

# Anatomic variability of the coronary arterial orifices

## Koroner arter orifislerinin anatomik değişkenliği

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### ABSTRACT

**Objective:** Anatomical differences in coronary orifices (CO) are important as they are associated with myocardial ischemia and sudden death. The location of coronary orifices to the aortic valve has been studied since it is a determining point in surgical and radiological attempts.

**Methods:** The number, position, and shape of the CO, and their relation to the sinotubular junction (SJ), were studied in 100 normal adult hearts. Student-t test, one- and two-way ANOVA with posthoc Tukey's HSD tests were applied for statistical analysis.

**Results:** The mean height of the right, non- and left coronary sinuses were 18.75±1.71, 17.86±1.55 and 16.41±1.21 mm, respectively. The mean height of the right, non- and left coronary cusps were measured as 16.2±1.2, 15.9±1.1 and 12.3±2.1 mm, respectively. The left coronary artery (LCA) was observed to arise from the lower part of the SJ in 58% of the patients, while in 29% of them it originated from the SJ, and in 13% of the cases it arose from the upper part of the SJ. The right coronary artery (RCA) arising from the lower part of the SJ was seen in 78% of the patients, while it originated from the SJ in 13% of the patients, and it was observed to arise from the upper part of the SJ in 9 specimens. The diameters of the LCA and RCA were measured as 4.22±0.72 and 3.32±0.82 mm, respectively. An accessory orifice was found on the left in 47 specimens, while it was seen on the right in 54 of them.

**Conclusions:** The location of the CO should be identified according to the vertical and horizontal surfaces of the sinus. In this study, the frequency of the coronary artery orifices with different locations was provided. Such data will increase the success of coronary interventions and decrease complication rate. (*Anadolu Kardiyol Derg 2010; 10: 3-8*)

**Key words:** Coronary arteries, coronary artery orifices, cardiac catheterization, aortic valve

### ÖZET

**Amaç:** Koroner arter orifislerinin anatomik farklılığı miyokard iskemisi ve ani ölümlle ilişkilendirildiğinden önemlidir. Koroner arter orifislerinin aort kapağına göre yerleşimi cerrahi ve radyolojik girişimler için kullanılan belirleyici nokta olması nedeniyle çalışıldı.

**Yöntemler:** Koroner arter orifislerinin aort kapağının sinotubuler bileşkesine (SJ) göre yatay ve dikey planlardaki konumları, sayı, durum, şekillerinin farklı parametreler kullanılarak detaylı anatomisi 100 normal yetişkin kalpte değerlendirilmiştir. Student-t testi, tek ve iki yönlü ANOVA ile Tukey HSD testleri ile istatistiksel analiz uygulandı.

**Bulgular:** Sağ, non ve sol koroner sinuslerin yüksekliği sırasıyla 18.75±1.71, 17.86±1.55 ve 16.41±1.21 mm idi. Sağ, non ve sol koroner arterin yüksekliği 16.2±1.2, 15.9±1.1 ve 12.3±2.1 mm olarak ölçüldü. Sol koroner arter (LCA) SJ'nin altından, üstünden ve çizgisinden çıkışı sırasıyla 58%, 29% ve 13% sıklıkla görüldü. Sağ koroner arter (RCA) SJ'nin altından, üstünden ve çizgisinden çıkışı sırasıyla 78, 13 ve 9 örnekte izlendi. Sol koroner arter ve RCA çapları sırasıyla 4.22±0.72 ve 3.32±0.82 mm idi. Aksesuar koroner arter orifisi solda 47, sağda ise 54 örnekte izlendi.

