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Quantitative analysis of right coronary artery morphology by digital subtraction angiography

Mesut Gitmez[1], Arzu Mumcu[2]

[1]*Batman Training and Research Hospital, Department of Cardiology, Batman, Türkiye*
[2]*Batman University, Vocational High School of Health Services, Department of Anatomy, Batman, Türkiye*

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Abstract

The right coronary artery (RCA) is a major target for interventional and surgical procedures, but its anatomical variations and normal reference values are not well established. This study aimed to establish the normal distribution values of the length, diameter and angle measurements of the RCA. Angiography images of the RCA of 143 patients were analyzed using digital subtraction angiography techniques. The RCA images of each patient were divided into three sections (Proximal RCA, Middle RCA, Distal RCA) and length and diameter measurements were made separately for each section. In addition, the angles formed between the posterior descending artery (PD) and posterior lateral artery (PL) of the RCA and the lengths and diameters of the PD and PL branches were measured separately. The RCA length-diameter measurements were 1.75-4.7 mm for proximal RCA, 4.75-4.2 mm for middle RCA, and 7.45-3.5 mm for distal RCA. The mean values of the angles formed between RCA-PL, PL-PD (bifurcation angle), and RCA-PD were 144.33±19.22˚, 62.67±18.94˚, 151.40±19.33˚, respectively. Our study provides important epidemiological data on the length-diameter-angle values of the RCA. The presented data will be useful in guiding the success and clinical outcomes of the RCA in both interventional and surgical procedures.

Keywords: Angiography, anatomy, right coronary artery, morphometric analysis, measurements

Introduction

The right coronary artery (RCA) is one of the main coronary arteries that provide blood to the heart. It arises from the aorta below the left main coronary artery and runs along the right atrioventricular sulcus. The RCA gives off the conus artery, sinoatrial nodal artery (SA), acute marginal branches, posterior descending artery (PD) and posterior lateral ventricular branch (PLV) during its course. The PLV is a branch of the RCA that perfuses the lateral wall of the left ventricle and is classified by Nomina Anatomica as a branch of the RCA. The RCA is dominant in 70%-90% of humans, implying that the PD artery perfuses at least 75% of the posterior wall of the left ventricle [1-4].

The RCA morphology, including its length, diameter and angle, is crucial for the diagnosis and treatment of coronary artery diseases. These measurements influence the procedural success and clinical outcomes of percutaneous coronary interventions and coronary artery bypass graft surgery. However, the RCA morphology varies widely among individuals and populations, which may have clinical and surgical consequences. Therefore, it is essential to establish the normal distribution values of the RCA morphology measurements and their potential gender differences [5-8].

Coronary artery disease is prevalent in all populations, as many epidemiological studies have demonstrated [9-11]. The length, diameter and angle of the coronary arteries are essential anatomical data for the diagnosis and treatment of coronary artery diseases. These data are particularly useful in percutaneous coronary interventions and coronary artery bypass graft surgery. The anatomic characteristics of the coronary arteries influence procedural success and clinical outcomes [12-14].

Digital subtraction angiography (DSA) is a technique that improves the contrast between blood vessels and surrounding tissues by subtracting pre-contrast images from post-contrast images [15-18]. However, morphological studies performed with this technique, especially for the RCA are very limited. This study

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Corresponding Author: Mesut Gitmez, Batman Training and Research Hospital, Department of Cardiology, Batman, Türkiye
Email: drmesutgitmez@gmail.com

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aimed to quantify the RCA morphology by using DSA technique and to examine its distribution by gender.

This study used the DSA technique to analyze the RCA morphology and to compare it with the literature. The study obtained the length, diameter and angle of the RCA by DSA and evaluated the gender difference in the RCA morphology. The study also presented the normal distribution values of the RCA morphology measurements and compared them with those in the literature. The study assumed that DSA could offer accurate and consistent measurements of the RCA morphology, that there was no notable gender difference in the RCA morphology, and that the normal distribution values of the RCA morphology measurements varied from those reported in the literature.

Material and Methods

This study was approved by the Scientific Research Ethics Committee of Batman Training and Research Hospital (Decision Date/No: 12.01.2022/291). The principles of the Helsinki Declaration were taken into consideration at all stages of our study.

Patients who underwent coronary angiography at Batman Training and Research Hospital-Angiography Unit between January 2019 and January 2021 and whose coronary arteries were found to be normal and RCA dominant were included in this retrospective study (Figure 1). Patients with a history of coronary artery bypass surgery, coronary artery stenosis, non-dominant RCA, coronary artery balloon angioplasty and/or stenting, coronary artery anomalies, heart failure, cardiomyopathy and valvular heart disease were excluded from the study. Consequently, 143 patients (57 females, 86 males) aged between 33 and 83 years were included in the study. The mean age was 58.23±12.02 years.

