

## Gender Differences in the Types and Frequency of Coronary Artery Anomalies

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Coronary artery anomalies are rarely encountered in general population. Gender may play a role in the types and incidence of coronary artery anomalies, although the effect of gender is not well established. In the present study, we therefore aimed to investigate the frequency and location of various types of coronary artery anomalies and their correlation with gender. We assessed retrospectively the coronary angiography movies of 7,810 patients (2,214 females and 5,596 males), the method of which is distinct from the earlier studies with angiographic archive records. We defined and classified the coronary artery anomalies according to their origin, course (myocardial bridge), and termination (fistula). The incidence of coronary artery anomalies was 3.35% (262 of 7,810): 130 individuals with anomalous origin (1.66%), 105 individuals with myocardial bridges (1.34%), and 27 with fistulas (0.35%). The frequency of the coronary artery anomalies was significantly higher in the females than the males ( $p = 0.001$ ). Of the coronary artery origin anomalies, the circumflex and the left anterior descending artery originating from separate ostia in the left aortic sinus were higher in the females compared to the males ( $P < 0.001$ ). In contrast, the frequency of myocardial bridges was higher in the males ( $P = 0.01$ ). No gender difference was detected in fistulas. Thus, gender affects the types of coronary artery anomalies, except for fistulas. The determination of the presence of the coronary artery anomalies during the coronary angiography is critical for the planning of the treatment and for the proper clinical follow-up of patients.

**Keywords:** Congenital anomaly; coronary artery anomaly; fistula; gender; myocardial bridge  
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The anatomical arrangement and distribution of the coronary arteries in the normal heart are well established (Angelini et al. 1999; David and Fiss 2007; Loukas et al. 2009; Hlavacek et al. 2010). Comprehensive understanding of normal anatomy of coronary arteries, their variations, and anomalies is becoming progressively critical element in dealing with inborn and acquired heart diseases. These may deteriorate coronary circulation, which not only demands intricate surgical restorations but detailed perception of coronary circulation components to improve operational outcomes. Since substantial heterogeneity in coronary vasculature exists, no firm descriptions of the anomalous, atypical, accessory, ectopic, incidental, variant, or important have been well established yet (Frescura et al. 1998; Angelini 2002; David and Fiss 2007; Loukas et al. 2009; Hlavacek et al. 2010). The definition of the coronary artery anomalies covers not only the anomalous origin but also abnormal course and aberrant termination of the coronary arteries (Wilkins et al. 1988; Angelini 2002). Nevertheless, the terms of anomalous, atypical or abnormal coronary arteries are used in most of the publications to define any varia-

tions encountered between 0.2-5.6 percent of the general population (Engel et al. 1975; Wilkins et al. 1988; Yamanaka and Hobbs 1990; Topaz et al. 1992; Angelini et al. 1999; Sundaram et al. 2010).

Anomalous origin of the coronary arteries is the most frequently studied anomaly among the coronary artery anomalies (Chaitman et al. 1976; Wilkins et al. 1988; Angelini 2002). The coronary artery anomalies are congenital anomalies encountered incidentally during angiography and surgical interventions. Most of the coronary artery anomalies are benign in nature; nevertheless, they can infrequently cause myocardial infarction and sudden cardiac death through preventing blood flow to myocardium (Eckart et al. 2004). Even though these anomalous are seldom, they are culprit for the sudden cardiac death, particularly in young athletes (Eckart et al. 2004; Link and Mark 2008).

Myocardial bridge is the second most common type of the coronary artery anomalies. Coronary arteries normally run over the cardiac musculature; however, occasionally a part of a coronary artery dips into and underneath the heart muscle and then comes back out again, known as the myo-

cardial bridge. Majority of the myocardial bridges reside on the left anterior descending artery (LAD) and less frequently on the circumflex artery (Cx) and the right coronary artery (RCA) (Juillière et al. 1995; Aydinlar et al. 2005; Cay et al. 2006).

Coronary artery fistulas, abnormal terminations of the coronary arteries, are another frequent type of the coronary artery anomalies (Yamanaka and Hobbs 1990; Vavuranakis et al. 1995). The coronary arteries normally taper and terminate in the capillary plexus situated deep within the myocardial wall (Angelini et al. 1999; David and Fiss 2007; Loukas et al. 2009). However, in rare cases the coronary arteries could drain into one of the heart chambers, great vessels, e.g., pulmonary artery or into coronary sinus (Sapin et al. 1990; Cheung et al. 2001). Majority of the coronary artery fistulas are small in size and are clinically insignificant. Nevertheless, the fistulas may rarely present with congestive heart failure and pulmonary hypertension (Sunder et al. 1997; Sapin et al. 1990; Yamanaka and Hobbs 1990; Cheung et al. 2001). Coronary angiography can determine the origin, course, termination, and size of the fistulas.

