

Anatomical features of the radial artery in the Xinjiang population in China and its impact on the transradial coronary intervention procedure

T. Naman¹, G.Q. Li², H. Cheng², B. Hu³

¹People's Hospital of Yakan County in Xinjiang China, Yakan in Xinjiang China, Yakan, China

²Department of Cardiology, People's Hospital of Xinjiang Uygur Autonomous Region, Urumqi, Xinjiang, China

³Department of Cardiology, East Hospital, Tongji University School of Medicine, Shanghai, China

[Received: 30 April 2019; Accepted: 14 June 2019]

Background: The anatomical features of the radial artery (RA) influence the transradial coronary intervention. The aim of this study is to discuss the anatomical features of the RA in the Xinjiang population and to guide interventionists in decreasing complications and improving success rates.

Materials and methods: We enrolled 1731 patients in this study. All relevant basic information was recorded in detail, and the RA diameter was examined. Patients were divided into a RA variation group and a RA non-variation group; univariate and multivariate factor analyses were performed to evaluate the relevant factors for RA diameter and the predictive value of the variable factors in RA variations.

Results: The mean RA diameter for all patients was 3.01 ± 0.14 mm. The multi-factorial analysis showed that height, gender, and occupation are significantly associated with RA diameter ($p < 0.05$). The incidence of RA variation was 4.97% (86/1731). Multi-factorial analysis showed that: gender (OR 2.72, 95% CI 1.469–5.037, $p < 0.01$), occupation (OR 2.228, 95% CI 1.0.000–0.012, $p < 0.001$) and RA inner diameter (OR 0.002, 95% CI 0.000–0.012, $p < 0.001$) are significantly associated with the incidence of RA variation.

Conclusions: The mean RA diameter in the Xinjiang population was 3.01 ± 0.14 mm, height, gender, occupation are associated with RA diameter, gender, farmer, RA diameter are associated with RA variation. These factors can guide the interventionists to choose the appropriate equipment before the operation then can increase the efficiency of operation and prevent from the complications. (Folia Morphol 2020; 79, 2: 226–235)

Key words: radial artery, predictive factors, transradial coronary intervention

INTRODUCTION

As the internal diameter of the femoral artery is large, the puncture site can conveniently be located. Puncturing is easy, thus, it is used for initial coronary intervention [6]. However, due to important vascular and nerve companions with the femoral artery

pathway and the anatomical position is deeper, there are complications such as puncture site bleeding; thus, interventionists realise the drawbacks of the femoral artery approach. The transradial approach (TR) for percutaneous coronary intervention (PCI) has been shown to decrease vascular complications

and improve clinical outcomes compared with the transfemoral approach (TF) in both young [1] and elderly patients [9]. The TR-PCI is associated with a lower risk of access site bleeding and haematoma [7, 16], early patient ambulation [4], shorter length of hospital stay [8], and lower hospital costs [2, 20]. Therefore, the radial artery (RA) approach has been widely used as an alternative access for coronary intervention in many centres [13]. However, because of the variation in the RA, it is prone to spasm, and puncturing is not easily accomplished [10], it is also possible that intubation difficulty and RA occlusion may occur [15].

The purpose of this study is to analyse the anatomical features of the RA in the Xinjiang population, its clinical predictive factors and impact on the transradial artery coronary intervention, therefore providing some information about anatomical features of RA to the interventionists to select the appropriate interventional instruments and operation routes.

MATERIALS AND METHODS

Study population

A total of 1731 patients who underwent transradial coronary intervention for the first time during the period of January 2016 to June 2016 in People's Hospital of Xinjiang Uyghur Autonomous Region. The inclusion criteria were as follows: 1) positive Allen's test; 2) the patients underwent first-time transradial coronary procedures and simultaneously completed angiography of the RA; 3) the patient signed an informed consent form. The exclusion criteria were as follows: 1) negative Allen's test; 2) faint or no RA pulse; 3) failure of the RA puncture or requiring alternative arterial access to complete the angiography; 4) previously performed transradial intervention; 5) patients with peripheral vessel disease.

Methods

All patients were examined for the inner diameter of the right RA by ultrasound. Measurement of the RA diameter was made at a point approximately 2 cm proximal to the styloid process, where the puncture of the RA is usually made. A mean of three readings was taken for the diameter of the RA, and then RA angiography was undertaken, recording the anatomic variation of the RA. If the procedure failed, the route changed to the right RA or the femoral artery route, the choice was left to the interventionist's discretion. Procedure length of time, fluoroscopy time, and

radiation dose were recorded, and coronary arteriography or the coronary intervention was performed. Univariate and multivariate factor analyses were performed to evaluate the predictive value of variable factors for RA variations.