In our study, each RCA was firstly divided into three sections: 1- Proximal RCA (between RCA ostium and sinoatrial nodal artery) 2- Middle RCA (between sinoatrial nodal artery ostium and acute margin branch ostium) 3- Distal RCA (between acute margin branch ostium and RCA bifurcation point). Then, the diameters of each of these three segments were measured by considering their theircentre points and the lengths between the start and end points of each of them were measured separately (Figure 2a-c). After that, the angles formed between RCA-PL, PL-PD (RCA bifurcation angle), PD-RCA and the lengths (from the beginning to the endpoint) and diameters (from the center points) of PD and PL branches were measured separately (Figures 3, 4a,4b). All measurements were performed according to the 2D measurement technique.

Statistical analysis of the data obtained in the study was performed using SPSS-21 (IBM SPSS Statistics for Windows, New York, USA). Descriptive statistics were used to summarize the data as mean±standard deviation for continuous variables and frequency and percentage for categorical variables. Independent Samples t test was used for comparison between genders for continuous variables and the Chi-square test was used for comparison between genders for categorical variables. $p<0.05$ value was considered statistically significant.

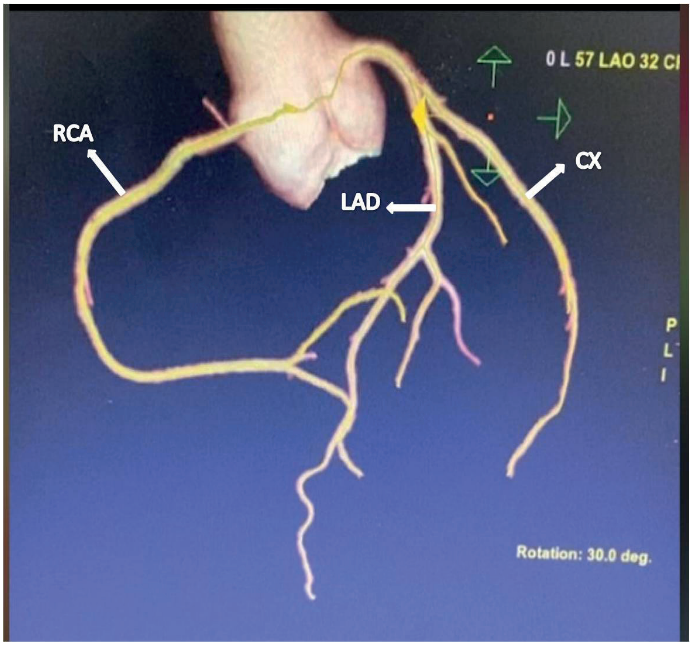

Figure 1. The three-dimensional (3D) representation of the right coronary artery (RCA), the left main coronary artery (LMCA), and the aorta (beginning part)

