Original Research Article

ASSESSMENT OF CORRELATION BETWEEN RADIAL ARTERY OCCLUSION AND ITS PREDICTORS AFTER TRANSRADIAL APPROACH

Siva Naga Chennakesava Rao Kuchiraju[1], Jagadeesh Reddy Kolli [2], Kiran Kumar Kanjerla [3]

[1]Senior Resident Department of Cardiology, Osmania Medical College and Hospital, Hyderabad.

[2]Associate Professor, Department of Cardiology, Gandhi Hospital, Secunderabad, Telangana State.[2]

[3] Consultant Electrophysiologist, sunshine KIMS Hospital Secunderabad, Telangana State.

Corresponding Author: Dr. Jagadeesh Reddy Kolli

Abstract

Background: The radial artery is the most preferred access for coronary interventions. Radial artery occlusion (RAO) is a common complication and serious concern after transradial approach (TRA). The current study assessed the clinical, angiographic, and Doppler ultrasound correlation of RAO and its predictors after TRA.

Methods: This was a prospective, observational study done on 300 patients who underwent elective diagnostic coronary examination, and elective percutaneous coronary intervention (PCI) through TRA was included. Baseline, clinical, and procedure-related data were recorded, and radial artery patency was assessed by radial pulse examination. Radial artery diameter was measured by Color Doppler Ultrasonography (USG) and angiography, and it was estimated one day before the procedure, within 24 hours, and three months after the procedure. The incidence of RAO and their predictors were evaluated after TRA.

Results: The mean age of the study cohort was 53 ± 11 years, mainly males (69%). The mean radial arterial diameter on USG and radial angiography were 2.6 ± 0.36 mm and 2.55 ± 0.42 mm, respectively. After the procedure, the incidence of RAO (n=62, 20.66%) was confirmed via USG and 10 (16.12%) patients underwent recanalization after TRA. Weight, height, mid-arm circumference (MAC), and shoe size had a significant positive correlation ($p<0.01$) with pre-procedural radial artery diameter. On multivariate logistic regression analysis, females ($p<0.001$), smoking habits ($p<0.001$), height ($p=0.01$), and chronic kidney disease (CKD) ($p=0.01$) were found as independent predictors of the RAO.

Conclusion: Weight, height, MAC, and shoe size can be correlated with radial artery diameter. Females, smoking habit, height, and CKD were found to an independent predictor of RAO. However, the predictors of RAO following TRA are not well-defined; therefore, a proper understanding of the predictors of RAO can be beneficial for its prevention.

Keywords: Color Doppler; Radial artery angiography; Radial artery occlusion; Transradial approach.

Introduction

Coronary angiography (CAG) or percutaneous coronary intervention (PCI) can be done through femoral, brachial, ulnar, and radial artery access. The technique used in this procedure is the trans-radial approach (TRA) which was introduced by Campeau in 1989, has replaced the traditional transfemoral technique because of its benefits for the patient such as reduced discomfort, early mobilization, no bed rest, and shorter hospital stay [1-4]. In high-risk patients, it has been demonstrated that TRA is safer in terms of mortality and adverse cardiac events as compared to transfemoral access. However, the complications of TRA include radial artery occlusion, radial artery spasm, hematoma, pseudoaneurysm, radial artery perforation, hand ischemia, and compartment syndrome [5]. Radial artery occlusion (RAO) is one of the most frequent complications, developing in most patients with TRA (7, 8). Early RAO may develop after TCI, because of radial artery spasm and thrombosis, which may arise from endothelial damage due to catheterization and decreased blood flow resulting from sheath and catheterization [6]. The prevalence of RAO is from 1% to 42% depending on the time of assessment and the diagnostic technique applied. The risk of RAO is affected by patient attributes like age, sex, weight, diabetes mellitus, smoking status, renal disease, and peripheral arterial disease, and procedure-related factors like artery diameter, sheath size, procedure duration, use of anticoagulants and the number of previous procedures through the same artery. However, the signs of RAO about TCI are still ambiguous [6-9]. Radial artery diameter changes before and after the procedure were measured using Color Doppler Ultrasonography (USG) and radial artery angiography and the incidence of RAO and its predictors following trans-radial procedures was determined with a follow-up being done after three months. However, the indicators of RAO following TCI are not well-defined [6-9]. The current study employed Color Doppler Ultrasonography (USG) and radial artery angiography to assess changes in radial artery diameter before and after the procedure and evaluated the incidence of RAO and its predictors after transradial procedures, with a follow-up at three months.