Statistical analysis

SPSS software (version 23.0; SPSS Inc., Chicago, IL, USA) was used; continuous quantitative data were expressed as the mean $\pm$ standard deviation, while discrete quantitative data were expressed as frequency (percentage). Student's *t* test was used for the intra-group comparison of data, while a modified *t*-test was used when population variance was heterogeneous; the average value comparison of different groups was analysed via the standard variation, and the *t*-test and variance analysis were used for the comparison of the average number of samples. If there was homogeneity of variances with the log rank test and analysis of variance with Welch's *t* test, the χ^2 test was used for frequency data. Stepwise logistic regression was used to analyse the effect of the variables on the incidence of RA variation, and the goodness of fit of the logistic regression model was tested with the Hosmer-Lemeshow test. Multiple linear regression was used for relevant analysis, and $p < 0.05$ was defined as significant.

Definition of anatomical variations

Variations in the RA were defined as Numasawa et al. [15] anatomical variations in the RA, including abnormal origin of the RA, radioulnar loop and tortuous configuration. The site of abnormal origin was determined relative to the intercondylar line of the humerus. This line represented the proximal border of the antecubital fossa. Bifurcation of the brachial artery proximal to this line was considered to be abnormal origin of the RA. A radioulnar loop was defined as the presence of a full 360° loop of the RA distal to the bifurcation of the brachial artery. Tortuous configuration of the RA was defined as the presence of maximum angulation of $> 90^\circ$.

Definition of procedure length of time

The time period between the beginning of pushing the guidewire into the RA and the head end of the catheter reaching the sinus of the aorta was recorded. If the procedure was not succeed, it was necessary to change the access site, and it included all of the procedure time, which was used for disinfection of

Table 1. The univariate analysis of the relevant factors of radial artery diameter

Variables	Patients numbers	Inner diameter	$t/\chi^2/r$	P
Age	1731	–	–0.106	< 0.001*
Weight	1731	–	0.191	< 0.001*
Height	1731	–	0.318	< 0.001*
Body mass index	1731	–	0.023	0.331
Gender:			–13.156	< 0.001*
Male	1462	3.04 ± 0.129		
Female	269	2.91 ± 0.138		
Ethnicity:			0.536	0.709
Han	735	3.01 ± 0.15		
Uyghur	733	3.02 ± 0.13		
Hui	134	3.01 ± 0.13		
Kazakh	95	3.01 ± 0.13		
Other	34	3.00 ± 0.18		
Occupation:			14.737	< 0.001*
Cadre	1380	3.02 ± 0.14		
Farmer	187	2.98 ± 0.12		
Other	164	2.98 ± 0.12		
Smoking:			–5.717	< 0.001*
Yes	556	3.04 ± 0.125		
No	1175	3.00 ± 0.143		
Drinking alcohol:			–4.187	< 0.001*
Yes	357	3.04 ± 0.126		
No	1374	3.01 ± 0.141		
Hyperlipidaemia:			1.770	0.077
Yes	234	3.00 ± 0.145		
No	1497	3.02 ± 0.138		
Hypertension:			0.243	0.808
Yes	998	3.01 ± 0.137		
No	733	3.02 ± 0.140		
Diabetes:			–2.043	0.041*
Yes	516	3.01 ± 0.147		
No	1215	3.02 ± 0.127		

*Significant differences

the new puncture site, puncturing the new puncture site, etc.

RESULTS

Characteristics of the inner diameter of the radial artery and its related factors

For all patients, the mean diameter of the RA was 3.01 ± 0.14 mm, and the diameter of the RA was greater than a 6 F Cordis sheath in 98.5% (1705/1731) of the patients and greater than a 7 F Cordis sheath in 9.5% (164/1731) of the patients. A comparison

of the relevant factors for RA diameter is presented in Table 1.

The results showed that age, weight, height, female gender, farmer occupation, smoking, drinking alcohol, and diabetes are relevant for RA diameter ($p < 0.005$).

