | 4 (0.32 %) |
| Artery occlusion | 5(0.4%) |
| Hemostasis time (min) | 225 ± 10 |
| Repeat hemostasis | 3 (0.24%) |
| Radial patency at discharge | 4 (0.32%) |

Although DRA access is a variation of traditional radial artery (RA) access, it has a distinct learning curve, mainly because the final segment of the RA moves in different directions along the carpal bones. Different types of analyses have been performed in an attempt to study the impact of the learning curve among our operators. A longitudinal analysis is illustrated in Figure 4.

**Figure 4**. Learning curve impact on puncture time and number of attempts in 240 consecutive subjects, by 4 operators over a period of 3 months.



We also tested the impact of the learning curve on a DRA-naïve operator (fellow) and, after experiencing 15 cases, the efficacy rate was already comparable with our main, the most experienced operator (Table 4). Of course, only the puncture time was kept almost double, to the detriment of the trainee.

**Table 4.** The impact of the learning curve in a dRA-naïve operator.

| | **2019 (n= 550)** | **2020 (n= 448)** | **2021 (n=242 )** | **P value** |
|---|---|---|---|---|
| **Sheath Time** | | | | |
| Ultrasonography Time (sec) | 23.9 | 20.5 | 11.82[c] | **0.001** |
| Puncture Time (sec) | 158 | 162 | 138[c] | **0.001** |
| Number of attempts | 2.32 | 1.9 | 1.64[b] | **0.02** |
| Wall puncture Anterior Wall | 261 | 223 | 148[c] | **0.001** |
| Anterior & Posterior Wall | 202 | 214 | 92[c] | **0.001** |
| **Cannulation Time** (sec) | 16.65 | 15.3 | 15.9 | 0.14 |
| **Procedure time** (min) | 38.1 | 45.2 | 41.48 | 0.13 |

The access site complication rate was acceptably low: at the end of the procedure, in 13 patients, there was some unfavorable alteration of the puncture area. No major bleeding occurred. However, some minor complications such as vasospasm (in six patients) and local hematomas (in four patients) were found. Morphine was used in only three cases of significant arterial spasm (0.2%). The most important safety issue, the occlusion of the radial artery, was observed in five patients (only 0.4% of the entire study population). However, the dissection of the artery wall without a significant compromise of the anterograde flow was found in five patients (0.4%) during the postprocedural USG. At 1 day follow up, no ischemic or further bleeding complications were observed. No patient complained about local numbness or any minor/major dysfunction of the hand, albeit four more (asymptomatic) radial artery occlusions were detected (0.32%). It means that the overall radial artery occlusion rate remained favorably low at 0.72%.

**DRA vs PRA for CTO PCI procedures**

In the second section, we aimed to study dual-DRA for coronary chronic total occlusion recanalization. DRA was particularly studied in 337 consecutive patients (mean age 64.6 ± 9.92 years, 72.4% male) who underwent radial-only CTO PCI between May 2016 and October 2021 at the same two institutions. Of these, access was obtained using PRA in 257 and using DRA in 80 cases. Propensity score

matching was used to adjust for pre-specified baseline characteristics that were potentially confounding variables. When compared with DRA, the PRA group had a higher prevalence of smoking (53.8% vs. 25.7%, SMD = 0.643), family history of cardiovascular disease (35.0% vs. 15.2%, SMD = 0.553), and dyslipidemia (95.0% vs. 72.8%, SMD = 0.500). The prevalence of the other risk factors was similar. The complexity of the CTOs was slightly higher in the DRA group, being characterized by higher degrees of calcification and tortuosity of the target lesions (both SMD > 0.250), and a higher prevalence of bifurcation lesions (45.0% vs. 13.2%, SMD = 0.938) and blunt entry shape (67.5% vs. 47.1%, SMD = 0.409).

Intraprocedural characteristics are summarized in Table 5. In the unmatched cohort, the distribution of CTO was significantly different between both groups: anterograde dissection reentry was more frequent in the DRA group (27.8% vs. 3.89%, $p < 0.001$) whereas anterograde wire escalation, retrograde dissection reentry, and retrograde wire escalation were more frequent in the PRA group (all $p < 0.001$). Cases in the DRA group had higher use of intravascular ultrasound (IVUS, 16.2% vs. 7.39%, $p = 0.032$), greater use of guidewires (median 3.00 vs. 2.00, $p = 0.001$), and longer stents (median 56.5 mm vs. 40.0 mm, $p < 0.001$). Furthermore, contrast volumes (median 120 ml vs. 146 ml, $p = 0.045$) and dose area product (DAP) (median 928 mGy × cm2 vs. 1,300 mGy × cm2, $p < 0.001$) were lower in the DRA group. On the other hand, PRA was characterized by shorter procedure times (median 38.5 min vs. 55.0 min, $p < 0.001$) and fluoroscopy times (median 19.0 vs. 27.5 min, $p = 0.042$).

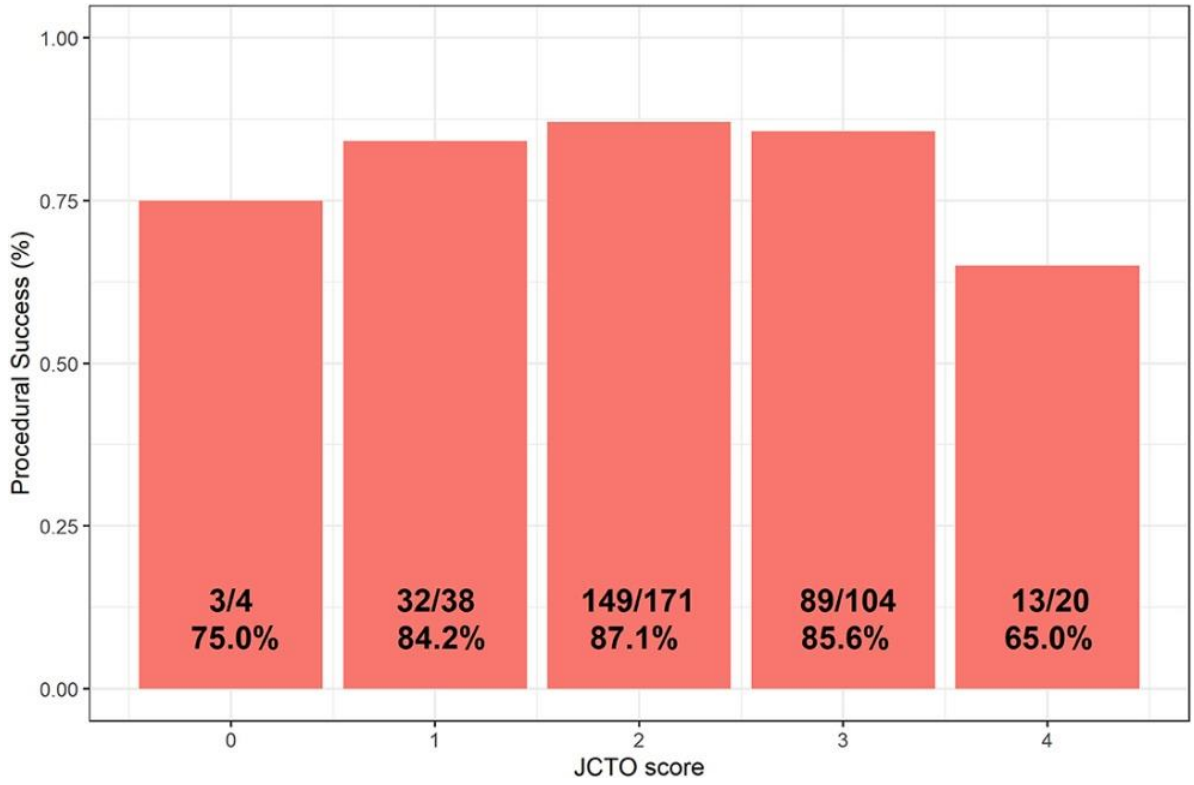
**Table 5**. Intraprocedural characteristics.