Material and Methods

This was a prospective, observational study conducted at a Tertiary Care Center in India. A total of 300 consecutive patients who underwent elective diagnostic coronary examination or elective PCI through trans-radial access were included. Patients who underwent transradial procedures (CAG and PCI) through the right radial artery were also recruited. The patients with a history of peripheral arterial disease, decompensated heart failure, severe sepsis, pregnant women, and those who were lost to follow-up were excluded. The study was approved by the Institutional Ethics Committee and the written informed consent was taken from each enrolled patient or the patients' legal representative whenever required.

Study procedure, data collection, and follow-up: Data regarding demographics, medical history, and procedural characteristics were recorded. Biochemical estimation including routine hemogram, renal function tests random blood sugar levels, and left ventricular ejection fraction (LVEF) using echocardiography was measured for all the patients.

Clinical radial artery patency was assessed by radial pulse examination. Modified Allen's test was performed on all patients. The wrist was sterilized and draped in the usual pattern**.** Before the arterial puncture, local anesthesia was administered with 2 to 3 mL of 2% lidocaine. A 20 G (gauge) needle at an angle of 25-30°, 1-2 cm proximal to the styloid process or 2-3 cm proximal to the wrist line was used for the radial artery puncture. After the appearance of the pulsatile flow, a 0.018-inch guide wire was advanced into the radial artery lumen through a 20 G needle. The needle was then removed with the guide wire in situ and threaded by the sheath and dilator over it. A small percutaneous incision was made for the smooth gliding of the sheath into the access site. A 6 F radial sheath was used in all patients. Following removal of the dilator and guide wire, a cocktail of 1 mL of diltiazem and 2 ml of nitroglycerine i.e., 200 µg (total 3 mL) and 5000 IU heparin diluted to 10 mL saline was administered. Radial angiography was then performed using the contrast media diluted in saline (1:1). The coronary angiography and angioplasty were done under Siemens Axiom Artis DFC (Munich, Germany) cath lab Machine. The patients' radial artery diameter was measured at 5 cm proximal to the sheath end as the reference point with calibration software of the cath lab machine**.** Then, coronary angiography or angioplasty procedures were performed as per the routine method. At the end of the procedure, a radial angiogram was checked before removing the sheath.

Radial artery diameter was measured by Color Doppler USG and angiography by a trained radiologist was blinded to the study. A reference point at a level of 15 cm above the level of the styloid process of the right hand was used for assessing the diameter. The dimension of the radial artery (inner wall to inner wall) was used for measuring the inner luminal diameter by calipers. The flow was assessed by the Color Doppler and pulsed wave Doppler using a portable diagnostic ultrasound system with a 3C5P vascular probe (Mindray, Mindray Head Quarters, Shenzhen, China). The radial artery diameter was measured one day before the procedure, within 24 hours after the procedure, and three months after the procedure during follow-up.

Statistical analysis: Dichotomous variables are reported as numbers and proportions. Continuous variables are presented as mean ± standard deviation. Potential risk factors for small radial artery size and post-procedural RAO were investigated first by univariate logistic regression analysis. A multivariate logistic regression model with all significant variables was established to estimate odds ratios (ORs) and inclusive 95% confidence bounds. All tests were performed as two-sided at a significance level of $p<0.05$. Statistical analysis was performed with Statistical Package for the Social Sciences version 25.0 (IBM-SPSS, Armonk, NY).

Results

Out of 750, a total of 300 consecutive patients who underwent elective diagnostic coronary examination or elective PCI through transradial access were analyzed in the current study and the mean age was 53±11 years. The study population constituted predominantly males (69%), mean body mass index (BMI) was 26.09 ± 4.3 kg/m2, and mean mid-arm circumference (MAC) was 27.49 ± 3.03 cm (Table 1).

Table 1: Baseline characteristics of cases included in the study

Variable	*Number of patients (n=300)*
Age (years), mean ± SD	53 ± 11
Gender	
Female, n (%)	93(31)
Male, n (%)	207(69)
Weight (kg), mean ± SD	69 ± 13
Height (cm), mean ± SD	162.54 ± 9.06
BMI (kg/m^2), mean ± SD	26.09 ± 4.3
MID circumference (cm), mean ± SD	27.49 ± 3.03
Median shoe size [(inches) (Range)]	8 (5 - 10)
Occupation	
Outdoor workers, n (%)	110(36.7)
Indoor workers and office workers, n (%)	190(63.3)

The average shoe size of the study population was 8 inches. Most of the study population are indoor and office workers (63.3%). About one-third (43%) of patients were diabetic and about one-half (54.3%) were hypertensive. More than one-third of the patients were smokers (49%) and alcoholics (39.3%). About 90% of patients had acute coronary syndrome, while the rest had stable coronary artery disease. One and more than one prior radial interventions were done in 16% of the patients. Nearly one-third of the patients needed more than one puncture attempt for radial cannulation. More than one catheter was used in around 10% of the study population and the mean fluoroscopy time was 19.28 ± 7.3 minutes. Baseline, clinical, and procedural characteristics are depicted in Table 2.