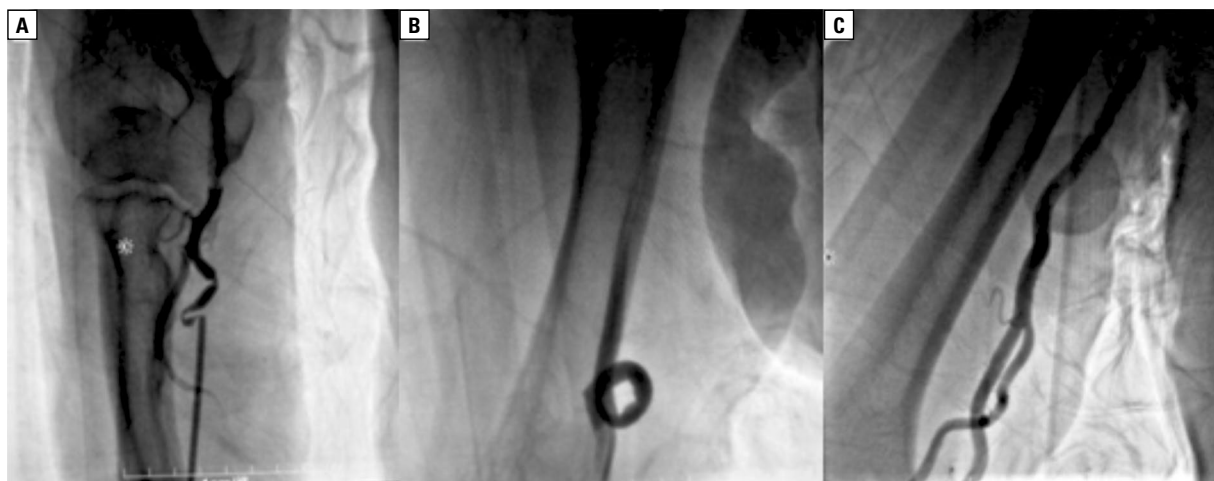
Multivariate factor analysis of relevant factors with $p < 0.1$ was performed (Table 2).

The results showed that height, female gender, and occupation of farmer are significantly associated with the RA diameter ($p < 0.001$).

Table 2. Multivariate logistic regression analysis of radial artery diameter

Variables	B	SE	β	t	P	95.0% CI	
						L-limit	U-limit
Constants	2.479	0.077		32.256	0.000	2.328	2.630
Age	-0.004	0.003	-0.030	-1.258	0.209	-0.009	0.002
Height	0.004	0.000	0.237	8.615	0.000*	0.003	0.005
Weight	0.000	0.000	0.009	0.345	0.730	0.000	0.001
Gender	-0.082	0.010	-0.214	-8.420	0.000*	-0.101	-0.063
Occupation	-0.024	0.010	-0.053	-2.342	0.019*	-0.044	-0.004
	-0.032	0.011	-0.067	-2.984	0.003*	-0.053	-0.011
Smoking	0.001	0.009	0.002	0.059	0.953	-0.017	0.018
Drinking	0.001	0.010	0.004	0.122	0.903	-0.018	0.021
Hyperlipidaemia	-0.012	0.009	-0.030	-1.367	0.172	-0.030	0.005
Diabetes	0.001	0.007	0.003	0.135	0.893	-0.012	0.014

*Significant differences; CI — confidence interval; SE — standard error

**Figure 1.** Types of radial artery variation founded in this study; **A.** Tortuous; **B.** Loop; **C.** Abnormal origin.

The incidence of radial artery variation and types

The total incidence of RA variation in the Xinjiang population is 4.97% (86/1731); the incidence in females is higher than the incidence in males (14.5% vs. 3.32%, $p < 0.001$). The incidence in various ethnic groups is: Hanzu: 5.17% (38/735), Uyghur: 5.59% (41/733), Hui zu: 2.98% (4/134), Kazakh: 3.15% (3/95), and other ethnic groups 0% (0/34).

There were several types of variations found: radial artery tortuous, radioulnar loop and abnormal origin of the radial artery (Fig. 1).

Its incidence are 3.99% (69/1731), 0.29% (5/1731), and 0.7% (12/1731), respectively (Fig. 2).

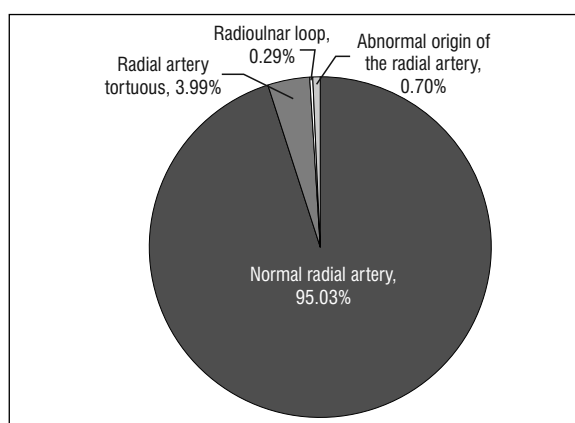
**Figure 2.** The percentage of various kind of radial artery variations.