| | Before Matching | | | After Matching | | |
|---|---|---|---|---|---|---|
| **Variable** | **DRA (n=80)** | **PRA (n=257)** | **P-value** | **DRA (n=44)** | **PRA (n=44)** | **P-value** |
| CTO technique | | | <0.001 | | | 0.001 |
| Anterograde dissection reentry, n (%) | 22 (27.8%) | 10 (3.89%) | | 15 (34.9%) | 3 (6.82%) | |
| Anterograde wire escalation, n (%) | 55 (69.6%) | 218 (84.8%) | | 26 (60.5%) | 36 (81.8%) | |
| Retrograde dissection reentry, n (%) | 1 (1.27%) | 10 (3.89%) | | 1 (2.33%) | 0 (0.00%) | |
| Retrograde wire escalation, n (%) | 1 (1.27%) | 19 (7.39%) | | 1 (2.33%) | 5 (11.4%) | |
| Rotational atherectomy, n (%) | 9 (11.2%) | 23 (8.98%) | 0.701 | 3 (6.82%) | 5 (11.6%) | 0.484 |
| Dual access, n (%) | 46 (57.5%) | 130 (50.6%) | 0.340 | 26 (59.1%) | 25 (56.8%) | 1.000 |
| Antegrade approach used, n (%) | 78 (97.5%) | 252 (98.1%) | 0.672 | 42 (95.5%) | 44 (100%) | 0.494 |
| Retrograde approach used, n (%) | 6 (7.50%) | 13 (5.06%) | 0.410 | 6 (13.6%) | 2 (4.55%) | 0.266 |
| IVUS, n (%) | 13 (16.2%) | 19 (7.39%) | 0.032 | 7 (15.9%) | 2 (4.55%) | 0.157 |
| Number of guidewires | 3.00 (2.00;5.00) | 2.00 (1.00;4.00) | 0.001 | 3.00 (2.00;6.00) | 2.50 (1.75;3.00) | 0.003 |
| Number of balloons | 3.00 (2.00;4.00) | 3.00 (2.00;4.00) | 0.431 | 3.00 (2.00;4.25) | 3.00 (2.00;4.00) | 0.268 |
| Stent length, mm | 56.5 (37.5;82.0) | 40.0 (22.0;64.0) | <0.001 | 59.0 (41.5;79.8) | 46.0 (28.0;68.8) | 0.071 |
| Contrast volume, ml | 120 (90.0;190) | 146 (100;218) | 0.045 | 142 (100;205) | 157 (119;212) | 0.447 |
| Procedure time, min | 55.0 (33.8;87.0) | 38.5 (20.0;64.0) | <0.001 | 70.0 (40.0;104) | 27.5 (15.0;69.2) | <0.001 |
| DAP, mGy × cm² | 928 (400;1500) | 1300 (593;2787) | <0.001 | 1000 (445;1500) | 1515 (668;3097) | 0.018 |
| Fluoroscopy time, min | 27.5 (10.0;52.0) | 19.0 (10.0;31.0) | 0.042 | 34.5 (13.0;61.2) | 21.5 (14.8;32.8) | 0.064 |

CTO, chronic total obstruction; DRA, distal radial access; IVUS, intravascular ultrasound; PRA, proximal radial access; DAP, dose area product.

The overall complexity of the procedures remained varied across all patients, although most had a Japanese chronic total occlusion (JCTO) score ≤2 (n = 171). However, no clear correlation between JCTO score and procedural success could be established (Figure 5).

**Figure 5.** Distribution chart showing procedural CTO success as a function of JCTO score. CTO, chronic total obstruction.




Procedural and long-term outcomes are presented in Table 6. In the unmatched cohort, a shorter hospital length of stay (median 2.00 days vs. 3.00 days, p = 0.006) was observed in the DRA group. Furthermore, the 12-months rate of MACCE tended to be lower in the DRA group (10.0% vs. 20.2%, p = 0.055), although this did not reach statistical significance. Numerically, local vascular complications were more common in the PRA group, although these did not meet statistical significance (radial artery occlusion [RAO]: 2.72% vs. 1.25%, p = 0.450; large hematoma: 0.72% vs. 0%, p = 1.000). After matching, no differences were observed in any of the observed outcomes.