Table 2: The clinical and procedural characteristics of cases included in the study

Comorbid conditions	*Number of patients (n=300)*
Diabetes mellitus, n (%)	129 (43)
Hypertension, n (%)	163 (54.3)
Smoker, n (%)	148 (49)
Alcohol, n (%)	118 (39.3)
Chronic Kidney Disease, n (%)	9 (3)
Diagnosis	
STEMI, n (%)	201 (67)
NSTEACS, n (%)	71 (23.7)
CSA, n (%)	25 (8.3)
Other, n (%)	3 (1)
LV Function	
Good, n (%)	81 (27)
Mild, n (%)	141(47)
Moderate, n (%)	72 (24)
Severe, n (%)	6 (2)
Random blood sugar (mg/dl), mean ±SD	167.67 ± 67.23
Procedural characteristics	
CAG, n (%)	275 (91.7)
PCI, n (%)	25 (8.3)

After the procedure, the mean radial artery diameter decreased, as shown by USG (2.6 ± 0.01 mm to 2.1 ± 0.03 mm) and angiogram (2.55 ± 0.01 mm to 2.06 ± 0.03 mm). No significant difference was observed between measurements using USG and angiography. The study population was divided into two groups based on the presence or absence of radial artery occlusion (RAO). The day after transradial access (TRA), the Doppler examination confirmed RAO in 62 (20.66%) patients. Of these, 20 (32.25%) still had a palpable pulse, and all were asymptomatic. Minor forearm hematoma was noted in six (2%) patients, and one patient developed a radial artery pseudoaneurysm, successfully treated with ultrasound-guided compression. After three months, spontaneous recanalization occurred in 10 (16.1%) of the 62 RAO patients, with no new RAO cases or symptoms noted (Table 3).

Table 3: Serial vascular Doppler assessment of radial artery

variable	*Before the procedure by USG*	*Before the procedure by angiogram*	*After procedure by USG Day 1*	*After the procedure by angiogram on Day 1*	*Day 90*
Radial artery diameter (mm), mean ± SD	2.6±0.01	2.55±0.01	2.1±0.03	2.06±0.03	2.34±0.15
RAO, n (%)	0(0%)	0(0%)	62(21%)	62(21%)	52(17.3%)

Pre-USG and pre-angiogram showed a positive correlation of RAO with variables outlined in Table 5. Both pre-USG and pre-angiography showed a weak but positive association with body weight ($r=0.24$; $p<0.01$ and $r=0.25$; $p<0.01$), height ($r=0.25$; $p<0.01$ and $r=0.23$; $p<0.01$) and shoe size ($r=0.21$; $p<0.01$ and $r=0.21$; $p<0.01$), respectively. MAC ($r=0.53$; $p<0.01$ and $r=0.51$; $p<0.01$) was moderately and positively associated with RAO.

Table 4: Correlation between demographic variables in Pre-Ultrasonography and Angiographic radial artery diameter

Variables	Pre-USG		Pre Angiogram	
	Cc(r)	*p-value*	*Cc(r)*	*p-value*
Age	0.06	0.29	0.02	0.76
Weight	0.24	<0.01*	0.25	<0.01*
Height	0.25	<0.01*	0.23	<0.01*
BMI	0.12	0.09	0.11	0.09
MAC	0.53	<0.01*	0.51	<0.01*
Shoe size	0.21	<0.01*	0.21	<0.01*

MAC: mid-arm circumference; Cc: correlation coefficient; USG: ultrasonography; * Indicates statistically significant value.

In a comparison of baseline characteristics between RAO and non-RAO groups (Table 5), female gender, low height, low body weight, low MAC, shoe size, occupation, procedural characteristics such as puncture attempts, number of catheters used, and fluoroscopic time were found to be more prone for RAO. Factors influencing RAO are demonstrated in Table 6. Multivariate regression analysis revealed female gender($p<0.001$), current smokers ($p<0.001$), CKD ($p<0.01$), and height ($p<0.01$) as significant predictors of RAO.

