BMC Cardiovascular Disorders

RESEARCH Open Access

The important role of preoperative ultrasound in the efficacy and safety of coronary intervention via distal transradial access

Tao Chen[1†], Lamei Li[2†], Anni Yang[2†], Xinyu Fan[2], Ganwei Shi[2], Feng Li[2] and Gaojun Cai[2*]

Abstract

Background The optimal inner diameter for enhancing the success rate of distal radial artery (DRA) puncture has not been documented. The aim of this study was to explore the appropriate inner diameter of DRA to increase the success rate of puncture and reduce vascular complications.

Methods This is a retrospective study. A receiver operating characteristic (ROC) curve was plotted to predict the DRA inner diameter for puncture success. The operative efficacy and safety were compared between groups with different DRA inner diameters, grouped according to the cut-off value.

Results A total of 670 patients were included in the study. The DRA inner diameter had a significant predictive value (AUC = 0.718) for puncture success, with a cut-off value of 1.95 mm. The puncture success rate was significantly lower in the DRA inner diameter < 2.0 mm group than in the DRA inner diameter ≥ 2.0 mm group (93.1% vs. 98.2%, $P = 0.001$). Twenty-five (3.7%) developed distal radial artery occlusion (dRAO) after the operation, including 15 dRAO without proximal radial artery occlusion (pRAO) and 10 dRAO with pRAO. The incidence of dRAO with pRAO was significantly greater in the DRA inner diameter < 2.0 mm subgroup than in the DRA inner diameter ≥ 2.0 mm subgroup (2.8% vs. 0.5%, $P = 0.041$).

Conclusions The success rate of puncture was lower in patients with DRA inner diameter < 2.0 mm, whereas the incidence of dRAO with pRAO was higher.

Clinical trial number Not applicable.

Keywords Ultrasound, Distal radial artery, Radial artery occlusion, Coronary intervention, Success rate, Distal transradial access

†Tao Chen, Lamei Li and Anni Yang contributed equally to this article.

*Correspondence:
Gaojun Cai
caigaojun@wjrmyy.cn
[1]Department of Cardiology, The First Affiliated Hospital Of Ningbo University, Ningbo City 315000, Zhejiang Province, China
[2]Department of Cardiology, Wujin Hospital Affiliated with Jiangsu University, the Wujin Clinical College of Xuzhou Medical University, Changzhou City 213017, Jiangsu Province, China

Background

The feasibility and safety of distal transradial access (dTRA) for coronary intervention have been widely demonstrated [1–3]. Compared with conventional transradial access (cTRA), dTRA has some advantages, such as higher patient comfort, shorter compression time, and lower incidence of proximal radial artery occlusion (pRAO) [1]. However, the puncture success rate with dTRA is lower than that in the cTRA [4]. There is still a learning curve for puncturing the distal radial artery (DRA) [5]. Previous research has shown that the success rate of DRA puncture is positively correlated with vessel diameter [6]. However, the critical value of vessel diameter corresponding to high puncture success rate has not been reported, limiting clinical guidance.

In addition, the incidence of distal radial artery occlusion (dRAO) via the dTRA has been reported in the literature, ranging from 0.12 to 5.2% [7, 8], and sheath-to-vessel mismatch is an important risk factor for vascular occlusion [9, 10]. Therefore, preoperative ultrasound detection of the inner vessel diameter is helpful for ensuring appropriate sheath-to-vessel to reduce the vascular injury risk [11]. The aim of this study was to explore the appropriate DRA inner diameter for coronary intervention through ultrasound to increase puncture success rate and reduce dRAO.

Methods

Patient selection

This is a retrospective study. Patients who underwent coronary intervention via the dTRA in our institution from January 2022 to December 2022 were retrospectively enrolled. The inclusion criteria were as follows: 1). Patients who planned coronary intervention via the dTRA; 2). Palpable pulsation of the DRA at the anatomical snuffbox. The exclusion criterion was a lack of preoperative and/or postoperative ultrasound data. A total of 894 patients were screened for coronary intervention through the dTRA, of whom 191 lacked preoperative radial artery ultrasound and 33 lacked postoperative radial artery ultrasound. The postoperative data collection was strictly limited to the condition of arterial occlusion. Ultrasonographic assessment of postoperative arterial conditions was limited to 24 h after the operation and the patient had not been discharged. Finally, 670 patients were included. The study was conducted in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of Wujin Hospital Affiliated with Jiangsu University (2022-SR-001). As the study was retrospective, patients were exempted from providing informed consent.

Ultrasound technique

The ultrasonic examination was described in detail in our previous research [12]. In brief, the patient was in the sitting position before the intervention, and the hands were positioned as if they were holding a wine glass. Ultrasound evaluations of the DRA and conventional radial artery (CRA) were performed using a Konica Minolta Sonine HS1 PLUS portable ultrasound with a "line array" probe (18 – 4 MHz). After the blood vessels were visualized on the screen, the probe was rotated slightly to clearly visualize the intima. In this study, the vascular inner diameter was defined as the distance from the lower edge of the anterior wall intima to the upper edge of the posterior wall intima during ventricular systole. The incidence of dRAO and/or pRAO was evaluated by ultrasound at 24 h after coronary intervention. Ultrasound examination was performed by the same physician, who had experience more than 500 cases of DRA and/or CRA.

Puncture technique

The DRA puncture method was described in our previous study [13]. Briefly, after disinfection, a subcutaneous injection of 1–2 mL of 2% lidocaine was given near the strongest arterial pulsation in the anatomical snuffbox. The Seldinger method was subsequently performed with a 20G trocar puncture needle. After successful puncture, the appropriate arterial sheath was inserted. A 6Fr conventional sheath (RADIFOCUS® INTRODUCER II, Terumo, Tokyo, Japan) was routinely used in our centre. All operators were blinded to the inner diameter of the vessels.