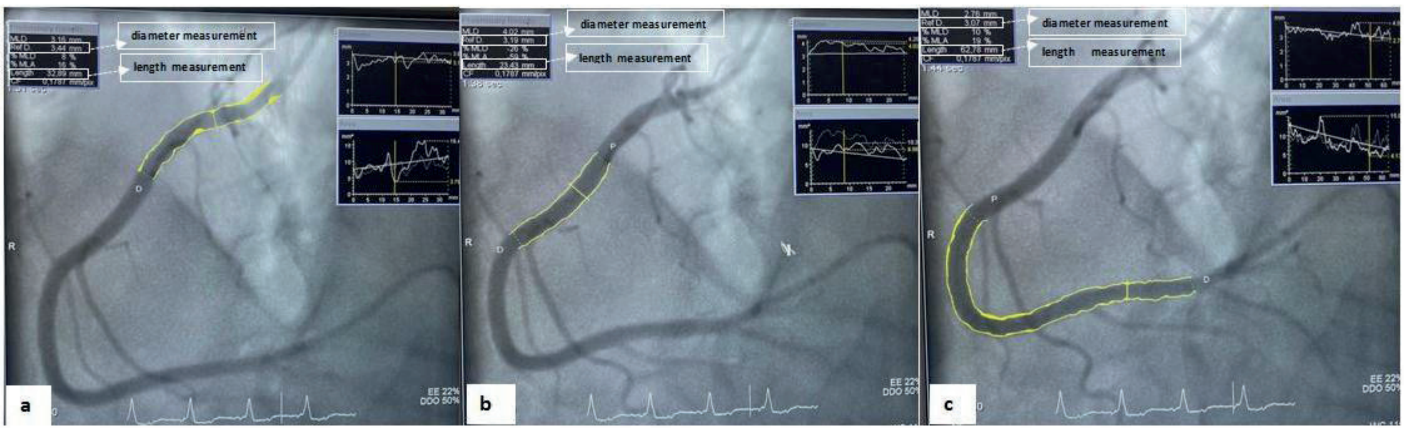

Figure 2. The measurements of RCA; (**2a**) Proximal RCA, (**2b**) Middle RCA, (**2c**) Distal RCA (RCA:right coronary artery)

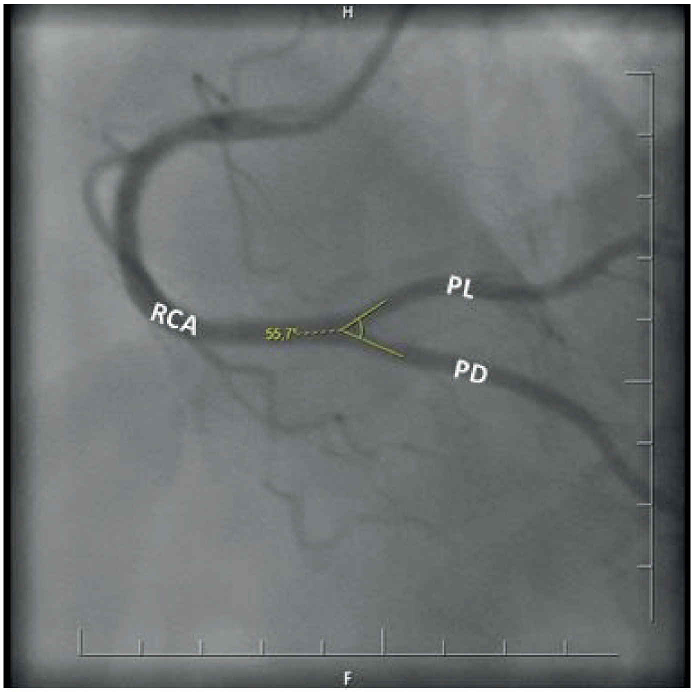

Figure 3. The RCA-bifurcation angle; the angle formed between PL and PL (RCA: right coronary artery, PD: posterior descending artery, PL: posterolateral artery)

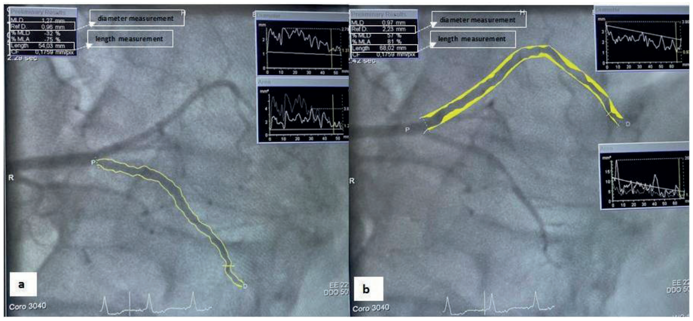

Figure 4. The measurements of PD and PL: (**4a**) Length and diameter measurements of of PD; (**4b**) Length and diameter measurements of PL (PD: posterior descending artery, PL: posterolateral artery)

Results

The results of length and diameter measurements of the proximal-middle-distal RCA and PD-PL branches for a total of 143 patients are shown in Table 1. The mean length of the proximal RCA was 17.5±0.86 mm, the mean diameter was 4.7±0.08 mm, the mean length of the middle RCA was 47.5±1.98 mm, the mean diameter was 4.2±0.07 mm, and the mean length of the distal RCA was 74.5±3.03 mm, the mean diameter was 3.5±0.07 mm. The mean length of the PD branch was 75.6±2.72 mm, the mean diameter was 1.9±0.04 mm, and the mean length of the PLV branch was 75.5±3.09 mm, the mean diameter was 1.8±0.05 mm.