Table 3. Distribution of radial artery (RA) variation and change in access site

Variation type	Case number	Right RA	Changed to left RA	Changed to femoral artery
Abnormal origin of RA	12	7	2	3
Radial artery loop	5	0	1	4
Radial artery tortuosity	69	56	6	7

Table 4. Interventional procedure outcome of patients by radial artery

Parameter (number/%)	Normal group	Variation group	P
Radial artery spasm	45/2.70%	29/33.80%	< 0.001*
Failure of TRI by right radial artery	25/1.50%	23/26.70%	< 0.001*
Relieving spasm	20/1.58%	6/0.07%	< 0.001*

*The differences are significant; TRI — transradial coronary intervention

The impact of radial artery variation on transradial coronary intervention

Distribution of radial artery variation and change of artery access. In 86 cases of patients with RA variation, 23 cases required changing the RA access, 9 cases changed to the opposite RA access, which included 2 cases of abnormal origin of the RA, 1 case of RA loop, and 6 cases of RA tortuosity. A total of 14 cases changed to femoral artery access, which included 3 cases of abnormal origin of the RA, 4 cases of RA loop, and 7 cases of RA tortuosity (Table 3).

Interventional procedure outcome of patients by radial artery. In the following coronary angiography (CAG) or PCI, 45 cases of serious spasm occurred in patients with normal RA, and there were 29 cases in the RA variation group; the difference between the two groups was significant ($p < 0.001$). Via giving antispasmodic drugs, waiting for a few minutes, or changing the primary guide wire to a super slip guide wire in the RA normal group, 20 cases had relieved spasm performing the CAG or PCI by right RA, and 25 cases did not have spasm relieved, which necessitated changing the RA access, 9 cases were changed to left RA access, and 16 cases were changed to femoral artery access. The failure rate of CAG or PCI by right RA was 1.5% (25/1645). In the RA variation group, 29 cases of serious spasm occurred. By using the same method with the spasm cases, which occurred in the RA normal group, 6 cases had relieved spasm performing the CAG or PCI by right RA, and 23 cases did not have spasm relieved, which necessitated changing the RA access, 9 cases were changed to left RA access and 14 cases were changed to femoral artery access. The failure rate of CAG or PCI by right

RA was 26.7% (23/86), and the difference between the two groups is significant ($p < 0.001$; Table 4).

The impact of radial artery variation on transradial coronary intervention procedure. The procedure length of time in the RA normal group was 85.19 ± 9.83 s and 267.75 ± 24.50 s in the RA variation not-changed route group, while it was 895.00 ± 80.40 s in the RA variation and changed-route group; the difference between the three groups is significant ($p < 0.01$). Fluoroscopy time in the RA normal group was 55.27 ± 5.90 s, and in the RA variation not-changed route group, it was 163.30 ± 23.62 s, while it was 204.61 ± 52.57 s in the RA variation and changed-route group, and the difference between the three groups is significant ($p < 0.01$). The radiation dose was 24.29 ± 3.08 mGy in the RA normal group and 76.59 ± 12.58 mGy in the RA variation not-changed route group, while it was 94.91 ± 24.15 mGy in the RA variation and changed-route group, and the difference between the three groups is significant ($p < 0.01$; Table 5).

The predictor factors of radial artery variation

According to the definition of RA variation, patients were divided into the RA variation group and the RA non-variation group. A comparison of clinical baseline data is shown in Table 6.

The results showed in the comparison of age, weight, height, inner diameter, female gender, occupation of farmer, smoking, drinking alcohol and hyperlipidaemia, the differences between the two groups are significant ($p < 0.05$).

The related factors for RA variation were analysed with multivariate logistic regression (Table 7).

Table 5. The impact of radial artery variation on transradial coronary intervention procedure

Variables	Radial artery normal	Radial artery variation not-changed route	Radial artery variation and changed route	F	P
Procedure length of time [s]	85.19 ± 9.83	267.75 ± 24.50‡	895.00 ± 80.40‡#	2634.154	< 0.001*
Fluoroscopy time [s]	55.27 ± 5.90	163.30 ± 23.62‡	204.61 ± 52.57‡#	706.172	< 0.001*
Radiation dose [mGy]	24.29 ± 3.08	76.59 ± 12.58‡	94.91 ± 24.15‡#	604.510	< 0.001*

Compared with the normal group ‡p < 0.05, compared with the radial artery variation not-changed route group #p < 0.05; *significant differences