**Table 6.** Procedural and long-term outcomes between DRA and PRA in CTO PCI.

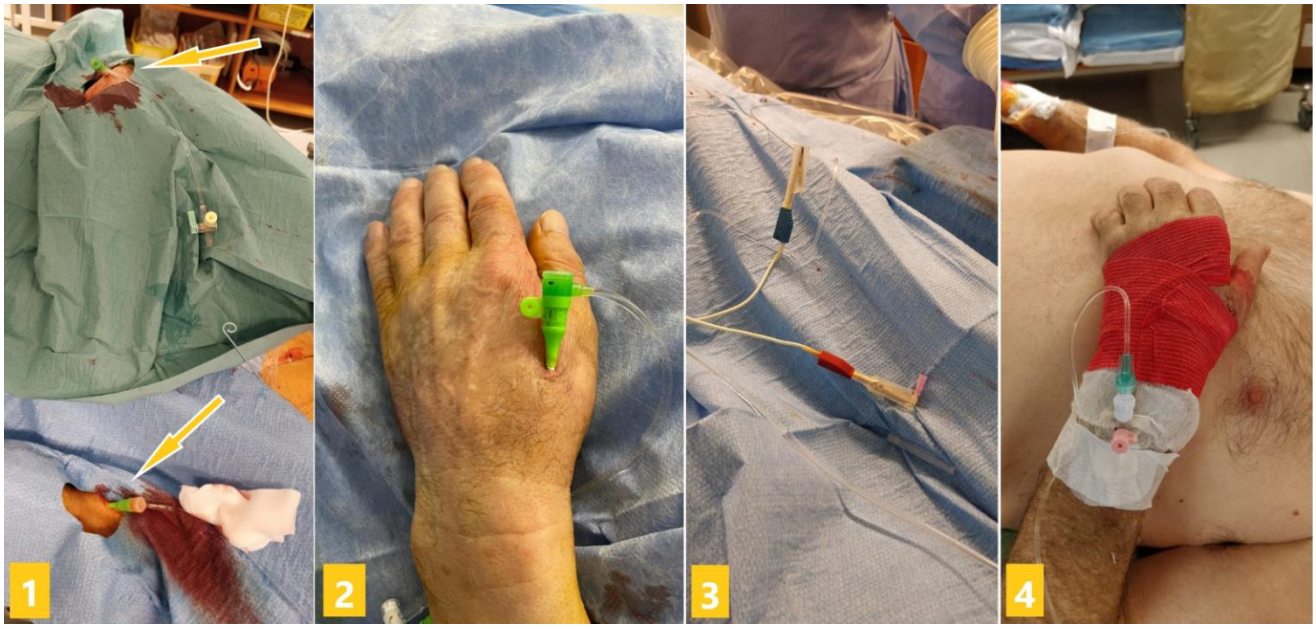
| | Before Matching | | | After Matching | | |
|---|---|---|---|---|---|---|
| **Variable** | **DRA (n=80)** | **PRA (n=257)** | **P-value** | **DRA (n=44)** | **PRA (n=44)** | **P-value** |
| **Procedural outcomes** | | | | | | |
| Access site complications | | | 0.820 | | | 1.000 |
| Large hematoma, n (%) | 0 (0.00%) | 2 (0.78%) | 1.000 | 0 (0.00%) | 0 (0.00%) | 1.000 |
| Small hematoma, n (%) | 2 (2.50%) | 4 (1.56%) | 0.577 | 2 (4.55%) | 1 (2.27%) | 0.557 |
| RAO, n (%) | 1 (1.25%) | 7 (2.72%) | 0.450 | 0 (0.00%) | 1 (2.27%) | 1.000 |
| Bleeding, n(%) | 0 (0.00%) | 0 (0.00%) | 1.000 | 0 (0.00%) | 0 (0.00%) | 1.000 |
| None, n (%) | 77 (96.2%) | 244 (94.9%) | 0.631 | 42 (95.5%) | 42 (95.5%) | 1.000 |
| Any complications*, n (%) | 7 (8.75%) | 10 (3.89%) | 0.138 | 3 (6.82%) | 3 (6.82%) | 1.000 |
| Procedural success, n (%) | 73 (91.2%) | 213 (82.9%) | 0.100 | 38 (86.4%) | 39 (88.6%) | 1.000 |
| Clinical success, n (%) | 70 (87.5%) | 167 (79.5%) | 0.161 | 37 (84.1%) | 32 (78.0%) | 0.664 |
| Hospital length of stay, days | 2.00 (2.00;3.00) | 3.00 (2.00;4.00) | 0.006 | 2.50 (2.00;3.25) | 3.00 (2.00;3.25) | 0.412 |
| **Long-term outcomes** | | | | | | |
| 30-day MACCE | 3 (3.75%) | 11 (4.28%) | 1.000 | 2 (4.55%) | 2 (4.55%) | 1.000 |
| 6-months MACCE | 7 (8.75%) | 31 (12.1%) | 0.538 | 4 (9.09%) | 4 (9.09%) | 1.000 |
| 12-months MACCE | 8 (10.0%) | 52 (20.2%) | 0.055 | 4 (9.09%) | 8 (18.2%) | 0.351 |
| 12-months redo PCI | 6 (7.50%) | 27 (10.5%) | 0.566 | 5 (11.4%) | 5 (11.4%) | 1.000 |
| 12-months target lesion revascularization | 3 (3.75%) | 12 (4.67%) | 1.000 | 1 (2.27%) | 4 (9.09%) | 0.360 |
| 12-months stent thrombosis | 1 (1.25%) | 1 (0.39%) | 0.419 | 1 (2.27%) | 0 (0.00%) | 1.000 |
| 12-months MI | 2 (2.50%) | 3 (1.17%) | 0.340 | 1 (2.27%) | 0 (0.00%) | 1.000 |
| 12-months TIA or stroke | 2 (2.50%) | 2 (0.78%) | 0.240 | 1 (2.27%) | 0 (0.00%) | 1.000 |
| 12-months death | 0 (0.00%) | 9 (3.50%) | 0.122 | 44 (100%) | 44 (100%) | 1.000 |

DRA, distal radial access; radial artery occlusion; MACE, major adverse cardiac events; MI, myocardial infarction; PCI, percutaneous coronary intervention; PRA, proximal radial access; TIA, transient ischemic attack.
* These included cardiac decompensation, coronary dissection, coronary perforation, and pericardial fluid/tamponade

**Distal radial balloon aortic valvuloplasty: the DR-BAV pilot study**

A particular interest of our study was to test the versatility of DRA with large bore catheters. This was a single-center experience involving 32 patients who underwent mini distal radial balloon aortic valvuloplasty (DR-BAV) from August 2020 to July 2021. We included 32 high-risk patients with severe symptomatic aortic stenosis in the study with a mean age of 80±8 years. Four main indications for BAV were included: 50% stratification (meaning BAV as emergency, with no prior Heart-Team decision for further TAVR/surgical aortic valve replacement), 31% bridge-to-TAVR, 6% bridge-to-SAVR and 12% palliative therapy. The technique is illustrated in Figure 6.

**Figure 6.** Intraprocedural illustrations: (1) dual 6F distal radial access (arrows), (2) right radial exchange with 7F sheath (3) rapid pacing with negative lead (blue) attached to the stiff wire, positive lead (red) attached to a needle which is inserted subcutaneously in the leg, (4) bandage compression with elastic band, the thumb is left free.




Technical success was achieved in all patients (100%). Hemodynamic success was achieved in 30 patients (93.75%). Invasive max and mean gradients were reduced from 73±22 mm Hg and 49±22 mm Hg to 49±19 mm Hg and 20±13 mm Hg, respectively (p = <.001), with a mean pre-procedural LV ejection fraction of 50.22% (the majority of patients suffered from normal-flow, high-gradient AS). Clinical success was achieved in 29 patients (90.6%). Nineteen (59%) and 26 (81%) patients were mobilized within 12 and 24 hours, respectively. The mean fluoroscopy and procedural times were 9.10±6.9 minutes and 47±20 minutes, respectively.

The maximum sheath sizes inserted in the distal and proximal radial segments were 9F and 10F, respectively. Due to the large aortic annulus, two cases required dual radial access with simultaneous double-balloon valvuloplasty. The technical success rate was 100% (the crossover rate to the femoral artery was zero), and the clinical success rate (measured by a decrease of one NYHA class) was 90%.