Majority of the studies concerning the coronary artery anomalies have focused on the types and frequencies of coronary artery anomalies in angiographic populations. There are few studies available on the effect of gender on the types and frequency of coronary artery anomalies. In the present study we therefore aimed to investigate the frequency and location of various types of the coronary artery anomalies (anomalous origin, course, and termination) and their correlation with gender.

### Materials and Methods

We evaluated retrospectively the angiography records of 7,810 patients who had undergone coronary angiography at the Department of Cardiology, Medical School of Eskişehir Osmangazi University, Eskişehir, Turkey between February 2007 and April 2011. The angiographic movies were carefully reviewed by an interventional cardiologist, and variations in coronary anatomy including normal and variant anatomy, and anomalies of coronary circulation were further revised by an experienced anatomist. We defined and classified the coronary artery anomalies according to the classification system described by Angelini et al. (2002).

At the present work, we mainly reviewed the records for (I) the coronary arteries with anomalous origin; (II) abnormal course (myocardial bridges); and (III) abnormal termination (coronary artery fistula). We studied the coronary artery anomalies in detail by determining: (a) the anomalous origin of the RCA-particularly whether it is originating from the left aortic sinus or arising from Cx, the presence of split RCA; (b) abnormal origin of Cx- if it is arising from the right aortic sinus or starting off the RCA; (c) atypical beginning of the LAD- whether arising from the right aortic sinus or from the RCA, (d) the Cx and LAD originating from separate ostia in the left aortic sinus (absent left main coronary artery (LMCA). We described split RCA if the RCA was originating from two separate ostia from the right aortic sinus or arising as a single coronary artery then dividing into two branches and running as duplicate. We then evaluated the pre-

sence of myocardial bridges in depth including bridge location, length, and frequency. We determined the presence of a myocardial bridge if the compression on the coronary artery segment during systole is more than 30% and returning to its normal state during diastole. Eventually, we checked thoroughly the presence of the coronary artery fistulas together with their origin, course and termination sites. For this study we formed a male and a female group and compared the frequencies and features of the coronary artery anomalies between the groups.

Excluded from evaluation were those cases wherein: 1) the patients undergone previous coronary artery bypass surgery; 2) the patients possessed one or more totally occluded major epicardial coronary artery; and 3) Digital angiography records showing poor quality to review.

### Statistical analysis

Continuous variables were expressed as mean  $\pm$  s.d.; categorical variables were defined as percentages. To compare continuous variables, we used Student's *t*-test or the Mann-Whitney *U* test, where appropriate. Categorical variables were compared via the chi-square test. For all the tests, a value of  $p < 0.05$  was considered to be statistically significant. The SPSS statistical software package (SPSS, version 16.0 for windows; SPSS Inc., Chicago, IL, USA) was used to perform all the statistical calculations.

### Results

The review of the digital angiography records of 7,810 patients (2,214 females and 5,596 males) showed that the mean age of the patients was  $57.3 \pm 10$  years (range: 18-99 years). Of the patients, 71.7% were male and 28.3% were female.

Overall, the incidence of the patients with at least certain types of coronary artery anomalies was 262/7,810 (3.35%). We determined the correlation of gender with the incidence of the coronary artery anomalies. Among the present angiographic population, we determined 130 individuals with coronary arteries with anomalous origin (1.66%), 105 individuals with myocardial bridges (1.34%), and 27 persons with coronary artery fistulas (0.35%). The percentage of the coronary artery anomalies was significantly higher in the females than the males ( $p = 0.001$ ). In contrast to higher incidence of the coronary arteries with anomalous origin in the females ( $P < 0.001$ ), the percentage of myocardial bridges in the males were notably elevated with respect to the females ( $P = 0.01$ ). Furthermore, we detected no significant difference in the frequency of the coronary artery fistulas between the males and females. Overall, the present findings indicated that gender associated with markedly increased percentage of the coronary arteries with anomalous origin in the females and increased percentage of myocardial bridges in the males. Gender-associated frequency of the coronary artery anomalies in the present population is summarized in Table 1.

The origins of the coronary arteries with anomalous origin in the males and females were accomplished. The percentage of the Cx and LAD originate from separate ostia in the left aortic sinus was notably higher in the females in

Table 1. Frequencies of coronary artery anomalies according to gender.

|                                                      | Total ( <i>n</i> = 7810) | Female ( <i>n</i> = 2214) | Male ( <i>n</i> = 5596) | <i>P</i> value |
|------------------------------------------------------|--------------------------|---------------------------|-------------------------|----------------|
| The sum of coronary artery anomalies ( <i>n</i> , %) | 262 (3.35)               | 98 (4.4)                  | 164 (2.9)               | 0.001          |
| Coronary artery With Anomalous Origin                | 130 (1.66)               | 69 (3.1)                  | 61 (1.1)                | < 0.001        |
| Myocardial Bridge                                    | 105 (1.34)               | 19 (0.85)                 | 86 (1.5)                | 0.01           |
| Fistula                                              | 27 (0.35)                | 10 (0.45)                 | 17 (0.3)                | 0.21           |