Table 6. Univariate-factor analysis of the related factors of radial artery variation

Variables	Variation (–)	Variation(+)	t/χ^2	P
Age [year]	58.90 ± 11.34	62.42 ± 9.88	–2.825	0.005*
Weight [kg]	75.82 ± 13.23	72.86 ± 14.8	2.008	0.045*
Height [cm]	167.87 ± 8.45	164.41 ± 9.16	3.685	< 0.001*
Inner diameter [mm]	3.02 ± 0.14	2.88 ± 0.14	9.423	< 0.001*
Body mass index [kg/m ²]	26.91 ± 4.90	26.95 ± 5.26	–0.071	0.943
Gender (number/%):			61.137	< 0.001*
Male	1415/86.00	47/54.65		
Female	230/14.00	39/45.35		
Ethnicity (number/%):			4.005	0.405
Han	697/42.47	38/44.19		
Uyghur	692/42.17	41/47.67		
Hui	130/7.92	4/4.65		
Kazakh	92/5.61	3/3.49		
Other	34/1.83	0/0.00		
Occupation (number/%):			15.457	< 0.001*
Cadre	1323/80.55	57/66.28		
Farmer	167/10.06	20/23.26		
Other	155/9.39	9/10.47		
Smoking (number/%):			5.149	0.023*
Yes	537/32.64	18/20.93		
Not	1108/67.36	68/79.07		
Drinking (number/%):			8.554	0.003*
Yes	349/21.22	7/8.14		
Not	1296/78.78	79/91.86		
Hyperlipidaemia (number/%):			4.335	0.037*
Yes	215/13.07	18/20.93		
Not	1430/86.93	68/79.07		
Hypertension (number/%):			1.000	0.317
Yes	943/57.33	54/62.79		
Not	702/42.67	32/37.21		
Diabetes (number/%):			0.117	0.732
Yes	488/29.67	27/31.4		
Not	1157/70.33	59/68.6		

*Significant differences

Table 7. Multivariate Logistic regression analysis of the related factors of radial artery variation

Parameter	β	SE	Wald	P	OR	95% CI	
						L-limit	U-limit
Constants	8.919	3.469	6.612	0.010	7472.917		
Age	0.209	0.119	3.095	0.079	1.232	0.976	1.555
Height	0.029	0.019	2.409	0.121	1.030	0.992	1.068
Weight	0.005	0.010	0.275	0.600	1.005	0.986	1.025
Inner diameter	-6.271	0.927	45.808	0.000*	0.002	0.000	0.012
Gender:							
Male					1.000		
Female	1.001	0.314	10.138	0.001*	2.720	1.469	5.037
Hyperlipidaemia:							
Not					1.000		
Yes	0.492	0.297	2.746	0.097	1.635	0.914	2.925
Smoking:							
No					1.000		
Yes	0.265	0.357	0.551	0.458	1.303	0.648	2.621
Drinking alcohol:							
Not					1.000		
Yes	-0.732	0.487	2.260	0.133	0.481	0.185	1.249
Occupation:							
Cadre					1.000		
Farmer	0.801	0.296	7.322	0.007*	2.228	1.247	3.980
Other	0.082	0.392	0.044	0.835	1.085	0.503	2.342

*Significant differences; CI — confidence interval; OR — odds ratio; SE — standard error

The results of Table 7 indicated that gender (odds ratio [OR] 2.72, 95% confidence interval [CI] 1.469–5.037, $p < 0.01$), occupation (OR 2.228, 95% CI 1.000–0.012, $p < 0.001$), and inner diameter of the RA (OR 0.002, 95% CI 0.000–0.012, $p < 0.001$) are significantly associated with the existence of RA variation; the risk of RA variation in females is 2.72 times as high as males. The risk of RA variation in farmers is 2.228 times as high as cadres, and the incidence of RA variation decreases 500 times with every additional 1 mm of RA diameter.

DISCUSSION

The transradial approach was initially described by Campeau in 1989 and is the common access sites for cardiac catheterisation [11, 18]. Although the radial approach has been shown to be an effective alternative that reduces vascular complications [5, 17], because of the existence of RA variation, it cannot be used in all patients. Our study analysed the anatomical features of the RA and their impact

on transradial coronary intervention, the predictive factors for RA variations.