No intraprocedural or periprocedural deaths occurred. Neither major intra- or periprocedural complications (balloon entrapment or compartment syndrome requiring surgical intervention) nor Valve Academic Research Consortium (VARC)-2 bleeding complications occurred in the study population. Only minor VARC-2 bleeding was reported (3 local hematomas not requiring surgery). At the 30-day echocardiographic follow-up, the radial artery was patent in 94% of the patients, and no patient showed symptoms related to radial artery occlusion. No patient developed acute severe aortic regurgitation, required definitive pacemaker implantation after the procedure, or had a procedure-related stroke. The

cumulative incidence rates of major adverse events at the 1- and 6-month follow-ups were 3.12% and 15.62%, respectively. The cumulative incidence rates of death at the 3- and 6-month follow-ups were 12.5% and 21.87%, respectively. Long-term mortality is still high due to comorbidities and associated diseases. Of note, half of our patients underwent "emergency" BAV as primary indication – a relevant aspect to put the mortality data into context.

**Transcatether aortic valve implantation: DRA as secondary access**

Another important structural intervention where DRA may play a role is TAVI. Clinical and angiographic data from 41 consecutive patients with severe, symptomatic aortic stenosis (AoS) were evaluated in a retrospective single-center study (Department of Internal Medicine, Division of Invasive Cardiology, Szeged, Hungary). Between November 2020 and April 2021 the patients were treated using dual arterial access, one distal-radial and one large bore femoral. Distal radial access was obtained using a 5 or 6 French sheath.

The main baseline clinical and procedural characteristics of the global population and according to the secondary approach (transfemoral versus transradial) are shown in Table 7.

**Table 7.** Demographic and clinical data of the 41 TAVI patients.

| | | n (%) |
|---|---|---|
| **Demographic data** | Age (years) | 76.0 ± 11.2 |
| | Male | 17 (41) |
| | Hypertension | 34 (82.9) |
| | Current smokers | 11 (26.8) |
| | Diabetes mellitus | 15 (36.5) |
| | IDDM | 4 (9.7) |
| | NIDDM | 11 (26.8) |
| | Weight (kg) | 79.4±16.7 |
| | Height (cm) | 167.1±9.9 |
| | COPD | 9 (21.9) |
| | Renal insufficiency | 15 (36.5) |
| | Family history | 9 (21.9) |
| | Dyslipidemia | 26 (63.4) |
| | Atrial Fibrilation | 17 (41.4) |
| **Cardiac and Vascular History** | Coronary artery disease | 13 (31.7) |
| | Peripheral artery disease | 7 (17.07) |
| | Previous PCI or coronary bypass | 10 (24.3) |
| | Previous valve surgery | 3 (7.31) |
| | Symptoms | |
| | - Angina | 34 (82.9) |
| | - Dyspnoea | 41 (100) |
| | - Syncope | 2 (4.87) |

IDDM, insulin-dependent diabetes mellitus; NIDDM, noninsulin-dependent diabetes mellitus; COPD, chronic obstructive pulmonary disease;

TAVI was successful in all cases. Procedural details are highlighted in Table 8. Technical success was achieved in all patients (100%). Clinical success was achieved in 40 patients (97,5%). Hemodynamic success was achieved in all patients (100%). By hemodynamic investigation, the peak-to-peak mean gradient decreased from 76.8 ± 27.2 to 10.7 ± 5.1 mmHg (p=0.001). Balloon postdilatation was performed in 19 cases (46.3%), and the crossover to urgent surgical aortic valve implantation was 0%. Secondary access was achieved through the left DRA only (100%) and the crossover rate to the femoral access site was achieved in 3 cases (7.31%) of major primary femoral access perforation. Temporary pacing was performed either through the jugular vein (n=19, 46.3%) or femoral vein (n=10, 24.3%) or directly on the TAVI stiff wire (n=12, 29.2%). The fluoroscopy time, X-ray dose, procedure time, and contrast consumption were 18.20 ± 7.6 min, 529.8 ± 484.6 mGy, 50.3 ± 28.1 min, and 64.9 ± 28.1 ml, respectively. Mean hospitalization duration over the cohort was 4 ± 2.5 days. Ultrasonography parameters before and after the procedure are summarized in Table 8.

**Table 8**. Procedural results

| | **Pre-interventional** | **Post-interventional** |
|---|---|---|
| **Clinical status (dyspnoe)** | | |
| NYHA 1 | 0 | 1 |
| NYHA 2 | 1 | 30 |
| NYHA 3 | 30 | 10 |
| NYHA 4 | 9 | 0 |
| **Vascular ultrasound (radial site)** | | |
| - Radial artery (mm) | 1.8±0.5 | 1.8±0.5 |
| - Hematoma (EASY 1-2) | 0 | 1 |
| - Hematoma (EASY 3-4) | 0 | 0 |
| - Radial artery occlusion | 0 | 0 |
| - Pseudoaneurysm | 0 | 0 |
| **Transthoracal ultrasound** | | |
| **LVEF** | | |
| - 50-70% | 34 (82.92) | 37 (90.24) |
| - 30-50% | 6 (14.63) | 4 (9.75) |
| - <30% | 1(2.43) | 0 (0) |
| **Aortic gradient (peak)** | 76.8 ± 27.2 | 10.7 ± 5.1 |
| **Aortic gradient (mean)** | 50.9±18.7 | 12.6 ± 9.3 |
| **AVA (mm2)** | 0,67 ± 0.13 | 2.4 ± 0.27 |
| **Aortic regurgitation** | | |
| - 0-2 | 24 (58.5) | 10 (24.39) |
| - 3-4 | 0 (0) | 0(0) |

LVEF, left ventricular ejection fraction; AVA, aortic valve area;

No complications occurred due to transradial access. Transfemoral vascular access site complications occurred in 7 cases (17.07%): 1 occlusion, 2 flow-limiting stenoses and 4 perforations of the common femoral artery. Three complications were successfully managed using balloon dilatation and balloon tamponade from the transradial access (Figure 3). The cases of major perforation (9.75%) were successfully treated with a covered stent delivered via direct ipsilateral superficial femoral retrograde 6F access and stent delivery with angiographic control from dRA (Figure 4). There were no additional major vascular complications at 30 days. Five cases of PCI (12.19%) and one case of left subclavian artery PTA (2.43%) were successfully performed through dRA, in the same session. Hemostasis of the primary transfemoral access was achieved percutaneously (vs surgical cut-down) in all patients, using two ProGlide devices (Abbott Vascular, Santa Clara, California) in 31.82% and one ProGlide plus one Angioseal 8F device (Terumo Medical Corporation, Somerset, NJ, USA) in 68.18% of the cohort. Sheath size for secondary access in the transradial group was 5 French (F), 6 F, and 7 F in 20(48.7%), 19 (46.3%) and 2 (4.87%) patients, respectively. Hemostasis of the radial access was achieved via compression in all cases, using a combination of one StatSeal Disc (Biolife, LLC, USA) with gauze compression. Standard hemostasis time was 3 hours. The need of repeating the hemostasis was not needed in any cases. Data regarding radial occlusion were collected 24 h after puncture and Doppler ultrasound revealed no artery occlusion. All-cause 30-day mortality was 2.4% %, one patient suffered esophageal and tracheal bleeding after extubation with hemorrhagic shock (autopsy report revealed bleeding from the esophageal vein). No stroke or myocardial infarction was observed.