Data analysis

Normally distributed variables are expressed as the mean ± standard deviation, and comparisons were performed through Student's t test. Non-normally distributed variables are expressed as medians (quartiles) and were compared using the U test. Categorical variables are expressed as frequencies and percentages and were compared using the chi-square test or Fisher's exact test. Binary logistic regression analysis was used to explore the factors affecting the success rate of puncture. A receiver operating characteristic (ROC) curve was plotted to predict the DRA inner diameter for puncture success, and the area under the curve (AUC) was calculated. The efficacy and safety of these regimens were compared between groups with different DRA inner diameters, grouped according to the cut-off value. A P value < 0.05 was considered to indicate statistical significance. The statistical analysis was performed using SPSS 25.0 (SPSS, Inc., Chicago, IL, USA).

Results

Patient characteristics

A total of 670 patients were included in this study. The mean age of the patients was 65.2 ± 10.6 years, with 416 (62.1%) were male (Table 1). The success rate of DRA puncture was 96.0% (643/670), 96.6% in males and 94.9% in females, respectively. Failure occurred in 27 patients, including puncture failure in 26 patients, and a guide wire could not be inserted in one patient. The mean DRA inner diameter was 2.1 ± 0.4 mm (Fig. 1), with smaller diameters in the failure group (1.8 ± 0.3 mm vs. 2.1 ± 0.4 mm, $P < 0.001$). A total of 652 patients were treated with a 6Fr conventional sheath, 4 with a 5Fr sheath, 9 with a 6Fr thin-walled sheath, and 5 with a 7Fr thin-walled sheath.

dRAO incidence

Among the 670 patients, 25 (3.7%) developed dRAO at 24 h after the intervention, including 15 isolated dRAO and 10 dRAO with pRAO. The incidence of dRAO was 3.7% (24/643) in the success group and 3.7% (1/27) in the failure group.

Factors influencing puncture success rate

Univariate analysis revealed that the puncture success rate was positively correlated with the DRA inner diameter ($P < 0.001$) and hyperlipidemia ($P = 0.046$). In multivariate regression analysis, only DRA inner diameter was an independent risk factor for the occurrence of puncture success rate (OR = 7.504, 95% CI = 2.588–21.755, $P < 0.001$) (Table 2). The ROC results showed that the DRA inner diameter had a significant predictive value for puncture success (AUC = 0.718), with a cut-off value of 1.95 mm (Fig. 2).

Comparison of results for different DRA inner diameter groups

The proportions of patients with an inner diameter of DRA ≥ 2.0 mm were 56.7% in total, 67.8% in males and 38.6% in females (Fig. 3). Patients were divided into two groups according to the DRA inner diameter (< 2.0 mm group, ≥ 2.0 mm group). The success rate of puncture (93.1% vs. 98.2%, $P = 0.001$), the prevalence of male sex and smoking (male, 46.2% vs. 74.2%, $P < 0.001$; smoking, 22.8% vs. 35.3%, $P < 0.001$) and the body mass index (BMI) (24.4 ± 3.6 kg/m^2 vs. 25.4 ± 3.3 kg/m^2, $P < 0.001$) in the DRA inner diameter < 2.0 mm group were significantly lower than those in the DRA inner diameter ≥ 2.0 mm group. However, the age, number of puncture attempts, puncture time and incidence of dRAO with pRAO (2.8% vs. 0.5%, $P = 0.041$) were greater in the DRA inner diameter < 2.0 mm group than those in the DRA inner diameter ≥ 2.0 mm group. There was no significant difference in basic medical history, compression time or dRAO without pRAO between the two groups (Table 3).

Table 1 Baseline characteristics

Characteristic	Total (*n* = 670)	Success group (*n* = 643)	Failure group (*n* = 27)	*P*-value
Age, yrs	65.2 ± 10.6	65.1 ± 10.6	67.8 ± 9.2	0.196
Male, n (%)	416 (62.1)	402 (62.5)	14 (51.9)	0.263
BMI, Kg/m^2	24.9 ± 3.5	25.0 ± 3.5	23.7 ± 2.8	0.070
Smoking, n (%)	200 (29.9)	190 (29.5)	10 (37.0)	0.405
Diabetes mellitus, n (%)	167 (24.9)	161 (25.0)	6 (22.2)	0.740
Hyperlipidemia, n (%)	38 (5.7)	34 (5.3)	4(14.8)	0.095
Hypertension, n (%)	482 (71.9)	466 (72.5)	16 (59.3)	0.134
Coronary heart disease, n (%)	252 (37.6)	238 (37.0)	14 (51.9)	0.119
History of ipsilateral DRA intervention, n (%)	91 (13.6)	87 (13.5)	4 (14.8)	0.849
Premedicate				
Antiplatelet drugs, n (%)	276 (41.2)	262 (40.7)	14 (51.9)	0.251
Lipid-lowering drugs, n (%)	205 (30.6)	198 (30.8)	7 (25.9)	0.591
Sheath				
5 F sheath, n (%)	4 (0.6)	4 (0.6)	0 (0)	0.528
6 F sheath, n (%)	652 (97.3)	626 (97.4)	26 (96.3)	
6 F thin-walled sheath, n (%)	9 (1.3)	8 (1.2)	1 (3.7)	
7 F thin-walled sheath, n (%)	5 (0.7)	5 (0.8)	0 (0)	
Type of procedure				
CAG, n (%)	527 (78.7)	505 (78.5)	22 (81.5)	0.715
PCI, n (%)	143 (21.3)	138 (21.5)	5 (18.5)	
dRAO, n (%)	25 (3.7)	24 (3.7)	1 (3.7)	0.994
DRA inner diameter, mm	2.1 ± 0.4	2.1 ± 0.4	1.8 ± 0.3	< 0.001