Features of the radial artery diameter

The mean inner diameter of all patients is 3.01 ± 0.14 mm, and the inner diameter of the RA was greater than a 6 F Cordis sheath in 98.5% (1705/1731) of patients and greater than a 7 F Cordis sheath in 9.5% (164/1731) of patients. The 6 F and 7 F Cordis sheath tubes, which have an outer diameter of 2.67 mm and 3.02 mm, respectively, are commonly used in coronary interventions. Li et al. [11] reported that the incidence of post-transradial coronary intervention stenosis and shunt of the RA dramatically increases when the ratio of the inner diameter of the RA to sheathing tube is < 1.0 , it is reported that [3]: it increase the occurrence of RA occlusion and the risk of medial dissections if the diameter/sheath ratios ≤ 1 . Therefore, it is safe to utilise a sheath tube, which has a smaller outer diameter than RA diameter; thus, it is important to evaluate the RA diameter by relevant factors to avoid complications.

Related factors of radial artery diameter

Multivariate analysis showed that gender, height, and occupation are significantly associated with RA diameter. The results of this study are different from other report [11] that: gender, weight, and diabetes affect the RA diameter. There is a coincidence in two reports: gender is the relevant factor for RA diameter; Li et al. [11] reported that weight positively affects RA diameter. This study found that: height are relevant with it, in some means: weight is directly related to height, therefore it can be seen that two report are same in a sense. As far as diabetes, others reported that diabetes affects the RA diameter, although in our study, the univariate-factor analysis, diabetes was shown to be relevant for the RA diameter, it can be seen that the two reports are the same in a sense.

Analysis of the related factors of radial artery diameter

The correlation between height and RA diameter: Height is the relevant factor for the RA diameter, and RA diameter increases 0.004 mm with every additional 1 cm increase in height. Normally, the diameter of every organ of the body is correspondingly related to body stature diameter, so there is no strange to association between RA diameter and height.

The correlation between gender and RA diameter: The result of our study: The mean inner diameter in female is smaller than in male, all of the female body diameter is smaller than the male and corresponds with a smaller RA diameter.

The correlation between occupation and RA diameter: The RA diameter of farmers is smaller than cadres and may have to do with the heavy activity of a farmer's life, and heavy activity may impact the diameter of the radial artery.

The incidence of radial artery variation and its predictive factors

The incidence of RA variation is reported differently in different literature. It is 16.2% in the population of Southern China [11], according to the Autopsy study, the incidence of upper limb artery variation is 4–18.5% [12]. In patients who accepted transradial coronary intervention, the incidence of RA variation is 7.4% to 22.8% [12, 19, 21, 23] found by angiographic examination.

This study found that the incidence of RA variation is 4.97% (86/1731). These data are lower than other data [11] because our study's scope is smaller, and is limited to the anatomical variation of the RA. The other researcher's study includes the variation of the RA and the upper limb artery, including RA variation, humerus artery variation, subclavian artery variation etc.

It is reported that [11] the failure rate of transradial artery coronary intervention is 1.8% in the normal RA group and 22.8% in the RA variation group. In our study, the failure rate of transradial artery coronary intervention is 1.5% in the normal RA group and 26.7% in the RA variation group. It can be seen that RA variation is the main cause for failure of transradial artery coronary intervention. Different studies have reported differently about the failure rate of coronary intervention by the RA [12, 14, 15, 19, 22]. The reason for these differences may be related to several factors, including the technical level of the surgeons and the existence of RA variation.

Predictive factors for RA variation: Multivariate analysis showed that the RA diameter, gender, occupation have predictive value for the existence of RA variation. It is reported that [11] the predictive factors for RA variation in Southern China population are: advanced age, female gender, short stature, body mass index, hypertension, hyperlipidaemia, smoking, etc. There are some differences in the reports of the two studies; possible reasons are that on the one hand our scope of research is smaller than other researchers and is limited to the anatomical variation of the RA. The other researchers study includes the variation of the RA and the upper limb artery, including RA variation, humerus artery variation, subclavian artery variation, etc. On the other hand, the study population is not the same and is relevant to the stature characteristics, habits and customs.

Analysis of the predictive factors for radial artery variation

The correlation between diameter and RA variation: The smaller the inner diameter is, the more prone to RA variation, perhaps the smaller the inner diameter is the more prone the tissue of the artery to relaxing, the more thin, and the more it impacts the changing of the structure of the radial artery.

The risk of RA variation in females is 2.72 times as high as males, and the vessels are smaller and

thinner in females than in males, females become nervous more easily than males, and this factor might influence the RA resulting variation.

The risk of RA variation in farmers is 2.228 times as high as cadres; the possible reasons are that a farmer's life is long-term dominated by heavy physical activity, and a cadre's life is dominated by mental labour; thus, in the farmer's life, heavy physical activity causes the RA to pull, and nervous spasm may be the result of the variation of radial artery.