Table 2. The role of gender on the frequency of coronary arteries with anomalous origin.

|                                                                                   | Total ( <i>n</i> = 130) | Female ( <i>n</i> = 69) | Male ( <i>n</i> = 61) | <i>P</i> value |
|-----------------------------------------------------------------------------------|-------------------------|-------------------------|-----------------------|----------------|
| Types of Anomalous Origin                                                         |                         |                         |                       |                |
| Cx and LAD originate from separate ostia in the left aortic sinus ( <i>n</i> , %) | 78 (60)                 | 47 (68.1)               | 31 (50.8)             | < 0.001        |
| RCA from left aortic sinus ( <i>n</i> , %)                                        | 12 (9.2)                | 5 (7.2)                 | 7 (11.5)              | 0.23           |
| RCA from Cx ( <i>n</i> , %)                                                       | 1 (0.8)                 | 0                       | 1 (1.65)              | 0.72           |
| Cx from right aortic sinus or RCA ( <i>n</i> , %)                                 | 19 (14.6)               | 8 (11.6)                | 11 (18)               | 0.14           |
| LAD from right aortic sinus or RCA ( <i>n</i> , %)                                | 6 (4.6)                 | 3 (4.4)                 | 3 (4.9)               | 0.22           |
| Split RCA ( <i>n</i> , %)                                                         | 13 (10)                 | 6 (8.7)                 | 7 (11.5)              | 0.13           |
| Single Coronary Artery ( <i>n</i> , %)                                            | 1 (0.8)                 | 0                       | 1 (1.65)              | 0.72           |

RCA, the right coronary artery; Cx, the circumflex artery.

Table 3. Features of myocardial bridges with respect to gender.

|                                                      | Total ( <i>n</i> = 105) | Female ( <i>n</i> = 19) | Male ( <i>n</i> = 86) | <i>P</i> value |
|------------------------------------------------------|-------------------------|-------------------------|-----------------------|----------------|
| LAD ( <i>n</i> , %)                                  | 100 (95.2)              | 18 (94.7)               | 82 (95.4)             | 0.64           |
| Cx ( <i>n</i> , %)                                   | 3 (2.9)                 | 1 (5.3)                 | 2 (2.3)               | 0.63           |
| RCA ( <i>n</i> , %)                                  | 0                       | 0                       | 0                     | –              |
| LAD and Cx ( <i>n</i> , %)                           | 2 (1.9)                 | 0                       | 2 (2.3)               | 0.51           |
| LAD and RCA ( <i>n</i> , %)                          | 0                       | 0                       | 0                     | –              |
| Cx and RCA ( <i>n</i> , %)                           | 0                       | 0                       | 0                     | –              |
| LAD, Cx, and RCA ( <i>n</i> , %)                     | 0                       | 0                       | 0                     | –              |
| Length of the myocardial bridge (mm) ( <i>n</i> , %) | 14.5 ± 8.1              | 10.2 ± 4.5              | 15.4 ± 8.4            | < 0.01         |

LAD, the left anterior descending artery; Cx, the circumflex artery; RCA, the right coronary artery.

comparison with the males ( $P < 0.001$ ). We noted no momentous difference in the frequency of other coronary arteries with anomalous origin between the males and the females ( $P > 0.05$ ). Overall, the most common type of coronary artery with anomalous origin was the Cx and LAD originating from separate ostia in the left aortic sinus both in the males and the females. The second most frequent type of the coronary arteries with anomalous origin was the presence of the Cx originating from the right aortic sinus or RCA. In this study, we noted 13 patients with split RCA. Of those, the RCA was originating from two separate ostia in five patients (three males and two females,  $P = 0.43$ ) and arising as a single coronary artery then was dividing into two branches and running as duplicate in eight patients (four males and four females,  $P = 0.16$ ). The frequency of subtypes of split RCA between males and females was similar. Gender-associated frequency of the coronary arteries with anomalous origin in the present population is summa-

rized in Table 2.

In the present work, we compared the frequency and the length of myocardial bridge in the females and males. We noted 107 myocardial bridges in 105 patients in the study population. The assessment of their location showed that 100 myocardial bridges were resided on the LAD. Of the remaining five myocardial bridges, three myocardial bridges were located on the Cx and two myocardial bridges were resided on the LAD and the Cx. The distribution of the myocardial bridges on the coronary arteries was similar between the males and females ( $P > 0.05$ ). In addition, the length of the myocardial bridges varied between 5mm to 51mm with the mean length of  $14.5 \pm 8.1$  mm. When we compared the mean length of the myocardial bridges in the males and females we noted that the length of the myocardial bridges in the males was noticeably longer than that of the females ( $P < 0.01$ ). Gender-associated frequency, location and length of the myocardial bridges in the present

Table 4. Characteristics of coronary artery fistulas with respect to gender.