DRA, distal radial artery; dRAO, distal radial artery occlusion; BMI, body mass index; CAG, coronary angiography; PCI, percutaneous coronary intervention

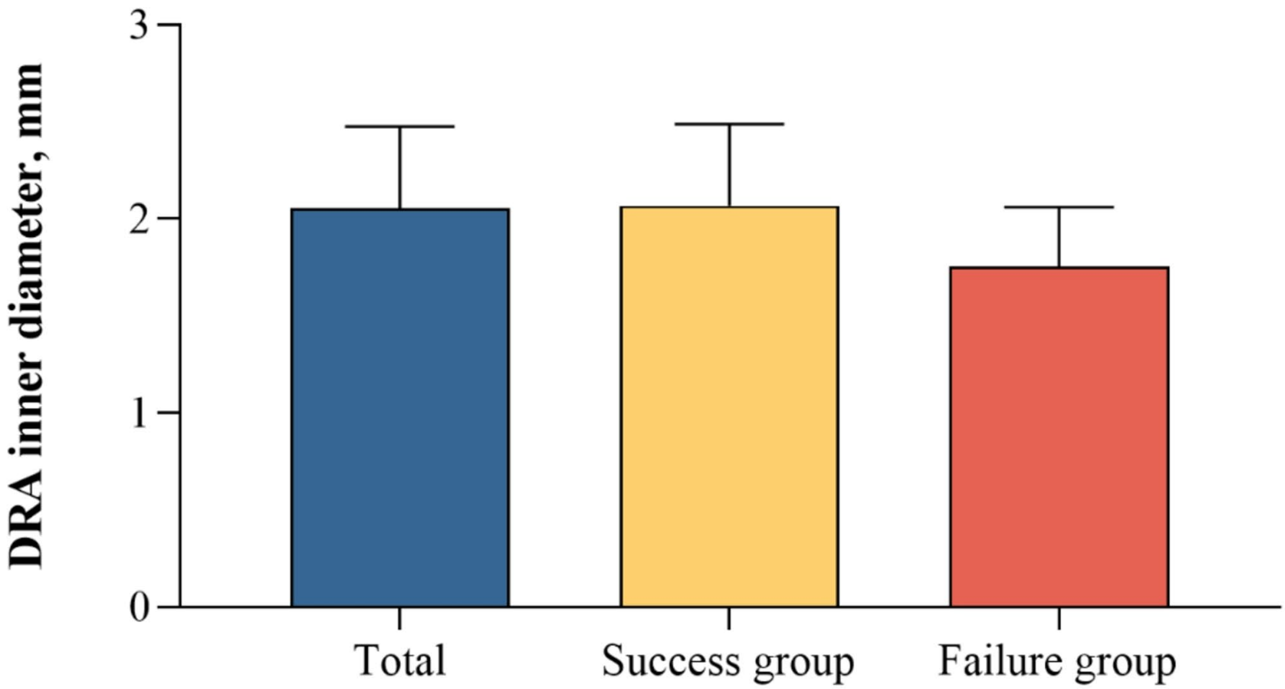

Fig. 1 Distribution of the inner diameters of the punctures. The inner diameters of the DRA were 2.1 ± 0.4 mm in total, 2.1 ± 0.4 mm in the success group and 1.8 ± 0.3 mm in the failure group. DRA, distal radial artery

Table 2 Binary logistic regression for predictors of puncture success rate

Predictor	Univariate analysis			multivariate analysis		
	OR	95% CI	*P*	OR	95% CI	*P*
DRA inner diameter	7.924	2.719-23.093	<0.001	7.504	2.588-21.755	<0.001
Hyperlipidemia	3.115	1.020-9.514	0.046	2.781	0.875-8.842	0.083
Age	0.975	0.937-1.013	0.197			
Male	1.549	0.716-3.351	0.266			
BMI	1.118	0.991-1.261	0.069			
Smoking	1.402	0.631-3.119	0.407			
Diabetes mellitus	0.855	0.339-2.156	0.741			
Hypertension	0.552	0.252-1.241	0.139			
Coronary heart disease	1.833	0.847-3.965	0.124			

DRA, distal radial artery

According to the sex distribution of the patients, the subgroup analysis showed that the male subgroup had a significantly lower puncture success rate in the DRA inner diameter < 2.0 mm subgroup than in the DRA inner diameter ≥ 2.0 mm subgroup (93.3% vs. 98.2%, $P = 0.02$)., Although the puncture success rates of the two groups were significantly different in the female subgroup (92.9% vs. 98.0%, $P = 0.078$), the statistic difference was not significant (Fig. 4). In both the male and female subgroups, there were no significant differences in the incidence of dRAO without pRAO or dRAO with pRAO between the DRA inner diameter < 2.0 mm group and the DRA inner diameter ≥ 2.0 mm group (Fig. 5).