Limitations of the study

In this study, the categorisation of patient's occupation was based on the basic information from when patients were hospitalised. In our study, it was deemed that a farmer's life is dominated by heavy physical activity, and a cadre's life is dominated by mental labour; the specific labour time and its volume of active strength was not specifically recorded, analysed and compared. There are no past reports about this; therefore, this report has a certain value for evaluating the correlation between occupation and RA diameter, RA variation. The specific reason needs further study.

CONCLUSIONS

To sum up, height, gender, occupation were correlated with RA diameter. Radial artery diameter, gender, occupation have predictive value for RA variation. Therefore, it is valuable to evaluate the patient's basic clinical information to estimate the RA diameter and to find the RA variation before the operation, as information about the RA diameter and abnormal anatomy of the RA can be given to the interventionists. It is convenient for the interventionists to choosing the appropriate equipment and operation route, thus preventing complications, optimising the operation procedures, and shortening procedure time, fluoroscopy time and radiation dose, and improving the operation's success to reduce the patient's pain.

Funding

There are two foundations which supported this research: 1) Anatomical variation of radial artery and the effect and management of transradial coronary intervention to radial artery inner diameter (Grand number-2017D01C133); 2) The Top-level Clinical Discipline Project of Shanghai Pudong (Grand number-PWYgf2018-02).

REFERENCES

1. Agostoni P, Biondi-Zoccai GGL, de Benedictis ML, et al. Radial versus femoral approach for percutaneous coronary diagnostic and interventional procedures; Systematic overview and meta-analysis of randomized trials. *J Am Coll Cardiol*. 2004; 44(2): 349–356, doi: [10.1016/j.jacc.2004.04.034](#), indexed in Pubmed: [15261930](#).
2. Bertrand OF, De Larochellière R, Rodés-Cabau J, et al. A randomized study comparing same-day home discharge and abciximab bolus only to overnight hospitalization and abciximab bolus and infusion after transradial coronary stent implantation. *Circulation*. 2006; 114(24): 2636–2643, doi: [10.1161/CIRCULATIONAHA.106.638627](#), indexed in Pubmed: [17145988](#).
3. Bi XL, Fu XH, Gu XS, et al. Influence of puncture site on radial artery occlusion after transradial coronary intervention. *Chin Med J (Engl)*. 2016; 129(8): 898–902, doi: [10.4103/0366-6999.179795](#), indexed in Pubmed: [27064032](#).
4. Cantor WJ, Mahaffey KW, Huang Z, et al. Bleeding complications in patients with acute coronary syndrome undergoing early invasive management can be reduced with radial access, smaller sheath sizes, and timely sheath removal. *Catheter Cardiovasc Interv*. 2007; 69(1): 73–83, doi: [10.1002/ccd.20897](#), indexed in Pubmed: [17139670](#).
5. Chase AJ, Fretz EB, Warburton WP, et al. Association of the arterial access site at angioplasty with transfusion and mortality: the M.O.R.T.A.L study (Mortality benefit Of Reduced Transfusion after percutaneous coronary intervention via the Arm or Leg). *Heart*. 2008; 94(8): 1019–1025, doi: [10.1136/hrt.2007.136390](#), indexed in Pubmed: [18332059](#).
6. Dandekar VK, Vidovich MI, Shroff AR. Complications of transradial catheterization. *Cardiovasc Revasc Med*. 2012; 13(1): 39–50, doi: [10.1016/j.carrev.2011.08.005](#), indexed in Pubmed: [22115936](#).
7. Jaffe R, Hong T, Sharieff W, et al. Comparison of radial versus femoral approach for percutaneous coronary interventions in octogenarians. *Catheter Cardiovasc Interv*. 2007; 69(6): 815–820, doi: [10.1002/ccd.21021](#), indexed in Pubmed: [17191214](#).
8. Jolly SS, Amlani S, Hamon M, et al. Radial versus femoral access for coronary angiography or intervention and the impact on major bleeding and ischemic events: a systematic review and meta-analysis of randomized trials. *Am Heart J*. 2009; 157(1): 132–140, doi: [10.1016/j.ahj.2008.08.023](#), indexed in Pubmed: [19081409](#).
9. Kassam S, Cantor WJ, Patel D, et al. Radial versus femoral access for rescue percutaneous coronary intervention with adjuvant glycoprotein IIb/IIIa inhibitor use. *Can J Cardiol*. 2004; 20(14): 1439–1442, indexed in Pubmed: [15614338](#).
10. Kiemeneij F, Hofland J, Laarman GJ, et al. Cost comparison between two modes of Palmaz Schatz coronary stent implantation: transradial bare stent technique vs. transfemoral sheath-protected stent technique. *Cathet Cardiovasc Diagn*. 1995; 35(4): 301–8, discussion 309, doi: [10.1002/ccd.1810350405](#), indexed in Pubmed: [7497502](#).
11. Li L, Zeng ZY, Zhong JM, et al. Features and variations of a radial artery approach in southern Chinese populations and their clinical significance in percutaneous coronary