Table 5: Difference in baseline characteristics between RAO and non-RAO groups

Variable	*RAO (n=62)*	*Non-RAO (n=238)*	*p-value*
Gender, n (%)			
Male	17(27.4)	190(79.8)	<0.001*
Female	45(72.6)	48(20.2)	<0.001*
Weight (kg), mean ± SD	65.74±11.68	69.71±12	0.02*
Height (cm), mean ± SD	156.76±10.5	164.05±8.020	<0.01*
MAC (cm), mean ± SD	26.84±3.29	27.66±2.95	0.05*
Shoe size(inches), mean ± SD	7.23±0.818	7.92±0.828	<0.01*
Occupation			
Outdoor workers, n (%)	10 (16.1)	100 (42)	<0.01*
Indoor and office workers, n (%)	52(83.9)	138(58)	<0.01*
Diabetes, n (%)	33(53.2)	96(40.3)	0.06
Chronic Kidney Disease, n (%)	5(8.1)	4(1.7)	0.02*
Smoking, n (%)	13(21)	135(56.7)	<0.01*
Alcoholism, n (%)	14(22.6)	104(43.7)	<0.01*
Puncture attempts, n (%)			
One	20(32.3)	196(82.4)	<0.01*
Two	39(62.9)	41(17.2)	<0.01*
Three	3(4.8)	1(0.4)	<0.01*
Number of catheters used n (%)			
One	45(72.5)	221(92)	<0.01*
Two	14(22.5)	17(7.17)	<0.01*
Three	2(3.22)	0	-
Four	1(1.6)	0	-
Time of procedure Mean (minutes), mean ± SD	23.19±9.742	18.26±6.143	<0.01*

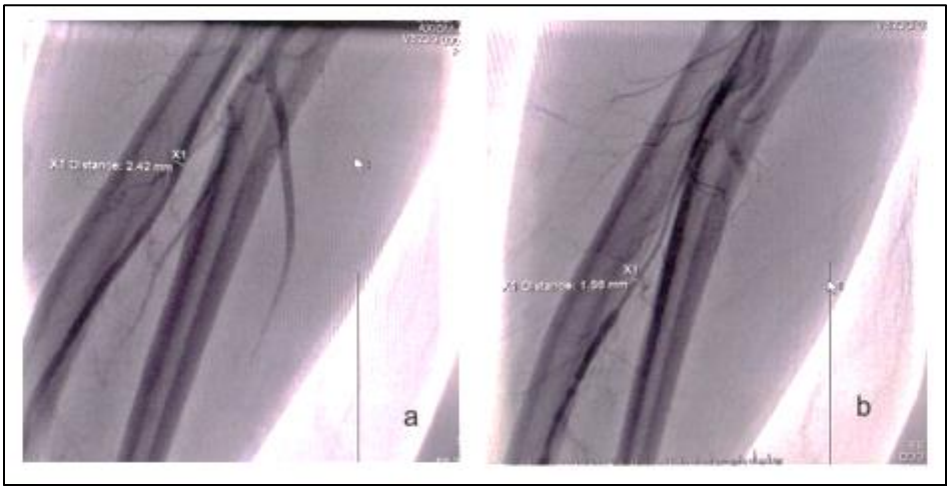

Figure 1. a: Pre-procedural radial angiogram. b: Post-procedural radial angiogram

Table 6: Multivariate regression analysis for factors influencing RAO

Variable	*OR (95% CI)*	*P-value*
Female	10.48 (5.52-19.90)	<0.001*
Current Smoker	0.20 (0.10-0.39)	< 0.001*
Alcohol	0.38 (0.12- 0.72)	0.003*
Diabetes	1.68 (0.96 - 2.95)	0.06
Hypertension	0.8 (0.46 - 1.41)	0.44
CKD	5.14 (1.34- 19.72)	0.01*
Height	0.82 (0.7 - 0.96)	0.01*