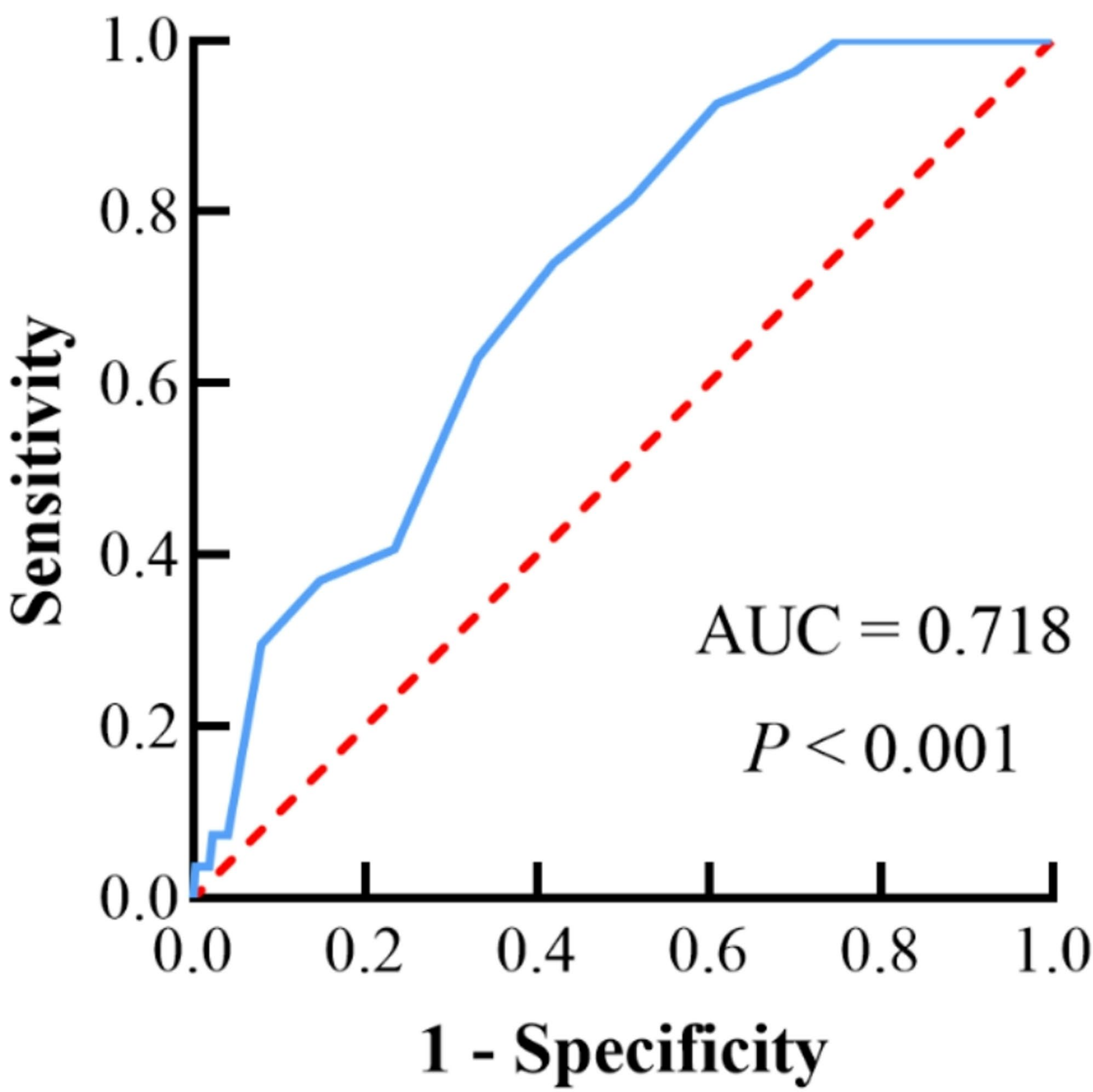

Fig. 2 ROC curve for DRA inner diameter predicted puncture success. The DRA inner diameter had a significant predictive value for puncture success (AUC = 0.718), with a cut-off value of 1.95 mm. DRA, distal radial artery; AUC, area under the curve

Discussion

This study establishes a DRA inner diameter threshold (1.95 mm) for optimizing puncture success and minimizing dRAO with pRAO. Preoperative ultrasound has important role for determining the efficacy and safety of coronary intervention via the dTRA.

The dTRA has gradually been popularized in clinical practice due to its short haemostatic time, good patient comfort and low pRAO rate [14]. Generally, the diameter of the DRA is less than that of the CRA [15]. Due to the limitation of vessel diameter, puncturing the DRA is more challenging. According to the literature, the success rates of DRA puncture are highly variable [4, 16, 17]. Early randomized controlled studies have shown that the success rate of DRA puncture is only 70%, whereas the success rate of DRA puncture under ultrasound guidance can reach 100% [16]. The overall success rate of DRA puncture in this study was 96.0%. In the cTRA, puncture failure is often closely related to vessel hypoplasia, spasm or a diameter that is too small [18, 19]. When patients with a small CRA diameter were divided into two groups according to the diameter of the CRA (1.6 mm), the