|                                  | Total ( <i>n</i> = 27) | Female ( <i>n</i> = 10) | Male ( <i>n</i> = 17) | <i>P</i> value |
|----------------------------------|------------------------|-------------------------|-----------------------|----------------|
| Origin of the Fistula            |                        |                         |                       |                |
| RCA ( <i>n</i> , %)              | 14 (51.9)              | 5 (50)                  | 9 (52.9)              | 0.6            |
| LAD ( <i>n</i> , %)              | 11 (40.7)              | 3 (30)                  | 8 (47.1)              | 0.32           |
| Cx ( <i>n</i> , %)               | 2 (7.4)                | 2 (20)                  | 0                     | 0.13           |
| Termination Site of the Fistula  |                        |                         |                       |                |
| Right Ventricle ( <i>n</i> , %)  | 16 (59.3)              | 5 (50)                  | 11 (64.8)             | 0.36           |
| Right Atrium ( <i>n</i> , %)     | 8 (29.6)               | 2 (20)                  | 5 (29.4)              | 0.47           |
| Pulmonary Artery ( <i>n</i> , %) | 3 (11.1)               | 3 (30)                  | 1 (5.8)               | 0.13           |
| Fistula size                     |                        |                         |                       |                |
| Large ( <i>n</i> , %)            | 3 (11.1)               | 1 (10)                  | 2 (11.8)              | 0.69           |
| Small ( <i>n</i> , %)            | 24 (88.9)              | 9 (90)                  | 15 (88.2)             |                |

LAD, the left anterior descending artery; Cx, the circumflex artery; RCA, the right coronary artery.

population are summarized in Table 3.

We further compared the origins, termination sites, and size of the coronary artery fistulas in the females and males. Overall we noted 27 fistulas: 14 fistulas (five in females and nine in males) originated from the RCA, 11 CAFs (three in females and eight in males) from the LAD, and 2 fistulas (in females) from the Cx. We noted no marked difference between the origin sites of the fistulas when they were compared between the males and females ( $P > 0.05$ ). Similar to origin sites, we found overall no marked difference between the termination sites of the fistulas between the males and the females ( $P > 0.05$ ). Moreover, sixteen fistulas were noted to drain into the right ventricle, eight fistulas were noticed to terminate into the right atrium, and three fistulas drained to the pulmonary artery. We detected large fistulas in only three individuals (two males, one female). The frequency of large and small fistulas between the males and females were comparable. Gender-associated frequency, origins, terminations sites and sizes of the fistulas in the present population are summarized in Table 4.

## Discussion

The incidence of coronary artery anomalies in our review was 3.35% (262 of 7,810). Among the subtypes of the coronary artery anomalies, the coronary arteries with anomalous origin were significantly higher in the females than the males. By contrast, the incidence of myocardial bridges was increased in the males than the females.

Overall, the frequency of the coronary artery anomalies in the present study is higher than most of the previously reported studies (Engel et al. 1975; Chaitman et al. 1976; Wilkins et al. 1988; Yamanaka and Hobbs 1990; Topaz et al. 1992; Aydinlar et al. 2005) but lower than in other studies. We propose some potential factors generating inconsistent frequency or the coronary artery anomalies reported in various studies. Among the several factors, the lack of the definite classification criteria for the coronary artery anomalies is the most critical cause. For instance, while some studies consider myocardial bridges and coro-

nary artery fistulas as part of the coronary artery anomalies, others do not classify them as part the coronary artery anomalies (Wilkins et al. 1988; Yamanaka and Hobbs 1990; Angelini et al. 1999). However, the definition of the coronary artery anomalies covers the anomalous origin, course, and termination of the coronary arteries (Angelini 2002). In the current study we assessed anomalous origin, course, and termination of coronary arteries in the context of the coronary artery anomalies. Conversely, majority of the studies do not classify the myocardial bridges as part of the coronary artery anomalies although they comprise a significant portion of the coronary artery anomalies (Engel et al. 1975; Chaitman et al. 1976; Wilkins et al. 1988; Yamanaka and Hobbs 1990; Topaz et al. 1992; Aydinlar et al. 2005).

Another reason for the higher percentage of the coronary artery anomalies in the current study might be the difference in the taxonomy of the coronary arteries with anomalous origin. We used the classification system proposed by Dr. Angelini (2002). In this respect, we classified Cx and LAD originating from separate ostia in the left aortic sinus and split RCA as type the coronary arteries with anomalous origin. By contrast, some studies do not include these two cases within the coronary arteries with anomalous origin (Chaitman et al. 1976; Wilkins et al. 1988). Methodological approaches can also lead to finding of different frequencies of coronary artery anomalies. While mainstream of the data regarding the incidence of the coronary artery anomalies are produced from angiographic records (Wilkins et al. 1988; Yamanaka and Hobbs 1990; Aydinlar et al. 2005), we, distinctively, reviewed the angiographic movies to describe the coronary artery anomalies. The data generated from angiographic records as to the coronary artery anomalies possess a number of drawbacks. Some of which can be listed as follows: 1) Since the coronary artery anomalies are rarely encountered entities, the physician reporting them may fail to accurately recognize and describe them in the records, 2) Because most of the coronary artery anomalies are usually considered benign in nature, a variance to normal, the specialist may not register them at