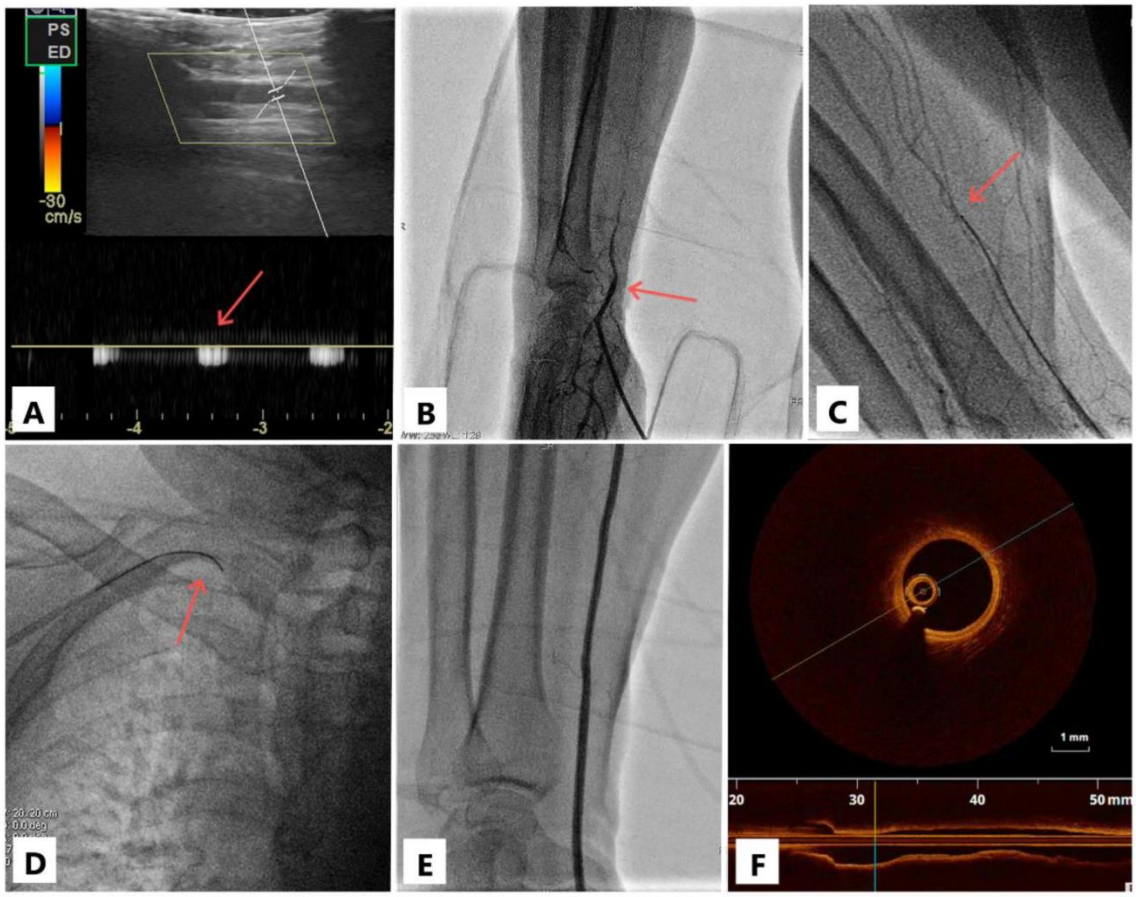
**DRA for chronic RAO recanalization: a pilot study**

In the last study, a special role for DRA was investigated: the antegrade puncture and radial angioplasty for the proximal chronic RAO via DRA. This was a proof-of-concept study. From July 2016 to March 2022, we prospectively enrolled 30 consecutive patients with RAO, the majority who presented in our catheterization laboratory for suspected or known coronary artery disease and who received DRA. Before the main procedure, they received radial percutaneous balloon angioplasty after wiring the chronic RAO from the DRA site.

The technique is briefly described (Figure 7). On a 21-gauge needle, the intraluminal access was confirmed by the ultrasound probe and not by the palpation of the pulse. Directly through the needle, the contrast was injected to visualize the occlusion. If partial advancement of the standard puncture guidewire (0.018″) was possible (for more proximal occlusions), the 5- or 6-French sheath could be partially inserted, and angiography was performed through it. On a case-by-case basis, the wiring was then

continued either via the 21-gauge needle or via the introducer needle inserted into the sheath valve. Under fluoroscopy, dedicated polymer-jacket hydrophilic chronic total occlusion (CTO) coronary or peripheral guidewires of 0.014″ or 0.018″ (Gladius 0.014, Gladius 0.018, [Asahi Intecc, Nagoya, Japan] Pilot 50 0.014 or Progress 40 0.014 [Abbott Vascular Inc., Temecula, CA, USA]) were advanced through the occlusion, either by intraluminal tracking (true lumen, through CTO microchannels) or by subintimal tracking and reentry, which can be easily performed with the Gladius knuckle. Of the two options above, the most favorable was chosen on an ad hoc basis depending on the level of occlusion and the possibility to advance the guidewire because the sheath provides support. In our experience, the safest wiring option would be directly through the needle with hydrophilic guidewires with a heavier tip-load—a good and fast success rate has been observed with these guidewires. Some puncture needles come with a plastic cannula that can be secured to the skin with sterile tape. Subsequently, a Y-connector can be attached directly to the cannula and the guidewire advanced through the respective tube. When the tip of the wire freely entered the brachial artery, a sheathless catheter was advanced over the wire through the occlusion by a push-and-rotate maneuver (similar to ″dotterization″). If we had encountered resistance, we would have added the sheath for support, but sheathless catheters were always preferred. The 0.018″ wire provides more support, and the balloon-assisted tracking technique may be useful when negotiating the sheathless catheter over the 0.014″ guidewire which offers less support. Subsequently, the coronary procedure was performed.

**Figure 7**. Case illustration. Doppler sign in the distal radial artery (panel (A), arrow); visualization of the radial artery occlusion (panel (B), arrow); the occlusion passage with a 0.018″ guidewire (panel (C), arrow) on which the sheathless catheter is then advanced (panel (D), arrow); after coronary angioplasty, the radial artery is visualized both with contrast (panel (E)) and by optical coherence tomography (panel (F)); note the three-layered structure of the arterial wall (intima, media, adventitia) suggestive of a normal morphology.




Three types of endpoints were defined: the feasibility endpoint (flow restoration from the brachial artery all along the radial artery until the two palmar arches), the efficacy endpoint (patency of the artery at 30 days, verified by ultrasound Doppler), and the safety endpoint (the absence of intra- or periprocedural major hematomas, digital ischemia, thrombus migration to brachial/ulnar artery, and compartment syndrome, and the absence of MACE).