**Sonuç:** Koroner arterler orifislerinin yerleşimi sinüsün dikey ve yatay düzlemlerine göre tanımlanmalıdır. Bu çalışmada farklı yerleşimlere sahip koroner orifislerinin görülme sıklığı verildi. Bu bilgi birikimi koroner arterlere yönelik girişimsel başarıyı arttıracak ve komplikasyonları azaltacaktır. (*Anadolu Kardiyol Derg 2010; 10: 3-8*)

**Anahtar kelimeler:** Koroner arter, koroner arter orifisleri, kardiyak kateterizasyon, aort kapağı

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**Accepted/Kabul Tarihi:** 11.11.2009

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doi:10.5152/akd.2010.002

## Introduction

Arterial blood reaches the cardiac tissues via two major coronary arteries, each of which arises from the base of the ascending aorta (1-3). The locations of the coronary artery orifices in relation to the aortic sinus have been reported in several studies for the identification of these anomalies by transthoracic echocardiography, angiography, and autopsy (1-4). These anomalies may act as potential causes of myocardial ischemia resulting in arrhythmias (5), angina, or infarction especially during exercise (6). Although the reason of sudden fatal events is generally unclear, they may be related to the anatomical variants and the proximal course of the coronary anomaly (7-10).

The great importance of coronary catheterization for diagnostic and therapeutic purposes has currently motivated several studies on the anatomical position of the coronary orifices (8, 11). Yet, despite the importance of the subject, most of these case studies were observed to include insufficient data concerning the detailed parameters and frequency.

The aim of our study is to determine the range in the size of the components of the aortic valve and relate this information to the anatomical pattern of the coronary arterial orifices in order to provide some data on the range of normality.

## Methods

In this study, we analyzed 100 human hearts, which were obtained in equal numbers from white male and female Turkish adults. The dissection was approved by a suitably constituted ethics committee of the institution within which the work was undertaken, and the study conforms to the Declaration of Helsinki, 1964.

The ages of individuals ranged from 29 to 79 years (mean age  $50.0 \pm 15.5$  years). The number of men specimens who were between 29-39 years of age were 20, the ones between 41-60 years-17, and those between 61-80 years-13; as for women specimens, 20 of them were between 29-39 years of age, 18 of them-between 41-60 years, and 12 of them-between 61-80 years. The average weight was 65.3 kg with a range from 50 to 82 kg. The average height was 1.70 m with a range from 1.60 to 1.95 m. Normal hearts whose causes of death were not related with heart diseases were studied at necropsy with macroscopic and microscopic views.

All fresh specimens were examined externally prior to the removal of the perivascular fatty tissue, where necessary, to expose the epicardial course of the coronary arteries. In all hearts, the aorta was opened by a longitudinal incision through its aortic cusps. The circumference of the valve was measured at the level of the sinotubular junction (SJ) which marked the transition from the aortic portion of the aortic trunk via Hagar dilators.

The sizes (height and width) of the three aortic sinuses at the level of the sinotubular junction were measured (Fig. 1). In each specimen, the number, position, and shape of the coronary arterial orifices and the presence of accessory orifices were recorded. The vertical position of each orifice was measured in

relation to the SJ and was described as either being above, below, or at the level of the junction. The radial position was measured as the distance from the orifice to the zone of apposition between the facing aortic valvular leaflets in the open position (Fig. 1).

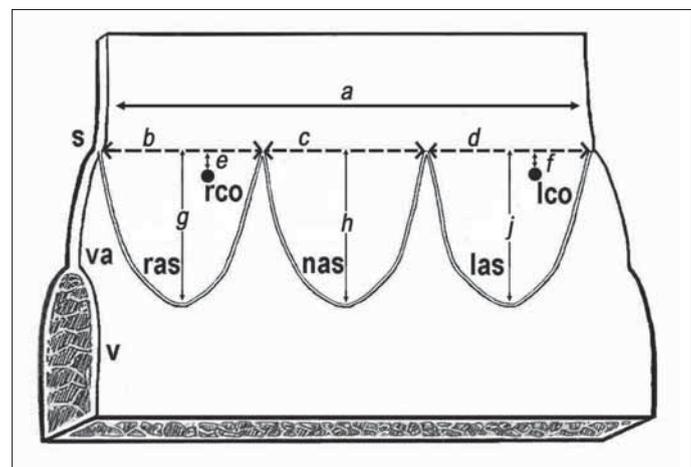
## Statistical analysis

Measurements were made by means of a digital flexible calliper in millimeters. The SPSS for Windows version 15 (Chicago, IL, USA) software was used for analysis. Student-t test, one- and two-way ANOVA with posthoc Tukey's HSD tests were applied for statistical analysis. The comparison of three aortic sinuses sizes was performed using ANOVA test. The comparison of distances between the coronary orifices and commissures of aortic leaflets were performed using Student-t test.