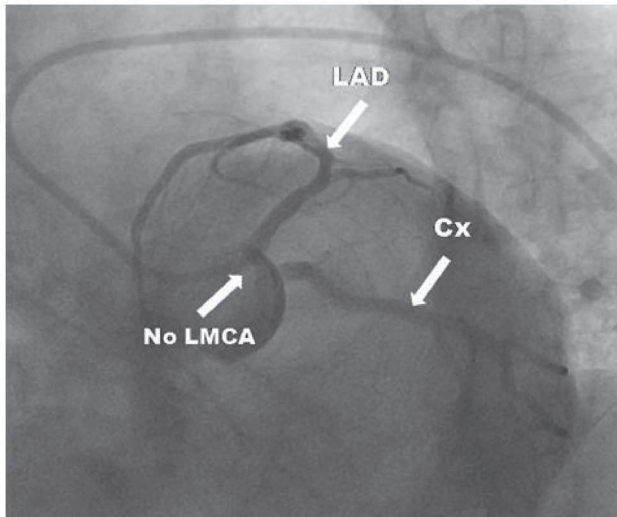


Fig. 1. The absence of LMCA.

Note that the LAD and the Cx arise from the separated ostia on the aorta.

LMCA: the left main coronary artery, LAD: the left anterior descending artery, Cx: the circumflex artery.

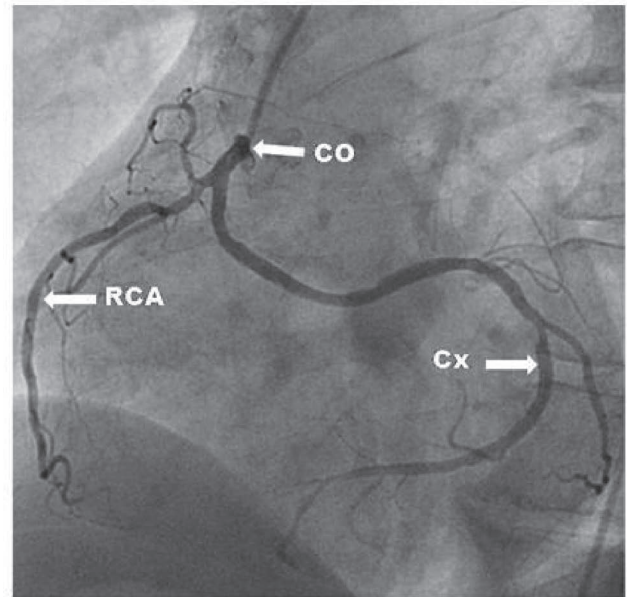


Fig. 2. The anomalous origin of the Cx artery from the RCA.

CO: coronary ostium, RCA: the right coronary artery.

all times, 3) In most of the published studies, angiographic records are evaluated by various cardiologists whose criteria for the classification of the coronary artery anomalies may well greatly vary, thereby yielding in non-homogeneous data concerning the coronary artery anomalies. Further factors that may meddle with the diverse frequencies of the coronary artery anomalies can spring from the geographic variations and genetic backgrounds. All of these parameters can play a role in the divergent range reported for the frequency of the coronary artery anomalies (Engel et al. 1975; Chaitman et al. 1976; Wilkins et al. 1988; Topaz et al. 1992; Aydinlar et al. 2005).

The most frequently encountered type of the coronary artery anomalies in our population was the coronary arteries with anomalous origin; among which, absent LMCA was the most commonly seen anomaly between the males and females (Fig. 1). The incidence of coronary arteries with anomalous origin was considerably higher in the females than the males. Interestingly, the frequency of the Cx and LAD originate from separate ostia in the left aortic sinus was also elevated in the females with respect to the males. Likewise, at their study, Yamanaka and Hobbs (1990), the largest study performed on coronary artery anomalies, report that Cx and LAD originate from separate ostia in the left aortic sinus is to be most spread anomaly with 0.41% among the coronary artery anomalies. However, they did not compare the frequency of Cx and LAD originating from separate ostia in the left aortic sinus between males and females (Yamanaka and Hobbs 1990). In contrast to our findings, some previous studies indicate that the incidence of coronary arteries with anomalous origin is higher in males than females. However, at their studies they did not classify Cx and LAD originate from separate ostia in the

left aortic sinus as type coronary arteries with anomalous origin (Chaitman et al. 1976; Wilkins et al. 1988). We failed to establish a plausible correlation for the increased frequency of the Cx and LAD originate from separate ostia in the left aortic sinus in the females; however, gender associated instructions that regulate the coronary artery ramification during the embryologic life may determine the presence or absence of the LMCA. The Cx and LAD originate from separate ostia in the left aortic sinus is considered a benign anomaly and does not cause hemodynamic deterioration. Since this type of the coronary artery anomalies can create difficulty during angiographic intervention, awareness of infrequent presence of this type of anomaly is critical for optimizing catheterization in the patients with this anomaly. Moreover, contrast injection into the left aortic sinus at the left anterior oblique to caudal projection provides the best view for making the distinction of the Cx and LAD originate from separate ostia in the left aortic sinus during angiography. While anteriorly direction of catheter selectively visualizes the LAD, its posteriorly direction selectively envisages the Cx. Sometimes, distinguishing the Cx and LAD originate from separate ostia in the left aortic sinus angiographically from the too short LMCA can be challenging. Occasionally, selective placement of catheter in the LAD or Cx can lead to false assessment of the Cx and LAD originating from separate ostia in the left aortic sinus.