The mean age of the patients was 63 ± 11 years, and 15 patients (50%) were men. Almost the entire cohort was known to have coronary artery disease (n = 27, 90%). Among the study population, 21 patients (70%) received right DRA, and the most common indication for the procedure was percutaneous coronary intervention (PCI) (19, 63.2%). Most patients had asymptomatic RAO (n = 28, 93.3%); only two (6.6%) reported numbness in their hand.

The procedural characteristics and success rate of DRA RAO recanalization are listed in Table 9. Procedural success through retrograde wiring was 100% (n = 30), and all cases (n = 30, 100%) were performed by the "dottering" technique with the sheathless system. Moreover, there were no major vascular complications (0%); only two EASY 1–2 hematomas were described (10%), and one had an angiographically visible perforation (3%). The remaining dissections were several (n = 16, 53%) but were not flow-limiting. All patients had a good flow at the end of the procedure when a final upper limb angiography was performed by continuous injection while withdrawing the catheter. One case of periprocedural stroke was reported (3%) with onset immediately after the procedure (after sheath removal) and recovering 24 h later. As for efficacy endpoint, 27 of the radial arteries (90%) remained patent at the one-month follow-up.

**Table 9**. Procedural results and outcomes. Vascular major complication was defined as hematoma EASY 3–4, digital ischemia, thrombus migration to brachial/ulnar artery, and compartment syndrome.

| | **Pre-interventional n (%)** | **Post-interventional n (%)** | |
|---|---|---|---|
| Symptoms | | | *p-value* |
| Pain | 0 | 0 | *1.0* |
| Numbness | 2 (6.6) | 0 | *0.12* |
| Weakness | 0 | 0 | *1.0* |
| Asymptomatic RAO | 28 (93.3) | 28 (93.3) | *1.0* |
| **Vascular ultrasound (radial site)** | | | |
| Radial artery (mm) | 2.1±0.5 | 2.1±0.5 | *1.0* |
| Hematoma (EASY 1-2) | 0 | 3 (10) | *0.92* |
| Hematoma (EASY 3-4) | 0 | 0 | *1.0* |
| Radial artery occlusion | 30 (100) | 0 | *0.001* |
| Pseudoaneurysm | 0 | 0 | *1.0* |
| **Wire used** | | | |
| 0.014" hydrophilic | | 14 (46.6) | |
| 0.018" hydrophilic | | 16 (53.3) | |
| **PTA result** | | | |
| Good final flow | | 30 (100) | |
| Dissection | | 16 (53.3) | |
| Perforation | | 1 (3.3) | |
| Thrombus migration | | 0 (0) | |
| **Occlusion** | | | |
| Length (mm) | | | |
| Calcific vessel | | | |
| CTO | 50 ± 60 | | |
| **Endpoints** | 9 (30) | | |
| Procedural success | 30 (100) | | 30 (100) |
| Vascular major complications* | | | 0 (0) |
| MACCE | | | 1 (3.3) |
| 1-month follow-up | | | |
| Re-occlusion | | | 3 (10) |

All occlusions were chronic (n = 30, 100%), most being recanalized using 0.018″ hydrophilic guidewires (53%). Approximately one-quarter of recanalization cases (23%) required the use of more than one type of guidewire, and the most commonly used guidewire was Gladius (Asahi Intecc, Nagoya, Japan) (either 0.018″ or 0.014″) in 63% of cases. None of the cases required the administration of a local thrombolytic agent or mechanical thrombaspiration. The mean amount of contrast material used was 140 ± 28 mL, and the mean procedure time was 41 ± 22 min; these measurements incorporated the entire intervention.

## DISCUSSION

DRA feasibility is supported by an overall high rate of success in all reported studies. Our review of the literature found a cannulation success rate using DRA between 76.3% and 100% (28-31). Moreover, no major safety issue has been reported so far among published registries, pointing out a very low incidence of radial artery spasm, shorter time to hemostasis, and a substantial absence of forearm RAO despite no mention of any dedicated strategy to favor vessel patency. In our large registry, the mean time to achieve DRA was also comparable to that of conventional TRA (18). Access site crossover was performed in 2.58% of the patients, mainly via the contralateral DRA. Distal and proximal radial artery pulses were palpable in 99.68% of all patients at hospital discharge. The rate of minor vascular complications was low (1.5%) (18); minor vascular complications were considered prolonged postprocedural hand numbness or pain, limited forearm hematomas (classification EASY I-II) or postprocedural bleeding that as not actionable and did not case the patient to seek unscheduled performance of tests, hospitalization, or treatment by a health care professional.

Ultrasound guidance can increase the success of DRA, either if implemented systematically or as a rescue after failure of tactile-guided approach. In the only study comparing both approaches, ultrasound guidance shifted DRA success from 87% to 97% (32). The main advantages of ultrasound guidance are accurate identification of the puncture site and careful assessment of the size and curvilinear course of the distal radial artery. An in-depth guide to ultrasound guidance in DRA has been recently published, providing valuable technical advice (33). Interestingly, ultrasound examination during DRA would have another advantage besides guidance, because the detection of calcifications in the radial artery wall was correlated with that in the coronary wall (34); arterial media calcification is mostly found in patients with high smoking index, chronic renal failure, and diabetes mellitus and its presence is associated with higher mortality rates (34,35). All catheters commonly used for the proximal radial access can be used for

coronary diagnosis and intervention. For patients taller than 185 cm, the usual catheter length of 100 cm may not be sufficient. It is recommended to use diagnostic and guide catheters with a length of 110 cm in such patients. Patients with a height of more than 200 cm over DRA can also be examined successfully. The distal radial artery, cephalic vein, and superficial branches of the radial nerve are all contained within the snuffbox.

In addition to the usual coronary interventions, the role of DRA has proved to be even more important during chronic total occlusion (CTO) recanalization. In these arduous procedures, dual arterial access is required in most instances. While conventional TRA access is possible, the patient's position quickly becomes uncomfortable due to forced supination of the hand. Moreover, the operator must bend over the patient's abdomen. For this reason, most CTO operators prefer radial-femoral right ipsilateral arterial access. This issue could be solved by adopting dual DRA, which would bring the left hand close to the right and provide increased comfort for both the operator and the patient. This attractive theory has been described in two recent studies, one of which was from our institution (36,37). Moreover, our comparative study also measured the radiation dose across two groups and not surprisingly, the dose area product received was lower in the DRA group compared to the traditional TRA (36).