Table 1. Length-diameter measurements of proximal-middle-distal RCA and PD, PL branches and distribution according to gender (n: 143)

Measurements		Gender	Mean±SD (mm)	General Mean±SD (mm)	t	P
Proximal RCA	**Length**	**Female**	16.1±0.80	17.5±0.86	-1.629	0.105
		Male	18.5±0.89			
	Diameter	**Female**	4.6±0.07	4.7±0.08	-1.130	0.260
		Male	4.8-0.08			
Middle RCA	**Length**	**Female**	46.8±1.92	47.5±1.98	-0.313	0.755
		Male	47.9±2.03			
	Diameter	**Female**	4.1±0.07	4.2±0.07	-1.155	0.250
		Male	4.2±0.08			
Distal RCA	**Length**	**Female**	75.8±2.99	74.5±3.03	0.391	0.697
		Male	73.7±3.06			
	Diameter	**Female**	3.5±0.06	3.5±0.07	-0.962	0.338
		Male	3.6±0.07			
RCA-PD	**Length**	**Female**	73.3±2.93	75.6±2.72	-0.815	0.416
		Male	77.1±2.57			
	Diameter	**Female**	1.7±0.04	1.9±0.04	-2.881	0.005*
		Male	2.0±0.04			
RCA-PL	**Length**	**Female**	73.8±2.87	75.5±3.09	-0.531	0.596
		Male	76.6±3.24			
	Diameter	**Female**	1.7±0.05	1.8±0.05	-1.616	0.108
		Male	1.8±0.05			

RCA right coronary artery; PD posterior descending artery; PL posterolateral artery

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In the statistical analysis of the detected measurements, no significant difference was found between the genders (p>0.05) in most of the measurements except for the diameter measurement of the PD branch (p<0.05). The mean diameter of the PD branch was significantly higher in males (2.0±0.04 mm) than in females (1.7±0.04 mm) (Table 1).

The measurements of the angles formed between RCA-PLV, PLV-PD (RCA bifurcation angle), and RCA-PD are shown in Table 2. The mean angle between RCA-PLV was 144.33±19.22 degrees, the mean angle between PLV-PD (RCA bifurcation angle) was 62.67±18.94 degrees, and the mean angle between PD-RCA was 151.40±19.33 degrees.

There was no statistically significant difference between genders in the results of angle measurements (p>0.05) (Table 2).

Table 2. Angle measurements between RCA-PL-PD and distribution according to gender (n: 143)

Angles (RCA-PL-PD)	Gender	Mean±SD(˚)	General Mean±SD(˚)	t	P
RCA-PL	**Female**	144.60±19.12	144.33±19.22	0.131	0.896
	Male	144.16±19.40			
PL-PD (RCA-bifurcation angle)	**Female**	64.19±19.12	62.67±18.94	0.780	0.437
	Male	61.62±18.86			
PD-RCA	**Female**	151.55±16.60	151.40±19.33	0.072	0.943
	Male	151.31±21.06			

RCA right coronary artery; PD posterior descending artery; PL posterolateral artery

Discussion

Cardiovascular diseases are the leading cause of death in the world and coronary artery diseases, which have a higher mortality rate, are of particular importance. The aim of this study was to determine the normal distribution of the length, diameter and angle measurements of the RCA and its branches in a large sample of patients using DSA technique. We hypothesized that DSA could offer accurate and consistent measurements of the RCA morphology, that there was no notable gender difference in the RCA morphology, and that the normal distribution values of the RCA morphology measurements varied from those reported in the literature.

Studies are showing that there are important relationships between some coronary artery diseases, especially atherosclerosis, and coronary artery morphology (diameter, length, angle and especially bifurcation angle), with differences observed between various races and populations [14,19-21].

Our study found that the RCA length-diameter measurements were 1.75-4.7 mm for proximal RCA, 4.75-4.2 mm for middle RCA, and 7.45-3.5 mm for distal RCA. The mean values of the angles formed between RCA-PL, PL-PD, RCA-PD were 144.33±19.22˚, 62.67±18.94˚, 151.40±19.33˚, respectively. The PD and PL branches had mean lengths of 16.67±5.83 mm and 15.40±6.12 mm, and mean diameters of 1.75±0.50 mm and 1.62±0.47 mm, respectively.