Second most common anomaly we detected in the present study was the anomalous origin of the Cx from the right aortic sinus or the RCA (Fig. 2). We found no notable difference in the frequencies of this anomaly between the males and females. The incidence for the present anomalous Cx is in agreement with other studies (Yamanaka and

Hobbs 1990). Failing to visualize the Cx during the angiography of the left coronary system should prompt the specialist regarding the existence of the anomalous origin of the Cx artery from the right aortic sinus or the RCA. Repositioning of the catheter at the RCA ostium or the posteriorly direction of the catheter at the right aortic sinus during the catheterization of the right coronary system enables better visualization of anomalous Cx. Paying attention to these details can decrease the time for coronary scopy and reduce the amount of contrast administered to patients during the procedure. Furthermore, this type of anomaly is benign in general and does not cause hemodynamic corrosion unless abnormal Cx does not run between the aorta and the pulmonary trunk. The interarterial course of the Cx between aorta and the pulmonary artery could trigger sudden cardiac death. Therefore, determining whether the abnormal Cx trace an interarterial course or not is critical for reducing such risk. The interarterial course of the abnormal Cx can be demonstrated via inserting catheter to the root of the aorta and at the right ventricular outflow tract during angiography (Keelan and Holmes 2001). However, we were unable to determine whether they course between the aorta and the pulmonary artery since our study was performed retrospectively.

The interarterial course of the coronary artery between aorta and the pulmonary artery could trigger sudden cardiac death. Therefore, determining whether the abnormal coronary artery trace an interarterial course or not is critical for reducing such risk. In some cases, the LAD arising from the RCA or the right sinus of Valsalva can run between the aorta and the pulmonary artery. The patient with such course of the LAD is reported to possess high risk for sudden cardiac death (Cheitlin et al. 1974; Chaitman et al. 1976) report that when the LAD originate from the RCA or the right sinus of Valsalva, it runs between the aorta and the pulmonary artery in 75% of the cases (Chaitman et al. 1976). In the present study, the LAD was originating from the RCA or the right sinus of Valsalva in six patients; however, we were unable to determine whether they course between the aorta and the pulmonary artery since our study was performed retrospectively. Interarterial course of a coronary artery can be demonstrated using coronary angiography, magnetic resonance imaging, or computed tomography (Chaitman et al. 1976). In this respect, the persons diagnosed with interarterial course of the abnormal coronary artery should be kept under close watch and whether prohibiting these persons from participating extraneous sports such as football and soccer should be a matter of future medical argument.

Split RCA was the third most frequent anomaly we spotted in the present study. We noted no significant difference in the frequency of split RCA between the males and females. The split RCA is defined as the RCA originating from two separate ostia located on the aorta or splitting into two branches right after exiting from the sinus Valsalva as viewed in Fig. 3. The split RCA is the most universal con-

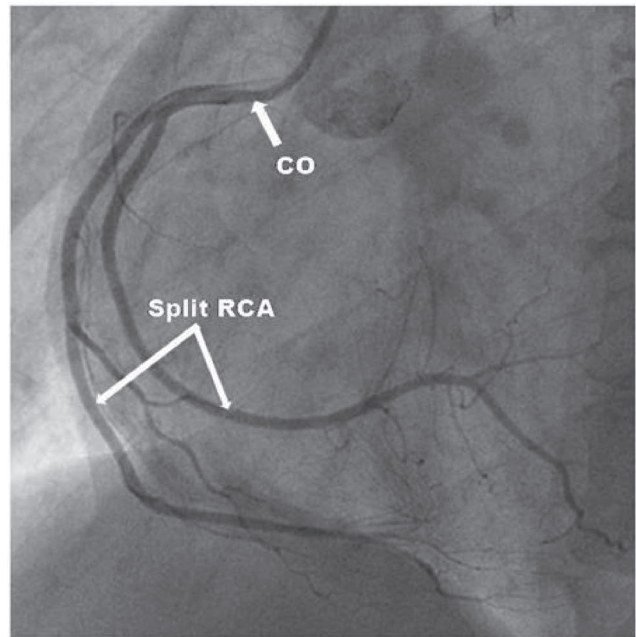


Fig. 3. The split RCA, third most frequent anomaly encountered in the present study.