Another concern was the performance of DRA in acute coronary syndromes (ACS), where time-to-access is paramount; the higher procedural time and crossover rate with DRA raise some concerns, hampering prompt reperfusion, and potentially affecting clinical outcomes. Therefore, upfront selection of the access site should balance the benefit coming from forearm RAO avoidance with the operator's proficiency to successfully perform diagnostic procedures and percutaneous coronary interventions (PCI) with that access site. This concern, however, was more theoretical because the 2017 ESC guidelines declared TRA as the first choice for coronary angiography or PCI in patients with STEMI, reflecting the maturity of this vascular access (10). A similar situation happens with DRA which has comparable access times. Sgueglia et al. studied 176 patients with ACS (DRA 88 and TRA 88). The results showed that dTRA and TRA have similar puncture success rates (97% vs 99%), operation times, fluoroscopy times, and surgery success rates, and the incidences of RAO by DRA were significantly lower than TRA (1% vs 4.5%) (38). Soydan and Akın compared 30 patients with acute STEMI undergoing DRA and 61 patients undergoing transfemoral (TF) PCI. The success rate of PCI in both groups was very high (90% vs 91.8%, $p = 0.795$), and the puncture time of the two groups was similar (28.63 s vs 28.93 s, $p = 0.767$). However, patients in the DRA group had shorter fluoroscopy times, total radiation doses, and hospitalization days, and patients in the TF group had a higher mortality rate during hospitalization (0% in the dTRA group and 18% in the TF group, $p = 0.013$) (39). Cao et al.'s review showed that the puncture time for coronary angiography or PCI using the DRA path for ACS is 28.63 s to $162 \pm 96$ s (40). As a perspective, the option of using large bore catheters in complex high-risk coronary cases remains open and must be tested

with DRA; for example, a 2.0 mm rotablation burr requires an 8-French catheter and not all arterial lumens support such a size. In this case, the role of ultrasound becomes relevant again by means of preoperative assessment of arterial diameter because the incidence of RAO is directly related to the ratio between the sheath and artery size (41).

As the experience with such approach increases, other potential fields of application are rising, including patients with occluded radial artery, carotid, femoral, and in general endovascular extracardiac interventions. Practically, DRA can take the role of access to any intervention and extracardiac procedures that are classically performed by femoral approach, such as carotid or limb ischemia (42,43). For example, a hybrid approach has been proposed for superficial femoral artery interventions, utilizing the radial and the pedal access (42). Interventional oncologists are beginning to use this access for embolization of pathologies of the pelvic organs (44). The neuroradiology field has also adopted this approach (45). A special role is played by the recanalization of the radial forearm artery (post-PCI RAO) and the continuation of the coronary procedure through the same ipsilateral approach. DRA can therefore reopen the jeopardized radial artery.

Perhaps most impressive, DRA has proven its versatility in structural interventions where the insertion of large sheaths (7–8F) has led to very low rates of cross-over or RAO, with high procedural and clinical success. Indeed, hardware originally made for large-bore accesses is now accessible for the radial approach as well, and the newer balloons for BAV are flexible and feasible via DRA. An additional advantage offered by DRA in BAV procedures is the maintenance of the radial artery patent, compared to the increased rate of postprocedural RAO by classical TRA approach, in the context of endothelial injury and immediate thrombosis secondary to large sheaths (46). Another useful role of the DRA is as a secondary access in transcatheter aortic valve implantations, where the left hand can be brought close to the primary, large-bore access, thus optimizing the workspace and avoiding the puncture of both femoral arteries (47).

The learning curve with distal radial access is navigable, but there are nuances to the technique that should be appreciated in the interest of patients' safety. At least 100 cases are needed to consistently maintain a high success rate of >96% (18).This is of particular importance if the aim is to push DRA in more difficult scenarios such as STEMI cases or Complex High-Risk Indicated Procedure/Patients. Marked improvement can be felt within the 50 cases, which is encouraging for a novice operator (48,49). Being more distal, the artery is slightly smaller in diameter (−0.2 to 0.3 mm) but the difference showed no impact on 6–7-French sheaths (50,51). However, as mentioned above, it may make the technique a little harder to master, along with its angled trajectory throughout the carpal bones. A 6-French sheath has an outer diameter of approximately 2.4–2.6 mm while the mean distal radial artery diameter is around the same (smaller in women), meaning that in most cases, the sheath occupies the whole arterial lumen.

Although this theoretically raises concern about flow-mediated dilatation and long-lasting functional impairment at the access site,(52) it has been shown that DRA, in fact, is associated with significantly less influenced vasomotor functions the day after the procedure, compared to the conventional TRA (53,54). Moreover, the recent RATATOUILLE study showed that DRA was not associated with hand function impairment at 1-year follow-up (55). As with permanent occlusion, there is no real clinical effect, forearm vascularization being quickly compensated by the rich collaterals of the ulnar and interosseous artery; rarely the patient complains of pain or numbness after RAO (56,57).

Default DRA can be accessed by palpation alone in most cases with some practice, and this can be improved further with ultrasound guidance. There is a subset of patients, especially in the elderly, where DRA access can be particularly challenging. The anatomical positioning of the distal radial segment varies more than the proximal segment, which is always rectilinear. Here the use of imaging would bring some benefits. While the use of ultrasound is standard of care for many transvascular interventions, its use in DRA remains at the discretion of the operator and the center's expertise, although there are signals for a higher patient satisfaction and success rate (multiple through-and-through attempts and inadvertent needle injury of underlying periosteum causes severe pain and predisposes to arterial spasm) (58). The same RATATOUILLE study used ultrasound-guided DRA for approximatively 85% of participants which highlights the effectiveness of US use in both DRA and TRA (55). In relation to hemostasis, DRA showed significantly shorter times (59). The same study showed a very low complication rate in the DRA group (partial occlusions 1.0% and arteriovenous fistula 0.5%), consistent with other reports that followed (60-62).

Of all, perhaps the most important is the low occlusion rate, which anyway, in case of occlusion, it was proven that it remains localized at that level, the flow through the superficial palmar arch remaining preserved and the distal radial artery patent (59). This has been confirmed by various recent meta-analyses.32–34 Moreover, the shorter compression time was clear amongst all three studies and no differences in the risk of developing hematomas or spasm at the access site were observed when comparing with conventional TRA (63-65). Recently, different methods shown to minimize the risk for RAO were reviewed in an international consensus document that supports their systematic implementation in everyday interventional practice and DRA has been proposed as a potential approach for RAO avoidance given its anatomic basis and physiological rationale (66). This fact becomes even more relevant after the publication of two recent studies which showed that RAO is not influenced either by the low dose of rivaroxaban (10 mg) administered short-term after the procedure nor by the systematic administration of nitroglycerin at the beginning and end of the procedure (67,68). Of note, in an experimental study involving healthy subjects, simulated occlusion of the distal radial artery in the anatomic snuffbox did not cause significant flow reduction in the forearm radial artery compared with

simulated occlusion of the radial artery at the wrist (69). This detail explains the asymptomatic occlusion and emphasizes more the importance of preserving the artery as a medical investment rather than having an immediate clinical impact.