## Results

### Aortic root

The aortic valves in 100 specimens were normal and possessed three cusps. The average circumference of the SJ was measured as  $8.1 \pm 0.2$  cm (range 5.2 to 8.7 cm). The average circumference of the ventriculoarterial junction was measured as  $9.2 \pm 0.1$  cm (range 5.4 to 10.7 cm) (Fig. 1). There were no significant differences between the sexes. The data for the right, non- and left coronary cusps are given in Table 1. Regarding the height of the cusps, the right coronary cusp was the highest and followed by the non-coronary and the left coronary cusps. ANOVA analysis showed the right coronary sinus to be the highest ( $F=3.583$ ,  $p=0.036$ ), followed by the non- and then the left coronary sinuses. It was also shown the right commissural distance to be the greatest, followed by the non-coronary and the left commissural ones ( $F=3.522$ ,  $p=0.025$ ). No significant differences were observed between the parameters of the aortic root in any subject - male or female ( $p>0.05$ ) (Table 1).



**Figure 1. Diagram of the aortic root**

las- left aortic sinus, lco- left coronary orifice, nas- non-coronary aortic sinus, ras- right aortic sinus, rco- right coronary orifice, s- sinotubular junction, v- ventricle, va- ventriculoarterial junction, a- circumference of the valve, b, c, d- width of the aortic sinuses, e, f- coronary orifice to sinotubular junction, g, h, j- height of sinuses

### Coronary arteries

In all the specimens, coronary arteries arose from the appropriate aortic sinuses, and the main right coronary orifice (RCO) and left coronary orifice (LCO) were connected to the right and left aortic sinuses, respectively (Fig. 2). The relation between the RCO and LCO to the SJ in each heart are shown in Table 2 and Figure 2.

The results of the measurements of the distances from the RCO and LCO to the commissures located on the right and left of

**Table 1. Measurements of cusps and sinuses of aortic root according with gender**

Orifice	Sex	Age	Right	Non-coronary	Left
Height of cusps, mm	Male	29-40	16.2±1.2	15.9±1.1	12.3±2.1
		41-60	16.2±1.4	15.9±1.2	12.3±2.2
		61-80	16.2±1.5	15,9±1,2	12.4±2
	Female	29-40	16.1±1.1	15.8±1.6	12.3±1.1
		41-60	16.1±1.2	15.9±1.7	12.3±1.4
		61-80	16.1±1.4	15.9±1.2	12.3±1.6
Height of sinuses, mm	Male	29-40	18.6±1.4*	17.8±1.4	16.4±1.2
		41-60	18.7±1.3*	17.8±1.5	16.4±1.5
		61-80	18.7±1.4*	17.8±1.5	16.5±1.2
	Female	29-40	18.6±1.4*	17.8±1.8	16.4±0.2
		41-60	18.5±1.5*	17.8±1.7	16.4±0.9
		61-80	18.6±1.3*	17.8±1.2	16.4±1.2
Width of commissures, mm	Male	29-40	19.1±0.4**	17.2±1.6	16.4±1.7
		41-60	19.1±1.2**	17.2±1.8	16.4±1.8
		61-80	19.1±1.2**	17.2±1.2	16.4±2.4
	Female	29-40	19.0±0.3**	17.1±1.9	16.4±1.1
		41-60	19.0±0.3**	17.1±1.8	16.4±1.2
		61-80	19.0±0.5**	17.1±1.2	16.4±1.1

Data are presented as mean ±SD  
One-way ANOVA test, \* - F=3.583, p=0.036, \*\* - F=3.522, p=0.025

the referred orifices are shown in Table 3. The mean distances from the LCO and RCO to the bottom of the corresponding aortic sinus were 11.8±3.2 mm and 13.1±3.2 mm, respectively. No significant differences were observed between the parameters of the distances between the coronary orifices and commissures of the aortic cusps in any age groups in males (p>0.05). In females specimen group, on the other hand, significant differences were observed between the same parameters in age groups 29-40 and 41-60; 29-40 and 61-80 years (p<0.05) (Table 3).