Discussion

In this study, the radial artery diameter was assessed using Color Doppler USG and angiography before and after the procedure, identifying risk factors for Radial Artery Occlusion (RAO) over a three-month follow-up period. Angiography offers advantages in detecting anatomical variations and immediate complications like dissection or perforation [10]. Research has shown that Asians typically have a smaller radial artery diameter (2.63 ± 0.35 mm) compared to Western populations (3.67 ± 0.8 mm) [11]. In this study, the mean radial artery diameter was measured at 2.6 ± 0.01 mm before intervention and 2.1 ± 0.03 mm after the procedure using USG. Similarly, Aykan et al. [12] reported the mean diameter of the right radial artery as 2.62 ± 0.45 mm using USG. Costa F et al. [13] found that the radial artery diameter decreased three hours post-procedure (baseline: 2.25 ± 0.50 mm versus 3 hours: 2.02 ± 0.66 mm; p=0.01) and partially recovered at a 30-day follow-up (3 hours: 2.02 ± 0.66 mm versus 30 days: 2.14 ± 0.68 mm; p=0.38). In a Turkish population, Okuyan H et al. [14] reported the angiographically derived mean radial artery diameter as 2.3 ± 0.40 mm, which is lower than the 2.06 ± 0.03 mm reported in this study. A study by Dwivedi et al. [15] found a 12% incidence of RAO, while this study reported a 21% incidence, likely due to the use of color Doppler to confirm RAO. In this study, 10 (16.1%) patients with RAO achieved complete recanalization over the three-month follow-up. Nagai S et al. [16] found RAO in 9% of patients, with 60% requiring recanalization after surgery. The present study found a significantly lower weight in the RAO group (65.74 ± 11.68 kg; p=0.02) compared to the non-RAO group (69.71 ± 12 kg; p=0.02). Similarly, Rashid M et al. identified body weight as a predictor of RAO, likely due to larger radial arteries in heavier individuals [5].

Mid-arm circumference (MAC) was observed as a possible predictor of RAO, although other studies, such as those by Aykan et al. [12] and Okuyan H et al. [14] considered wrist circumference instead. This study found a statistically significant difference in occupation between the RAO and non-RAO groups. Out of 62 patients in the RAO group, 52 (83.9%) were indoor and office workers, who are more susceptible to RAO than outdoor workers 10 (16.1%). Occupational adaptation in the body may lead to enhanced blood supply to more active organs, resulting in muscle hypertrophy. This may lead to larger vessel diameters and increased blood supply to the extremities in outdoor workers [12]. In this study, shoe size emerged as another RAO variable, with the mean shoe size being lower in the RAO group compared to the non-RAO group (7.23 ± 0.818 inches vs. 7.92 ± 0.828 inches). Aykan AC et al. [12] also reported shoe size and occupation as possible predictors of RAO [12]. Procedure-related factors, such as the number of catheters used, the number of puncture attempts, and the duration of the procedure, appeared as possible predictors of RAO. Costa F et al. [13] found that the number of puncture attempts for radial cannulation was associated with a loss of radial artery pulsation (p=0.027) and an increased likelihood of RAO (p=0.022). According to Sadaka et al. [17] the RAO group (2.2 ± 1.4; p=0.032) used more catheters overall than the non-RAO group (1.7 ± 0.9; p=0.032).

In this study, multivariate regression analysis identified smoking habit (p<0.001, CI 95%=0.20), height (p=0.01, CI 95%=0.82), female gender (p<0.001, CI 95%=10.48), and CKD (p=0.01, CI 95%=0.82) as independent predictors for RAO. However, the PROPHET-II study did not find significant associations between RAO and smoking habit (p=0.17) or height (p=0.14) [18]. More than half of the patients developed RAO in the presence of CKD, possibly due to endothelial dysfunction and a hypercoagulable state in CKD [19]. However, the PROPHET study did not find a significant association between CKD and RAO [20]. This study reported a substantial difference in females, similar to studies by Garg N. et al. [8] and Uhlemann M. et al. [15] Their research suggests that females are more prone to RAO, potentially leading to radial artery spasm. Once radial artery patency was confirmed by USG and angiography the day after transradial access (TRA), no further RAO incidents occurred. Moreover, patients with RAO were asymptomatic at the three-month follow-up, indicating that RAO is generally a benign phenomenon.

Study limitations

The study was conducted at a single centre with a small number of patients and short-term follow-up. The current study included more male participants than female participants. Additionally, the enrolled cases of CAG were more than PCI.

Conclusion

RAO was the most commonly encountered clinical complication after TRA. Decreased radial artery diameter (evident on USG and angiogram) and incidences of recanalization were observed after TRA. Weight, height, MAC and shoe size can be the predictors of radial artery diameter. Height, female gender, CKD, and smoking habits were found as independent predictors of RAO; hence, they should be considered while predicting RAO. Nevertheless, future study with a larger sample size is warranted to explore more about predictors of RAO.

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