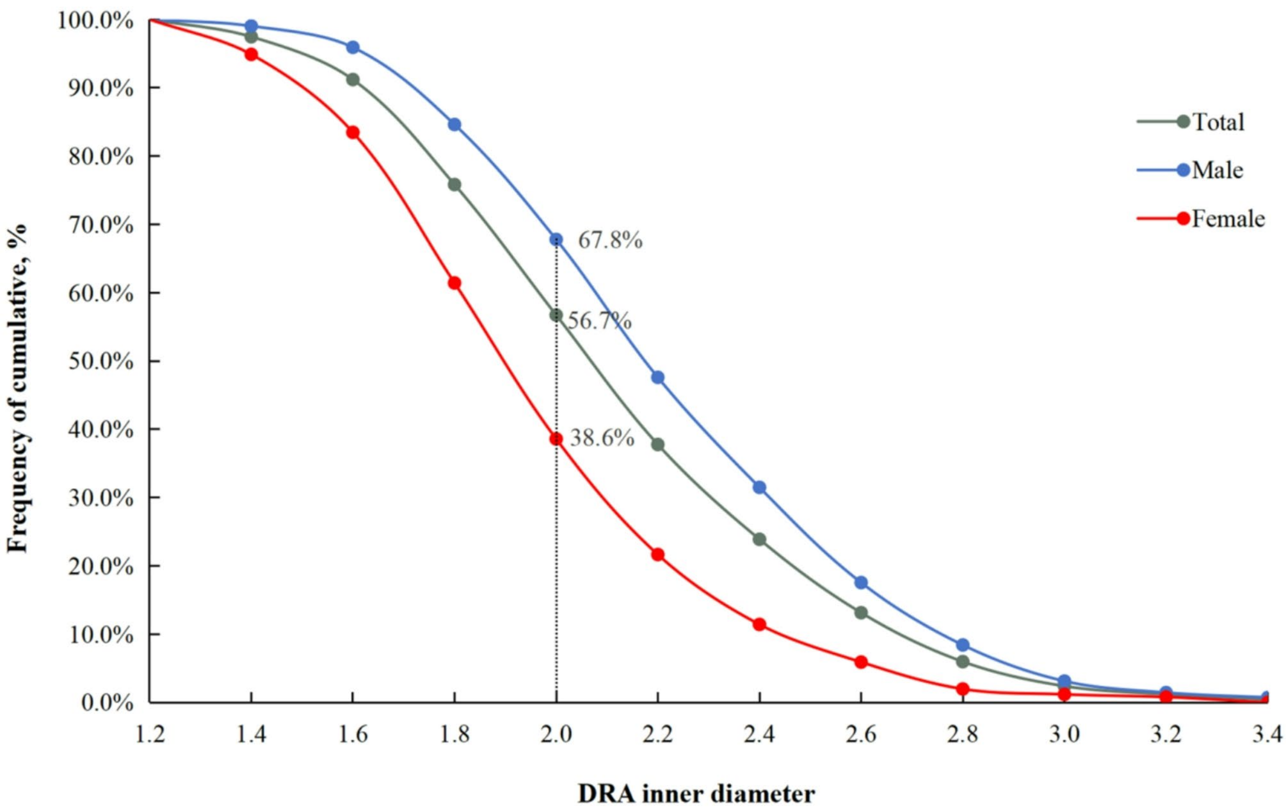

Fig. 3 DRA inner diameter cumulative frequency. The proportions of patients with an inner diameter of DRA ≥ 2.0 mm were 56.7% in total, 67.8% in males and 38.6% in females. DRA, distal radial artery

Table 3 The comparison of results for DRA inner diameter grouping

Characteristic	DRA inner diameter < 2.0 mm (*n* = 290)	DRA inner diameter ≥ 2.0 mm (*n* = 380)	*P*-value
Age, yrs	66.6 ± 9.9	64.1 ± 11.0	0.002
Male, n (%)	134 (46.2)	282 (74.2)	< 0.001
BMI, Kg/m^2	24.4 ± 3.6	25.4 ± 3.3	< 0.001
Smoking, n (%)	66 (22.8)	134 (35.3)	< 0.001
Diabetes mellitus, n (%)	81 (27.9)	86 (22.6)	0.116
Hyperlipidemia, n (%)	17 (5.9)	21 (5.5)	0.852
Hypertension, n (%)	204 (70.3)	278 (73.2)	0.422
Coronary heart disease, n (%)	114(39.3)	138 (36.3)	0.428
History of ipsilateral DRA intervention, n (%)	29 (10.0)	62 (16.3)	0.018
The success rate of puncture, n (%)	270 (93.1)	373 (98.2)	0.001
Number of puncture attempts, freq	1 (1, 2)	1 (1, 1)	0.001
Puncture time, s	60 (50, 120)	60 (50, 80)	< 0.001
Compression time, hour	3 (3, 4)	3 (3, 4)	0.688
dRAO, n (%)	14 (4.8)	11 (2.9)	0.191
Isolated dRAO, n (%)	6 (2.1)	9 (2.4)	0.795
dRAO combined with pRAO, n (%)	8 (2.8)	2 (0.5)	0.041

DRA, distal radial artery; BMI, body mass index; dRAO, distal radial artery occlusion; pRAO, proximal radial artery occlusion

puncture time in the CRA diameter < 1.6 mm group was longer than that in the CRA diameter ≥ 1.6 mm group [19]. Ghose T et al. showed that when coronary intervention was performed through ultrasound-guided puncture of the dTRA, the success rate was 96.3%, and the diameter of the DRA in patients who underwent failed puncture was less than 2.0 mm [20]. In our study, the cut-off value of the DRA inner diameter for predicting puncture success was 1.95 mm, and the success rate of puncture was much lower in the DRA inner diameter < 2.0 mm group than in the DRA inner diameter ≥ 2.0 mm group (93.1% vs. 98.2%, $P = 0.001$). We also found that the puncture