- intervention. *Chin Med J (Engl)*. 2013; 126(6): 1046–1052, indexed in Pubmed: [23506576](#).
12. Lo TS, Nolan J, Fountzopoulos E, et al. Radial artery anomaly and its influence on transradial coronary procedural outcome. *Heart*. 2009; 95(5): 410–415, doi: [10.1136/hrt.2008.150474](#), indexed in Pubmed: [18977799](#).
13. Mann T, Cubeddu G, Bowen J, et al. Stenting in acute coronary syndromes: a comparison of radial versus femoral access sites. *J Am Coll Cardiol*. 1998; 32(3): 572–576, doi: [10.1016/s0735-1097\(98\)00288-5](#), indexed in Pubmed: [9741495](#).
14. Nie B, Zhou Yj, Li Gz, et al. Clinical study of arterial anatomic variations for transradial coronary procedure in Chinese population. *Chin Med J (Engl)*. 2009; 122(18): 2097–2102, indexed in Pubmed: [19781291](#).
15. Numasawa Y, Kawamura A, Kohsaka S, et al. Anatomical variations affect radial artery spasm and procedural achievement of transradial cardiac catheterization. *Heart Vessels*. 2014; 29(1): 49–57, doi: [10.1007/s00380-013-0324-3](#), indexed in Pubmed: [23430268](#).
16. Rao SV, Ou FS, Wang TY, et al. Trends in the prevalence and outcomes of radial and femoral approaches to percutaneous coronary intervention: a report from the National Cardiovascular Data Registry. *JACC Cardiovasc Interv*. 2008; 1(4): 379–386, doi: [10.1016/j.jcin.2008.05.007](#), indexed in Pubmed: [19463333](#).
17. Sciahbasi A, Pristipino C, Ambrosio G, et al. Arterial access-site-related outcomes of patients undergoing invasive coronary procedures for acute coronary syndromes (from the ComPaRison of Early Invasive and Conservative Treatment in Patients With Non-ST-Elevation Acute Coronary Syndromes [PRESTO-ACS] Vascular Substudy). *Am J Cardiol*. 2009; 103(6): 796–800, doi: [10.1016/j.amjcard.2008.11.049](#), indexed in Pubmed: [19268734](#).
18. Trilla M, Freixa X, Regueiro A, et al. Impact of Aging on Radial Spasm During Coronary Catheterization. *J Invasive Cardiol*. 2015; 27(12): E303–E307, indexed in Pubmed: [26630646](#).
19. Valsecchi O, Vassileva A, Musumeci G, et al. Failure of transradial approach during coronary interventions: anatomic considerations. *Catheter Cardiovasc Interv*. 2006; 67(6): 870–878, doi: [10.1002/ccd.20732](#), indexed in Pubmed: [16649233](#).
20. Wiper A, Kumar S, MacDonald J, et al. Day case transradial coronary angioplasty: a four-year single-center experience. *Catheter Cardiovasc Interv*. 2006; 68(4): 549–553, doi: [10.1002/ccd.20743](#), indexed in Pubmed: [16969848](#).
21. Yan Zx, Zhou Yj, Zhao Yx, et al. Anatomical study of forearm arteries with ultrasound for percutaneous coronary procedures. *Circ J*. 2010; 74(4): 686–692, doi: [10.1253/circj.cj-09-0577](#), indexed in Pubmed: [20197630](#).
22. Yang HJ, Gil YC, Jung WS, et al. Variations of the superficial brachial artery in Korean cadavers. *J Korean Med Sci*. 2008; 23(5): 884–887, doi: [10.3346/jkms.2008.23.5.884](#), indexed in Pubmed: [18955798](#).
23. Yoo BS, Yoon J, Ko JY, et al. Anatomical consideration of the radial artery for transradial coronary procedures: arterial diameter, branching anomaly and vessel tortuosity. *Int J Cardiol*. 2005; 101(3): 421–427, doi: [10.1016/j.ijcard.2004.03.061](#), indexed in Pubmed: [15907410](#).