### The left coronary artery (LCA)

The LCA arose below the SJ in 58 specimens (58%). In 13 specimens it arose at the SJ (13%), and above it in 29 (29%) (Fig. 3). The highest position was 3 mm above the SJ, whereas the lowest point in the sinus was measured as 3 mm below it (Fig. 4). The distance of the LCO in relation to the attachment of left the aortic cusps at the SJ had a mean of 9.2±2.9 mm (range 2 to 16). The data concerning the diameter and the shape of the LCO are in Table 4. In 75% of the cases (in 75 hearts), the diameter of the LCO was greater than that of the RCO, and in 5 specimens, the diameters of the LCO and RCO were equal. No significant differences were observed between the parameters of the orifices of coronary arteries among three age groups in male or female subjects (p>0.05). An accessory orifice was observed in 47 specimens and two accessory orifices were found in 33 specimens.

### The right coronary artery (RCA)

The RCA arose below the SJ in 78 specimens (78%) (Fig. 4), while in 13 specimens it arose above the SJ (13%) (Fig. 3), and in 9 of them it arose at the level the SJ (9%) (Fig. 5). The highest position was 2 mm above the junction, whereas the lowest was 3 mm below it. No significant differences were observed between the parameters of the orifices of coronary arteries among three age groups in any male or female subjects (p>0.05). The average distance of the RCO from the attachments of the right aortic cusps at the SJ was 8.2±2.3 mm (range 1 to 14). The majority of orifices

**Table 2. Location of the coronary orifice in relation to the sinotubular junction in each heart according to gender and age**

Coronary orifice	Frequency						
	Male (Age, years)			Female (Age, years)			Total
	29 - 40	41 - 60	61 - 80	29 - 40	41 - 60	61 - 80	
Both below	8	8	7	7	10	7	47%
Both above	4	2	1	3	1	1	12%
Right above, left below	2	1	-	2	1	1	7%
Right below, left above	2	2	2	2	2	2	12%
Right at the line, left below	-	1	1	1	1	-	4%
Right at the line, left above	1	1	1	1	1	-	5%
Right below, left at the line	1	1	1	3	2	1	9%
Right above, left at the line	1	1	-	1	-	-	3%
Both at the line	1	-	-	-	-	-	1%

Data are presented as proportions, percentages

were situated either at the SJ or right below it. The data concerning the diameter and shape of the RCO are shown in Table 4. An accessory orifice was found in 54 specimens (Fig. 4) and two accessory orifices were observed in 16 of them.

## Discussion

The analysis in this study shows that the right sinus structures have the greatest dimensions followed by the non-coronary, and the left coronary sinuses. According to our measurements, it can be stated that the coronary arterial orifices are not located in the center of each aortic sinus, or close to the level of the free horizontal margin of the aortic sinus. Regarding the SJ, most

coronary orifices levels were within the SJ line or are located below it. It has also been observed that the diameter of the LCO is greater than that of the RCO.

### Aortic root

Since the aortic root preserving methods are spreading in heart surgery, the importance of aortic root anatomy is increasing (1, 2, 7-10). The present study quantitatively analyzed the curvature characteristics of the acetabular cartilage surface, which have not been reported previously. The researchers reported that the average distance of the right sinus commissure was measured as 18.8 mm, and those of the non- and left coronary sinuses as 17.4 and 15.2 mm, respectively (7-10). The

**Table 3. Mean values of the distances between the coronary orifices and the commissures of the aortic leaflets according to gender and age**

Orifice	Commissure to	Mean distance, mm					
		Male (Age, years)			Female (Age, years)		
		29-40	41-60	61-80	29-40	41-60	61-80
Left	Left	12.4±3.8					
		12.4±3.7	12.4±3.6	12.4±3.9	12.3±2.1	12.3±2.2	12.3±2.2
	Right	11.4±2.22					
		11.4±2.2	11.4±3.1	11.4±4.2	10.7±1.2	11.1±1.2	11.1±1.3
Right	Left	14.2 ± 3.12					
		14.3±3	14.3±3.2	14.3±3.6	14.1±2.1	14.1±2.9	14.1±2.7
	Right	11.2±3.22					
		11.2±4.2	11.2±4.3	11.3±4.5	10.4±1.2*	10.9±2.4	11.2±3.2*