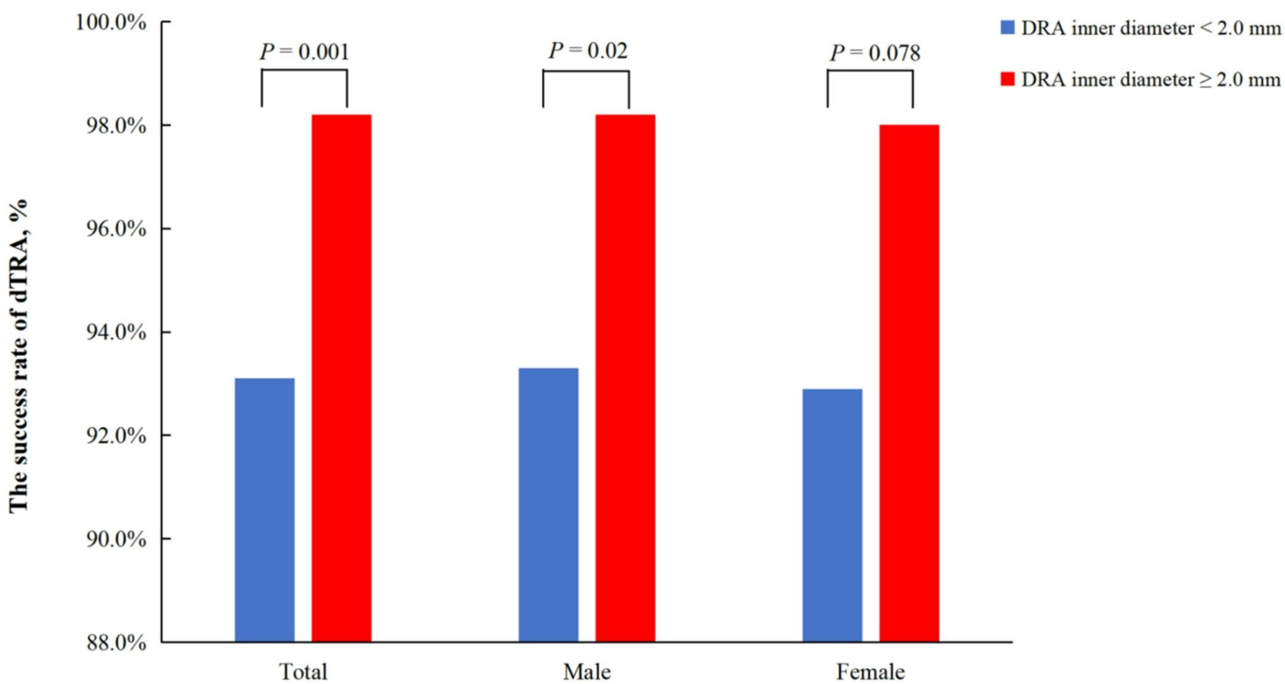

Fig. 4 Subgroup analysis of the puncture success rate. The male subgroup had a significantly lower puncture success rate in the DRA inner diameter < 2.0 mm subgroup than in the DRA inner diameter ≥ 2.0 mm subgroup (93.3% *vs*. 98.2%, $P = 0.02$). DRA, distal radial artery; dTRA, distal transradial access

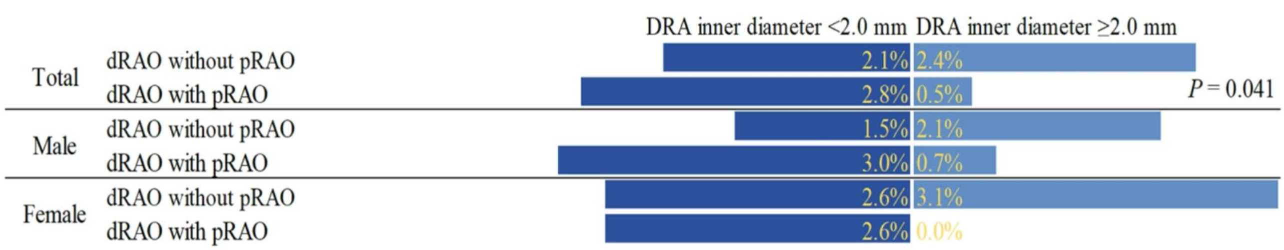

Fig. 5 Comparison of occlusion rates among the different DRA inner diameter groups. The percentage of patients with dRAO combined with pRAO (2.8% *vs*. 0.5%, $P = 0.041$) in the DRA inner diameter < 2.0 mm group was greater than that in the DRA inner diameter ≥ 2.0 mm group. According to our subgroup analyses, there were no differences in the incidence of dRAO without pRAO or dRAO combined with pRAO between the two groups. DRA, distal radial artery; dRAO, distal radial artery occlusion; pRAO, proximal radial artery occlusion

time was significantly longer in the DRA inner diameter < 2.0 mm group. Therefore, preoperative ultrasonography is particularly important for selecting appropriate patients for DRA puncture, which will helps to increase the success rate of puncture and increase self-confidence, especially for beginners. Of course, puncture can be performed in patients with a small inner diameter of the DRA by an experienced operator or ultrasound guidance. Ultrasound-guided visualization can improve the success rate of puncture [21] and reduce the risk of vascular injury [8].

Several studies have suggested that vessel size is related to the pRAO [9, 22]. However, Chugh Y et al. reported no significant difference in the pRAO among different CRA diameter groups [19]. We found that the incidence of dRAO was greater in the DRA inner diameter < 2.0 mm subgroup than that in the DRA inner diameter ≥ 2.0 mm subgroup (4.8% vs. 2.9%, $P = 0.191$); however, the difference was not statistically significant, possibly because of the small sample size. According to our subgroup analysis, there was no significant difference in the incidence of dRAO without pRAO between the two groups, and no patients with isolated pRAO on the puncture side were found. However, the incidence of dRAO with pRAO was greater in the DRA inner diameter < 2.0 mm subgroup than that in the DRA inner diameter ≥ 2.0 mm subgroup (2.8% vs. 0.5%, $P = 0.041$). In this study, 97.3% of the patients (652/670) were treated with a 6Fr conventional arterial sheath with an external diameter of 2.62 mm (RADIFOCUS® INTRODUCER II, Terumo, Tokyo, Japan). One study showed that the DRA diameter is approximately 80% of the CRA diameter [23]. For patients with a DRA inner diameter < 2.0 mm, the proportion of patients with a sheath-to-vessel mismatch is high, which is an independent risk factor for RAO [24]. When occlusion occurs in the CRA, the thrombus may extend to the DRA, resulting in simultaneous dRAO. Patients with DRA diameters ≥ 2.0 mm had relatively larger CRA diameters and less vascular injury caused by sheath insertion, so the risk of vascular occlusion was low. Interestingly, we found a patient with a failed DRA puncture (DRA inner diameter 1.5 mm) who also developed dRAO. The patient did not have a sheath placed via the dTRA, and the DRA puncture area was not compressed. We speculated that the cause of the occlusion may be repeated punctures, which disrupt the vascular endothelial barrier, followed by local thrombosis formation and acute dRAO [25]. In this study, we found that the number of puncture attempts in the DRA inner diameter < 2.0 mm group was significantly greater than that in the DRA inner diameter ≥ 2.0 mm group. Repeated puncture increases the risk of vascular injury and spasm [26, 27]. Therefore, the puncture of DRA with a small inner diameter is more likely to cause vascular damage.