**Table 10**. Baseline characteristics of the main randomized clinical trials comparing distal radial access with proximal radial access.

| Trial | Registration | Year (completed) | Country | N | Endpoint | Follow-up |
|---|---|---|---|---|---|---|
| Mokbel et al. | - | 2018 | Romania | 114 | RAO | In-hospital |
| Koutouzis et al. | - | 2019 | Greece | 200 | Cross-over rate | Not prespecified |
| Vefali et al. | - | 2020 | Turkey | 205 | Not prespecified | Not prespecified |
| DAPRAO | NCT04238026 | 2021 | Mexico | 282 | RAO | 1 month |
| ANGIE | NCT03986151 | 2021 | Greece | 1042 | RAO | 2 months |
| CORRECT | NCT04194606 | ongoing | Germany | 500 | RAO | 1 month |
| DISCO Radial | NCT04171570 | 2022 | Europe | 1330 | RAO | In-hospital |
| DIPRA | NCT04318990 | ongoing | USA | 300 | Motor hand function | 1 month |
| DRAMI | NCT03611725 | ongoing | South Korea | 352 | Puncture success in STEMI | - |
| TENDERA | NCT04211584 | ongoing | Russia | 1500 | RAO | 1 year |
| DC Radial | NCT04784078 | ongoing | China | 938 | RAO | In-hospital |
| RESERVE | NCT04861389 | ongoing | China | 414 | RAO | In-hospital |
| TunDRA | NCT05311111 | ongoing | Tunisia | 250 | Puncture success | - |

To promote a homogenous diffusion of DRA and allow meaningful comparisons between conventional TRA and DRA, several randomized trials have been completed or are still ongoing (Table 10). One of the largest of all, the DISCO Radial trial (70) recently announced its results regarding RAO: the rates were strikingly low, and similar between TRA and DRA groups (0.91% vs 0.31%; $p = 0.29$); moreover, there were no differences in bleeding and vascular complications across the two groups (bleeding 5.5% vs 6.8%; $p = 0.33$; vascular complications 1.2% vs 1.1%; $p = 0.81$). These findings resulted from the implementation of a rigorous hemostasis protocol following current best practice recommendations (70). The fact that RAO rates after DRA remain low even when compared to the best practice TRA protocols is noteworthy. As per other complications, it is worthy to mention that bleeding or vascular complications were comparable between conventional TRA and DRA (5.5% vs 6.8%; $p = 0.33$; 1.2% vs 1.1%; $p = 0.81$ respectively) (70). Crossover rates (7.4%) were still much lower than in DAPRAO , where crossover to TRA was 13.3% (16), and ANGIE, where it was as high as 22.3% (62). This speaks about the importance of the learning curve and the expertise of the operator (which was substantial in the DISCO Radial), but also shows one of the limitations of adopting DRA in regular

clinical practice where variously skilled operators intersect. Post-DRA care is shorter and more practical for both the patient and the nursing staff. Moreover, from the patient's perspective, leaving hospital earlier and without a bruise represents a significant benefit. DRA appears to combine the advantages of conventional TRA with additional benefits to patients. On a closer look, the DAPRAO trial also used patent hemostasis and prevention strategies in both groups (pneumatic band, gradual deflation, slender sheaths, arterial cocktail with heparin, nitroglycerine, verapamil) and still, the RAO rates were lower in patients receiving DRA; but this was a relatively small, single center study with first- and second-year fellows performing the access, therefore its external validity should be perceived as limited (16). The incidence of other complications (bleeding, arterial spasm, access time) remained consistently similar in both groups. Other randomized clinical trials comparing DRA with conventional TRA are expected to definitively establish its role in interventional cardiology and radiology. Nonetheless, available data highlight that DRA may allow the very same procedures as conventional TRA, including intervention for left main coronary artery and complex bifurcation lesion; intravascular imaging; calcium debulking devices; chronic total occlusion intervention; peripheral intervention for the carotid, lower extremity, and radial artery itself; and even balloon aortic valvuloplasty (BAV) (71-73).

In summary, transcatheter interventions are becoming increasingly complex, and the chronic nature of coronary artery disease forces patients to undergo repeated interventions throughout their lives. In this context, vascular access becomes as important as the intervention itself, and special attention must be paid to this part of the procedure and its education among the operators. Of course, RAO prevention remains desirable. Patent hemostasis should be universally indicated, and ultimately, radial artery recanalization via DRA may reopen "closed doors" for selected patients. While head-to-head comparisons between PRA and DRA have been started (as shown in Table 10), we believe randomized, controlled trials directly comparing DRA to PRA are not sine qua non with regard to juxtaposition between the two sites as one does not substitute the other. DRA represents an evolution and a complement of the developing nature of transradial access and nuances such as preservation of the common radial artery, easier hemostasis, and ergonomics play a role when choosing a specific entry site.

There are several limitations of our study that are worthy of mentioning. First, the retrospective nature of our study is subject to confounding; nevertheless, all included patients were consecutive patients and propensity score matching was performed to balance any clinically meaningful confounders between the two groups. Second, a specific protocol for ultrasound-guided puncture and transradial band air removal to target faster hemostasis was introduced for all DRA cases, while this protocol was not employed for conventional PRA. The potential impact of this protocol can thus not entirely be separated from the observed effect of the approach (DRA vs. PRA). Third, the data were only analyzed based on intention-to-treat whilst the rate of DRA failure and crossover percentage were not registered. We know

that the lumen of the radial artery is slightly smaller at the anatomical snuffbox and that inserting a sheath can be more challenging, especially in women (74-76). Therefore, beyond patient discomfort and increased radiation exposure, transradial access crossover may entail delayed revascularization and worse outcomes compared with successful radial access in acute coronary syndrome patients and abolishes the bleeding benefit offered by radial access over femoral access. However, in the setting of stable patients and achieved learning curve, this clinical impact should be almost completely diminished.

## CONCLUSION

DRA is a safe and feasible vascular access, with great versatility among different transcatheter procedures. Reduction in the number of early and late radial artery occlusions, nerve damage, local hematoma, and major bleeding are distinct advantages of the DRA over the PRA. Mastering the technique expands the access options for operators and increases patient comfort. In our study, we found no evidence of increased risk of periprocedural or long-term adverse outcomes for DRA across all types of interventions. Furthermore, we demonstrated the personalized role of Doppler ultrasound in guiding DRA and showed different types of learning curve patterns. Even in the hands of an experienced interventional cardiologist, questions remain regarding its routine use, especially in patients with acute coronary syndrome when it is necessary to minimize the time of puncture and catheterization of the access artery. Randomized studies would elucidate the impact of DRA on hard clinical endpoints such as severe bleeding or mortality.

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## ABBREVIATIONS

TRA transradial access
DRA distal radial access
PRA proximal radial access
RA radial artery
USG ultrasonography
IV intravenous
NTG nitroglycerine
RAO radial artery occlusion
PCI percutaneous coronary intervention
CTO chronic total occlusion
BAV balloon aortic valvuloplasty
TAVI transcatheter aortic valve implantation
MACE major adverse cardiac events
MI myocardial infarction
TIA transient ischemic attack
TLR target lesion revascularization
CABG coronary artery bypass graft

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