Data are presented as mean ±SD  
One-way ANOVA test, \*-p<0.05

**Table 4. Comparative data for diameters and shapes of the right and left coronary orifices according to gender and age**

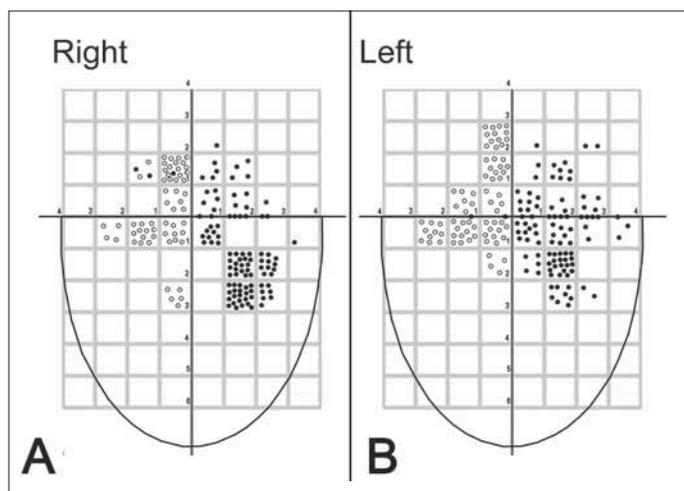
Coronary Orifices	Frequency											
	Right						Left					
	Male (Age, years)			Female (Age, years)			Male (Age, years)			Female (Age, years)		
	29 - 40	41 -60	61-80	29-40	41-60	61-80	29-40	41-60	61-80	29-40	41-60	61-80
Diameter, mm	3.3±0.8	3.3±1.0	3.3±1.2	3.3±1.1	3.3±1.2	3.3±1.1	4.22±1.2	4.23±1.3	4.3±1.4	4.2±0.9	4.21±1.2	4.22±2.3
	3.32±0.82						4.22±0.72					
Circular shape	12	10	7	12	7	1	11	10	6	12	10	6
	60						55					
Ellipsoidal	6	6	4	7	5	4	6	5	4	6	5	4
	32						30					
Cresenteric	2	1	2	1	1	1	3	2	3	2	3	2
	8						15					
One accessory orifice	10	11	6	16	10	3	10	9	4	10	9	3
	54						47					
2 and more accessory orifices	4	2	2	3	3	2	8	9		8	8	-
	16						33					

Data are presented as mean±SD and proportions  
Student's unpaired t test

mean heights of the right, non- and left coronary sinuses were 19.4, 17.7 and 17.4 mm, respectively. The average circumferences of the aortic root base and the SJ were found as 69.2 and 65.8 mm, respectively. The average diameter of the aorta was  $21.8 \pm 3.6$  mm and it increased progressively with the increase in age (9, 10); however, there were no significant gender or racial differences.