Age, sex and BMI may be related to DRA diameter [23, 28, 29]. However, the results were inconsistent [15]. The results of this study suggested that the proportions of men and smokers and of BMI were lower in the DRA inner diameter < 2.0 mm subgroup than that in the DRA inner diameter ≥ 2.0 mm subgroup, while age was greater. It should be noted that the inner diameter of the blood vessels was measured in this study. We hypothesized that elderly patients may be more prone to peripheral atherosclerosis and intimal hyperplasia.

Limitations

First, this was a single-centre retrospective study. Even for small vessels, the success rate of puncture in our centre is relatively high due to the puncture performed by experienced operators. Multicentre prospective studies are needed for further validation. Second, DRA puncture was performed by different operators in this study, and different skilled operators may have different effects on the success rate of puncture and the rate of radial artery occlusion after operation. In the real world, vascular puncture in cardiovascular intervention centres is generally not limited to one operator, and some surgeons are even novice interventional doctors. Third, it has been reported that patients with dRAO may recanalize [30]. However, there was no long-term follow-up in this study, and the long-term blood flow in patients who developed dRAO is unclear. A prospective cohort study will be conducted to determine the effect of vessel size on long-term dRAO. Fourth, the DRA diameter measured in this study was the DRA inner diameter, which may underestimate the vessel diameters of the patients. However, precisely assessing the inner diameter of the vessel is more valuable for influencing the success rate of puncture and the sheath-to-vessel mismatch.

Conclusions

The success rate of puncture was lower in patients with DRA inner diameter < 2.0 mm, whereas the the incidence of dRAO with pRAO was higher. If the inner diameter of DRA is less than 2.0 mm, we can select small-sized sheath in advance to reduce the risk of vascular injury and minimize the discomfort of patients. Preoperative ultrasound has great value for evaluating the efficacy and safety of coronary intervention via the dTRA.

Abbreviations

DTRA	Distal transradial access
cTRA	Conventional transradial access
DRA	Distal radial artery
BMI	Body mass index
dRAO	Distal radial artery occlusion
CRA	Conventional radial artery
AUC	Area under the curve
pRAO	Proximal radial artery occlusion

Author contributions

Gj. C. conceived and designed the article; Xy. F, Gw. S. and F. L. collected the data; Lm. L. and An. Y. analyzed the data; T. C. reviewed ultrasound diagnosis and wrote the paper.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by Changzhou Sci&Tech Program (No. CJ20241047) and Changzhou High-Level Medical Talents Training Project (2022CZBJ102). No funding body participated in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and local laws. As the study was retrospective, patients were exempted from providing informed consent. The study protocol was approved by the Ethics Committee of Wujin Hospital Affiliated with Jiangsu University (2022-SR-001).

Competing interests

The authors declare no competing interests.

Received: 10 February 2025 / Accepted: 14 May 2025
Published online: 26 May 2025

References

1. Tsigkas G, Papageorgiou A, Moulias A, Kalogeropoulos AP, Papageorgopoulou C, Apostolos A, et al. Distal or traditional transradial access site for coronary procedures. JACC Cardiovasc Interv. 2022;15(1):22–32.
2. Chinese Expert Consensus on Percutaneous Coronary Intervention through Distal Transradial Artery Access. Cardiol Plus. 2020;5(4):175–85.
3. Sgueglia GA, Lee BK, Cho BR, Babunashvili A, Lee JB, Lee JW et al. Distal radial access. JACC Cardiovasc Interv 2021, 14(8): 892–906.
4. Koutouzis M, Kontopodis E, Tassopoulos A, Tsiafoutis I, Katsanou K, Rigatou A, et al. Distal versus traditional radial approach for coronary angiography. Cardiovasc Revasc Med. 2019;20(8):678–80.