The split RCA is described as the RCA originating from two separate ostia located on the aorta or splitting into two branches right after exiting from the sinus Valsalva as viewed in this figure.

genital anomaly of the RCA (Angelini et al. 1999). Our literature review indicated that previous studies have not evaluated the effect of the gender on the incidence of split RCA. However, the use of improperly named “double right coronary” as another anomalous form of the RCA instead of split RCA reduces the frequency of split RCA reported in the literature (Kunimasa et al. 2007; Lemburg et al. 2007). In fact, there are not two RCAs, but only split portions of the inferior interventricular branch of the RCA, with two separate proximal courses. When the split RCA arises from the two separate ostia resided on the aorta, the selective cannulation of the one ostium can mask the other, thereby preventing proper identification of the second ostium. Obtaining the first angiographic pose as non-selective during the RCA angiography would help avoid this confusion.

The coronary arteries with anomalous origin infrequently cause myocardial ischemia and sudden cardiac death through preventing blood flow to myocardium (Frescura et al. 1998; Angelini 2002; Rohit et al. 2008; Loukas et al. 2009). These types of coronary anomalies are designated as malignant or potentially lethal anomalies. The most widespread malignant coronary anomaly is the presence of the coronary artery arising from the opposite aortic sinus, with a proximal course between aorta and pulmonary trunk. That is to say, the LMCA originates from the right aortic sinus or the RCA arises from the LSV. In the present study we noted potentially lethal coronary arteries with anomalous origin in 13 patients. While we found seven RCA originating from the left aortic sinus and one

single coronary artery anomaly (Fig. 4) in the males, we noted five RCA arising from the left aortic sinus in the females (Table 2). The frequency of potentially lethal coronary arteries with anomalous origin was similar between the females and males in our study. This type of coronary anomaly is particularly vital in young athletes since it is the most common cause of sudden cardiac death after the hypertrophic cardiomyopathy (Maron 1993; Taylor et al.

1997).

Single coronary artery anomaly is barely seen and can cause sudden cardiac death with the frequency of 0.024-0.066% in general population (Cheitlin et al. 1974; Angelini et al. 1999). In the current study there was a single coronary artery anomaly, originating from the right sinus Valsalva, only in one patient. Since single coronary artery anomaly consists of an exceptionally heterogeneous group of arteries, angiographic imaging should be obtained at multiple angles and dimensions to properly identify the LAD, Cx, and RCA. When this anomaly is suspected, the aortic root is visualized angiographically to ensure whether another coronary artery ostium exists. Likewise, pulmonary angiography should be performed to eliminate the presence of a coronary artery originating from the pulmonary artery.

Myocardial bridge is recognized by a systolic narrowing of a coronary artery segment, returning to normal during the diastole (milking effect). The incidence for the myocardial bridges in the present study was 1.36% (Fig. 5). While the incidence of myocardial bridges determined during autopsies is reported to be between 15-80%, it is shown to be between 0.5-2.5percent during angiography (Edwards et al. 1956; Polachek 1961; Nobel et al. 1976; Ishimori et al. 1977; Voss et al. 1980). A couple of factors generating this discrepancy can be accountable. The myocardial bridges not causing enough compression on the relevant arterial segment can be remained undetected during angiography. Failing to determine all degrees of myocardial bridges is a limiting feature of angiography. By contrast, autopsies allow us to determine the presence of myocardial

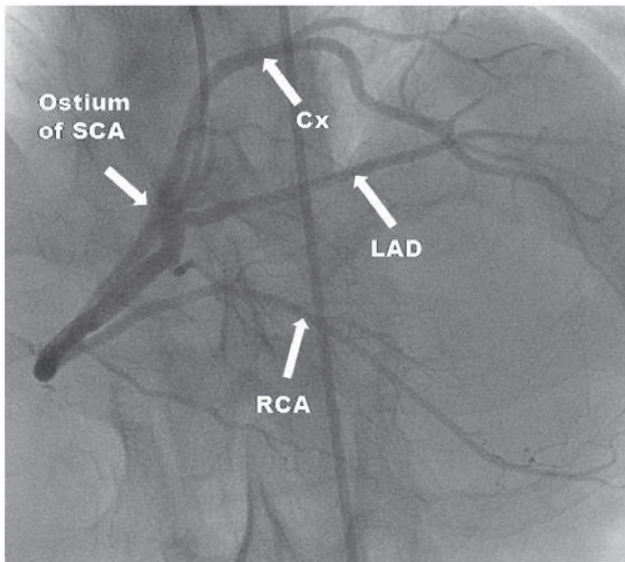


Fig. 4. The single coronary artery.

Note that all the coronary arteries arising from the single ostium on the right sinus of Valsalva. SCA: single coronary artery.