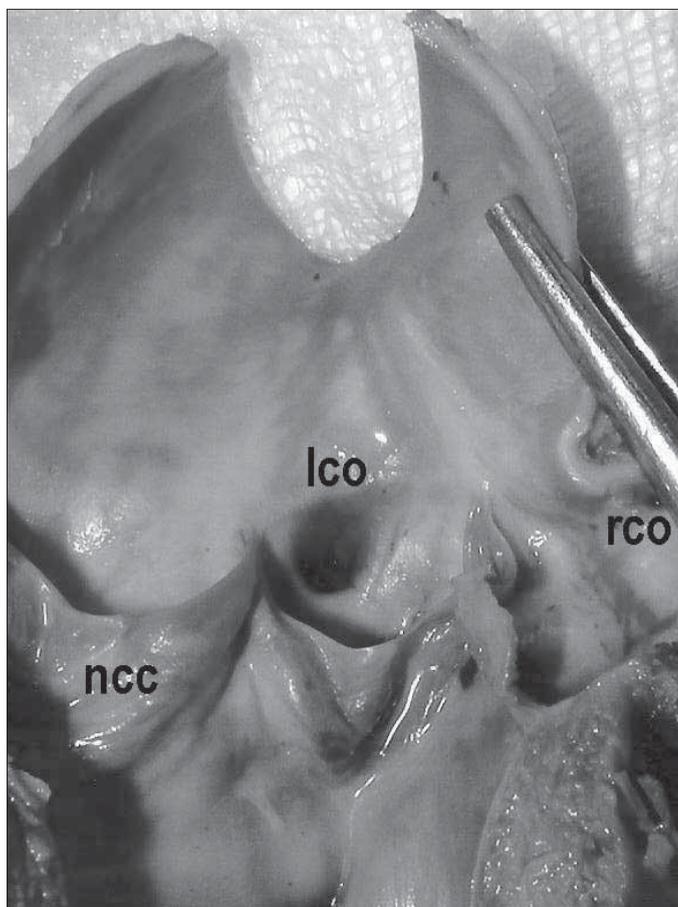
### Coronary orifices

Previous researchers investigated the morphometric and topographic aspects of the coronary orifices by correlating them with the aortic cusps (12, 13). The levels of the coronary orifices

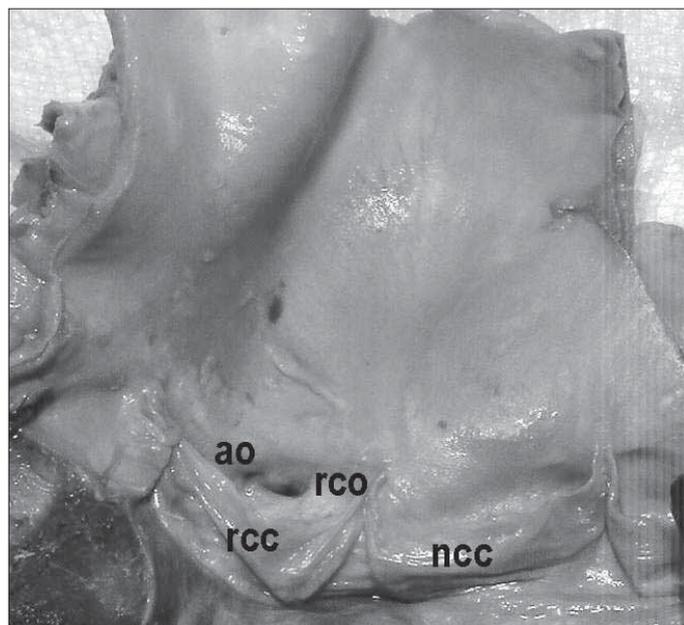


**Figure 2. Diagram showing the locations of the right coronary orifice (A) and the left coronary orifice (B) relative to the sinotubular junction**