5. Roh JW, Kim Y, Lee O-H, Im E, Cho D-K, Choi D, et al. The learning curve of the distal radial access for coronary intervention. Sci Rep. 2021;11(1):13217.
6. Li SS, Li JM, Liu LL, Liu W, Yang H, Feng CG. Analysis of the risk factors related to the success rate of distal transradial artery access in patients with coronary heart disease. Risk Manag Healthc Policy. 2022;15:657–63.
7. Babunashvili A. Tct-810 novel distal transradial approach for coronary and peripheral interventions. J Am Coll Cardiol. 2018;72(13s):B323–323.
8. Flores EA, RPVI I C, Conyers G. Making the right move: use of the distal radial artery access in the hand for coronary angiography and percutaneous coronary interventions. Cath Lab Digest. 2018;26(12):16–25.
9. Garg N, Madan BK, Khanna R, Sinha A, Kapoor A, Tewari S, Kumar S, Goel PK. Incidence and predictors of radial artery occlusion after transradial coronary angioplasty: Doppler-guided follow-up study. J Invasive Cardiol. 2015;27(2):106–12.
10. Honda T, Fujimoto K, Miyao Y, Koga H, Hirata Y. Access site-related complications after transradial catheterization can be reduced with smaller sheath size and Statins. Cardiovasc Interv Ther. 2012;27(3):174–80.
11. Norimatsu K, Kusumoto T, Yoshimoto K, Tsukamoto M, Kuwano T, Nishikawa H, Matsumura T, Miura S-i. Importance of measurement of the diameter of the distal radial artery in a distal radial approach from the anatomical snuffbox before coronary catheterization. Heart Vessels. 2019;34(10):1615–20.
12. Chen T, Yu X, Song R, Li L, Cai G. Application of ultrasound in cardiovascular intervention through the distal radial artery approach: new wine in old bottles? Front Cardiovasc Med. 2022;9:1019053.
13. Li F, Shi GW, Yu XL, Song RX, Xiao JQ, Huang HM, et al. Safety and efficacy of coronary angiography and percutaneous coronary intervention through distal transradial artery access in the anatomical snuffbox: a single-centre prospective cohort study using a propensity score method. BMC Cardiovasc Disord. 2022;22(1):74.
14. Cai G, Huang H, Li F, Shi G, Yu X, Yu L. Distal transradial access: a review of the feasibility and safety in cardiovascular angiography and intervention. BMC Cardiovasc Disord. 2020;20(1):356.
15. Naito T, Sawaoka T, Sasaki K, Iida K, Sakuraba S, Yokohama K, et al. Evaluation of the diameter of the distal radial artery at the anatomical snuff box using ultrasound in Japanese patients. Cardiovasc Interv Ther. 2019;34(4):312–6.
16. Hadjivassiliou A, Cardarelli-Leite L, Jalal S, Chung J, Liu D, Ho S, Klass D. Left distal transradial access (ldTRA): A comparative assessment of conventional and distal radial artery size. Cardiovasc Intervent Radiol. 2020;43(6):850–7.
17. Coughlan JJ, Zebrauskaite A, Arnous S, Kiernan TJ. Left distal trans-radial access facilitates earlier discharge post-coronary angiography. J Interv Cardiol. 2018;31(6):964–8.
18. Kiemeneij F, Laarman GJ, de Melker E. Transradial artery coronary angioplasty. Am Heart J. 1995;129(1):1–7.
19. Chugh Y, Kanaparthy NS, Piplani S, Chugh S, Shroff A, Vidovich M, et al. Comparison of distal radial access versus standard transradial access in patients with smaller diameter radial Arteries(The distal radial versus transradial access in small transradial ArteriesStudy: D.A.T.A - S.T.A.R study). Indian Heart J. 2021;73(1):26–34.
20. Ghose T, Kachru R, Dey J, Khan WU, Sud R, Jabeen S et al. Safety and Feasibility of Ultrasound-Guided Access for Coronary Interventions through Distal Left Radial Route. J Interv Cardiol. 2022; 2022: 2141524.
21. Mori S, Hirano K, Yamawaki M, Kobayashi N, Sakamoto Y, Tsutsumi M et al. A Comparative Analysis between Ultrasound-Guided and Conventional Distal Transradial Access for Coronary Angiography and Intervention. J Interv Cardiol. 2020; 2020:7342732.
22. Rashid M, Kwok CS, Pancholy S, Chugh S, Kedev SA, Bernat I, et al. Radial artery occlusion after transradial interventions: A systematic review and Meta-Analysis. J Am Heart Assoc. 2016;5(1):e002686.
23. Lee JW, Son JW, Go TH, Kang DR, Lee SJ, Kim SE, et al. Reference diameter and characteristics of the distal radial artery based on ultrasonographic assessment. Korean J Intern Med. 2022;37(1):109–18.
24. Uhlemann M, Möbius-Winkler S, Mende M, Eitel I, Fuernau G, Sandri M, et al. The Leipzig prospective vascular ultrasound registry in radial artery catheterization. JACC: Cardiovasc Interventions. 2012;5(1):36–43.
25. Barrett CD, Hsu AT, Ellson CD, Miyazawa BY, Kong YW, Greenwood JD, et al. Blood clotting and traumatic injury with shock mediates complement-dependent neutrophil priming for extracellular ROS, ROS-dependent organ injury and coagulopathy. Clin Exp Immunol. 2018;194(1):103–17.
26. Dwivedi SK, Sharma AK, Nayak GR, Chaudhary GK, Chandra S, Pradhan A, et al. Factors influencing radial artery occlusion after transradial coronary intervention in the Indian population. Anatol J Cardiol. 2022;26(2):105–11.
27. Costa F, van Leeuwen MA, Daemen J, Diletti R, Kauer F, van Geuns RJ, et al. The Rotterdam radial access research: Ultrasound-Based radial artery evaluation for diagnostic and therapeutic coronary procedures. Circ Cardiovasc Interv. 2016;9(2):e003129.
28. Meo D, Falsaperla D, Modica A, Calcagno MC, Libra F, Desiderio C, et al. Proximal and distal radial artery approaches for endovascular percutaneous procedures: anatomical suitability by ultrasound evaluation. Radiol Med. 2020;126(4):630–5.
29. Kim Y, Ahn Y, Kim MC, Sim DS, Hong YJ, Kim JH, et al. Gender differences in the distal radial artery diameter for the snuffbox approach. Cardiol J. 2018;25(5):639–41.
30. Sgueglia GA, Hassan A, Harb S, Ford TJ, Koliastasis L, Milkas A, et al. International hand function study following distal radial access: the RATATOUILLE study. JACC Cardiovasc Interv. 2022;15(12):1205–15.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.