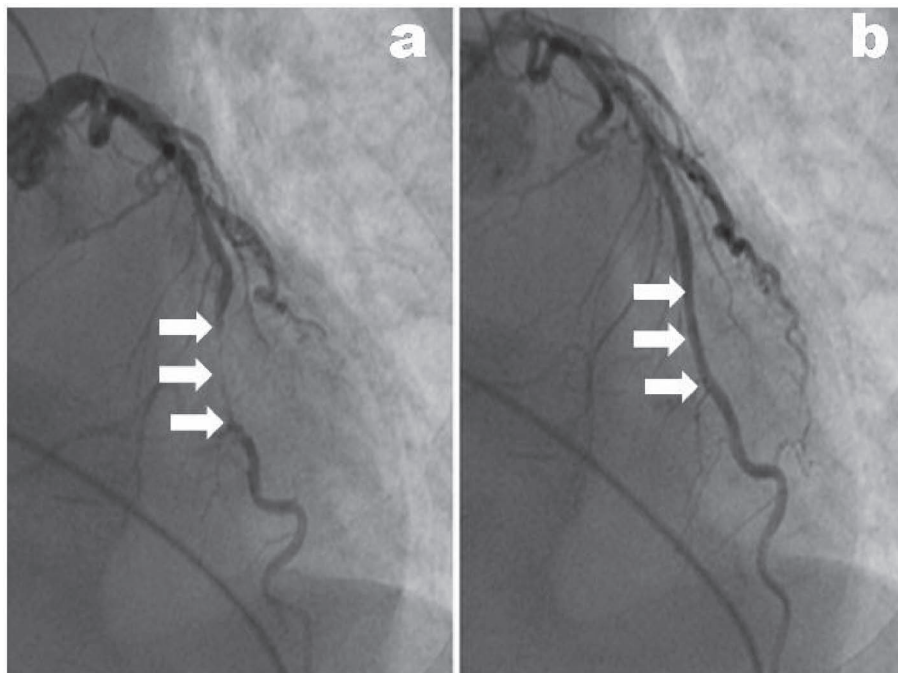


Fig. 5. Compression of the LAD during the systole.

Observe that the LAD is 99% compressed during the systole (a), and returned to normal during the diastole (b).



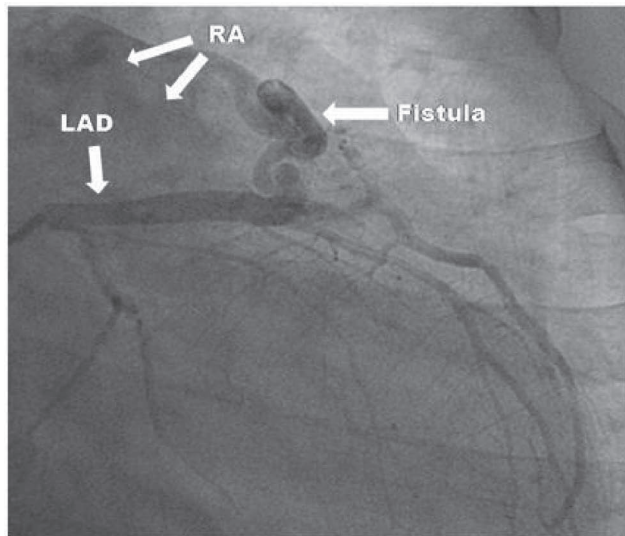


Fig. 6. The presence of a large fistula. Discern the large fistula originating from the LAD and draining to the right atrium.

bridges more accurately. Majority of the myocardial bridges (95.2%) were located on the LAD artery in the current study. Likewise, several other studies describe that greater part of the myocardial bridges reside on the LAD artery and less frequently on the Cx and the RCA (Juillière et al. 1995; Aydinlar et al. 2005; Cay et al. 2006). The incidence of myocardial bridges was higher in the males than the females in the current study, a finding consistent with other studies (Schwarz et al. 1997; Ge et al. 1999; Loukas et al. 2006). Moreover, the length of the myocardial bridges was longer in the males than females. The increase in the frequency and length of the myocardial bridges in the males could be owing to massive musculature of the body in respect to females.

The incidence for the coronary artery fistulas (0.35%) in the present study was slightly higher than previous studies (Yamanaka and Hobbs 1990; Aydinlar et al. 2005). The coronary artery fistulas in the current study most frequently originated from the RCA, LAD, and Cx and they mainly drained into the right ventricle, the right atrium, and pulmonary artery (Fig. 6). These observations were similar to earlier studies (Sapin et al. 1990; Sunder et al. 1997; Cheung et al. 2001). The ratio of the fistulas in the present study was alike between the males and females. The patients diagnosed with the fistulas during the cardiac catheterization should be carefully questioned for the presence of relevant symptoms and kept under close monitoring for the dilatation of the right heart chambers and the development of the pulmonary hypertension.

In conclusion, determination of the presence of the coronary artery anomalies during the coronary angiography is critical for the planning of the treatment and for the proper clinical follow-up of patients. The present study indicates that while the frequency of the Cx and LAD originating from separate ostia in the left aortic sinus is mar-

kedly higher in the females, the incidence of the myocardial bridges is elevated in the males.

### Conflict of Interest

All authors have no conflict of interest in this study.

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