Black points: coronary artery orifice, white points: accessory orifice

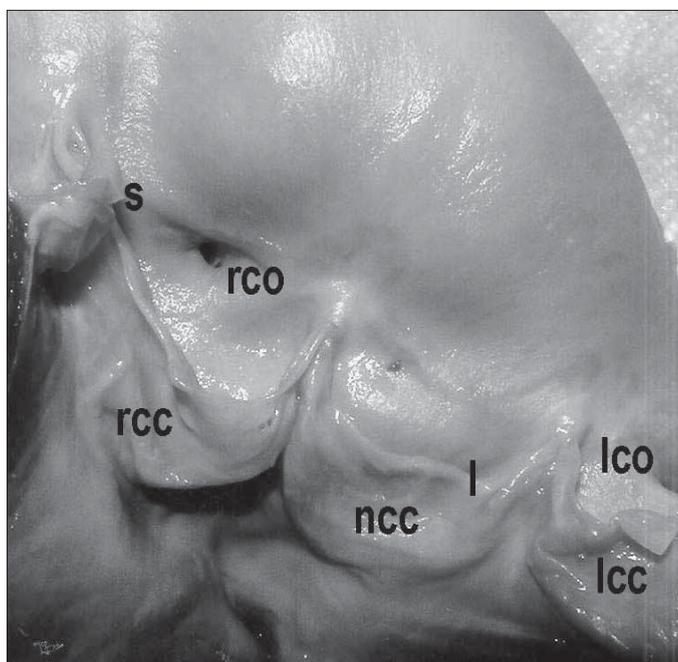


**Figure 3. Both right and left coronary orifices arising above the junction**  
lco- left coronary orifice, ncc- non-coronary cusp, rco- right coronary orifice



**Figure 4. The accessory orifice and the right coronary orifice arising below the sinotubular junction**

ao- accessory orifice, ncc- non-coronary cusp, rcc- right coronary cusp, rco- right coronary orifice



**Figure 5. The orifice of the right coronary artery arising at the level of the sinotubular junction**

lcc- left coronary cusp, lco- left coronary orifice, l- lunula, ncc- non-coronary cusp, rcc- right coronary cusp, rco- right coronary orifice, s- sinotubular junction

were variable; they were usually above or at the cuspal margins. These researchers found that the LCO was located below the SJ in approximately 42% of the cases, and it was observed above the SJ in 40%. They measured the average distance from the LCO to the bottom of the corresponding sinus as  $12.6 \pm 2.61$  mm. Former investigators reported that the RCO was located below the SJ in 60-69% of the cases and it was above the SJ in 22-28% of cases (12, 13). Previous studies showed that the mean distance from the RCO to the bottom of the corresponding aortic sinus was  $13.2 \pm 2.64$  mm. They reported that the RCO was predominantly located below the SJ (7, 8). An orifice arising one cm or more from above the SJ, which is called high takeoff, was determined as important in the genesis of turbulence, skimming of blood and sudden cardiac death (4, 5, 8, 13). The high origin is more important when there is a single coronary artery since the height of the orifice affects the axis of the left main stem together with the right proximal segment (11).

Based on the measurements of several studies, the caliber of the coronary arteries in both main stems and larger branches, ranged between 1.5 and 5.5 mm at their origins (4-6). The average reported diameters of the LCO and RCO were  $4.75 \pm 0.93$  mm and  $3.46 \pm 0.94$  mm, respectively.

#### Accessory coronary orifice

An accessory coronary orifice was found in the anterior aortic sinus in 74% of the cases. The most common of these anomalies were separate orifices of the anterior descending and left circumflex arteries from the left coronary artery (4, 5, 8-13). Another aspect that should be emphasized because of its importance in the development of collateral circulation is the presence of the accessory orifice supplying the infundibular branch of the right ventricle, which previous researchers have found in three-quarters of their specimens (13). Several mechanisms have been implicated as the cause of ischemia such as increased acuteness of the angle of origin, the orifice ridge, invariably present and functioning as a restraining valve mechanism, and compression of the anomalous artery by the right-left commissure of the aortic valve (5-7).

Embryological studies have shown that the coronary arteries develop after aortopulmonary septation, and the distal major coronary arteries develop subsequent to the formation of arterial orifices (14-16).

According to our measurements, it can be stated that all the parameters follow the pattern in which the right sinus structures have the greatest dimensions followed by the non-coronary, and the left coronary sinuses. There is also a potential importance in the arterial orifice related to the middle, the left or the right third of the space between the respective commissures. The analysis in this study show that the coronary arterial orifices are not located in the center of each aortic sinus, or close to the level of the free horizontal margins of the aortic sinus, as they were represented in many diagrams. Regarding the SJ, most coronary orifices levels were within the SJ line or are located below it. It has also been observed that the diameter of the LCO is greater than that of the RCO.

## Conclusions

The present anatomical data may help the cardiac surgeons to modify their surgical reconstruction of the aortic root in order to achieve satisfactory recovery. We believe that the results of our study will help surgery with their preoperative anatomical analysis.

#### Acknowledgements

Authors wish to thank the Council of Turkish Forensic Medicine for the permission to provide material support.

**Conflict of interest:** None declared

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