Raut et al. [22] evaluated coronary angiographies and found the diameter of the proximal RCA (the investigators defined the first acute marginal branch as proximal RCA) as 3.20±0.37 mm. In our study, the proximal RCA (between ostium-SA) was calculated as 4.7±0.08 mm. Zhang et al. [23] reported the mean length of the RCA as 18 cm, diameter as 3.97 mm at the origin, 2.15 mm at the distal end and bifurcation angle as 66˚ using computed tomography coronary angiography technique. In our study, we divided the RCA into three parts proximal, middle and distal found that the sum of the mean lengths of the parts was 139.5mm, the mean distal diameter was 3.5±0.07 mm and the bifurcation angle was 62.67±18.94˚. MacAlpin et al. [24] found proximal and distal RCA diameter measurements as 3.2±0.6 mm and 2.7±0.7 mm, respectively, in their study on coronary angiographies. These results are lower than our study (RCA proximal diameter 4.7±0.08 mm, RCA distal diameter 3.5±0.07 mm), and the reason may be related to the measurement technique. Medrano-Gracia et al. [25] found RCA diameter, PD diameter, PL diameter, RCA-PL, PL-PD, PL-PD, RCA-PD angle measurements at the crux level as 3.4±0.6 mm, 2.3±0.6 mm, 2.2±0.7 mm, 143.1±16.0˚, 59.6±21.9˚, 142.1±17.4˚, respectively, in their comprehensive study on coronary computed tomography angiograms. In our study, these results were found as 3.5±0.07mm (RCA distal diameter), 1.9±0.04mm, 1.8±0.05mm, 144.33±19.22˚, 62.67±18.94˚, 151.40±19.33˚, respectively. The aforementioned study is very similar to our study.

We also found that there was no significant difference between genders in most of the measurements except for the diameter measurement of the PD branch (p<0.05). The mean diameter of the PD branch was significantly higher in males (2.0±0.04 mm) than in females (1.7±0.04 mm). This finding is consistent with some previous studies that reported gender differences in coronary artery dimensions. However, other studies did not find any significant gender difference in RCA morphology [22-25]. The reason for this discrepancy may be related to different sample sizes, measurement techniques and population characteristics.

Our study provides important epidemiological data on the RCA morphology measurements in a Turkish population, which may differ from other populations in terms of the prevalence and severity of coronary artery diseases. The RCA morphology measurements are essential for the diagnosis and treatment of coronary artery diseases, as they may affect the risk, presentation, prognosis, and outcome of the patients. The RCA morphology measurements may also influence the selection and sizing of devices and techniques for the RCA, such as stents, balloons, grafts, and angioplasty.

Our study also aimed to be beneficial for PTCA and bypass surgery, which are two common methods of treating coronary artery disease. PTCA stands for percutaneous transluminal coronary angioplasty, which is a procedure that uses a balloon catheter to widen the narrowed artery. Bypass surgery, also known as coronary artery bypass grafting (CABG), is a surgery that creates a new route for blood flow using a graft from another part of the body. Both methods have advantages and disadvantages, and the choice of the best method depends on various factors, such as the number, location, and extent of the lesions, the patient's characteristics and preferences, and the availability and expertise of the facilities and personnel. Our study can help to guide the optimal choice and performance of these procedures for the RCA by providing accurate and consistent measurements of the RCA morphology, which may affect the procedural success and clinical outcomes. For example, the RCA length and diameter measurements may help to determine the appropriate size and length of the stents or grafts for the RCA. The RCA angle measurements may help to assess the complexity and difficulty of the lesions and the risk of restenosis or occlusion. The RCA branch measurements may help to evaluate the collateral circulation and the need for additional revascularization. According to some web search results [1-4], the RCA morphology measurements may also influence the quality of life and survival of the patients after PTCA or bypass surgery.

Conclusion

In conclusion, our study determined the normal distribution of the length, diameter and angle measurements of the RCA and its branches in a large sample of patients using DSA technique. We found that there was no significant gender difference in the RCA morphology and that the RCA morphology measurements varied from those reported in the literature. Our study provided important epidemiological data on the RCA morphology measurements in a Turkish population, which may differ from other populations in terms of the prevalence and severity of coronary artery diseases. Our study also provided useful information for guiding the optimal choice and performance of PTCA and bypass surgery for the RCA, which may affect the procedural success and clinical outcomes of the patients.

Limitations

This study has some limitations that should be acknowledged. First, this study was retrospective and based on a single center experience. Therefore, it may not reflect the general population characteristics and may be subject to selection bias. Second, this study only included patients with dominant RCA and unobstructed coronary arteries. Therefore, it may not be applicable to patients with non-dominant RCA or coronary artery stenosis or anomalies. Third, this study only measured some aspects of RCA morphology such as length, diameter and angle. Other features such as curvature, tortuosity and branching patterns were not evaluated.

Future directions

Future studies with larger sample sizes and multicenter designs are needed to confirm our findings and to explore other aspects of RCA morphology by using DSA technique or other modalities such as CTA or IVUS. Moreover, studies that correlate RCA morphology with clinical outcomes such as myocardial infarction or revascularization are also warranted.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
This study was approved by the lochal ethics committee of Batman Training and Research Hospital (Decision Date/No: 12.01.2022/291).

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