

Brief communication (original)

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Anatomic variations of coronary arteries: origins, branching patterns, and abnormalities

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Abstract

Background: Anatomic variations in orifices, courses, branching patterns, and abnormalities of coronary arteries could affect blood supply, hemodynamic characteristics, and clinical symptoms, and could be a risk of atherosclerosis.

Objectives: To investigate the location and number of both coronary orifices in the aortic cusps, branching patterns of left main trunk, dominant pattern of posterior interventricular artery (PIA), prevalence of right posterior diagonal artery (RPDA), myocardial bridge, and other abnormalities.

Methods: We dissected 95 heart specimens from cadavers of Thai donors without the history of surgery, and the dominant patterns, location and number of orifices in the aortic cusps, branching patterns, origin and number of conal arteries, and occurrence of RPDA were determined.

Results: Dual aortic origin of the coronary orifice was the most common condition. Anomalous 2 orifices in the left aortic cusp were found in one specimen in which the right coronary artery (RCA) arose from aortic cusp and had an interarterial course. Right dominance and trifurcated form of left main trunk were found more frequently. Most frequently 2 conal arteries were found. RPDA was found in 45% and mostly originated from RCA. The prevalence of myocardial bridge was 62% and located mostly on the anterior interventricular artery (AIA).

Conclusions: The prevalence of right dominance, RPDA, the atypical origin of RCA from the left sinus, and the prevalence of myocardial bridges was more frequent than reported by others, whereas the dual aortic origin from both cusps and the prevalence of bifurcated left main trunk was less frequent.


Keywords: anatomy; arteries; cardiovascular diseases; coronary vessels; coronary vessel anomalies; myocardial bridging

The number of patients with cardiovascular disease has increased every year. Cardiovascular diseases are a leading cause of death worldwide [1]. In Thailand, the incidence of ischemic heart disease has increased every year [2]. Knowledge of anatomical pattern, variations, and anomalies of coronary arteries is important for the proper interpretation of coronary angiographies and revascularization procedures.

The left coronary artery (LCA) and right coronary artery (RCA) originate from their own aortic cusps. The left coronary artery (LCA) continues into the coronary sulcus. It is also known as left main trunk before bifurcating into anterior interventricular artery (AIA) and circumflex artery (CxA). The additional branch that can be found between 2 arteries as a variation is the median artery (MA). The RCA it, travels down the coronary sulcus and gives off the sinoatrial node artery.

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However, the conal artery can be noticed as a variation near its origin. The RCA might give off the right posterior diagonal artery (RPDA) as a variation before it continues to the posterior interventricular sulcus as the posterior interventricular artery (PIA).

Anatomic variations in orifices, courses, branching patterns, and abnormalities of coronary arteries, which have been reported in previous studies could affect blood supply, hemodynamic characteristics, and clinical symptoms and could be a risk of atherosclerosis [3]. However, various populations in those studies lead to varieties of coronary artery information. To our knowledge, there is no cadaveric report of the anatomic variation in the Thai population. This descriptive study intended to investigate the location and number of both coronary orifices in the aortic cusps, branching patterns of coronary arteries, dominant pattern, prevalence of RPDA, myocardial bridge, and others abnormalities in the Thai population. The expected benefit is to provide a database of coronary arteries for coronary angiography.

Methods

After this cadaveric study was approved by the institutional review board (IRB) of the Faculty of Medicine, Chulalongkorn University (IRB No. 667/60, approval No. 044/2017), 95 heart specimens from cadaver donors without a history of heart surgery (48 male, 47 female) from the Department of Anatomy, Faculty of Medicine, Chulalongkorn University, were collected and preserved in 10% formalin. After dissection, the dominant patterns were determined by observing the origin of the PIA. The PIA originated from RCA was classified as right dominance. PIA from CxA was classified as left dominance, and if the PIA arose from both arteries it would be classified as codominance [4]. We identified the location and number of orifices in the aortic cusps, branching patterns of the LCA, origin and number of conal arteries from the RCA, the occurrence of RPDA and its origin.

Abnormalities of coronary arteries were classified according to Angelini et al. as abnormality of origins and courses [5]. All data are presented as percentages after analyses using IBM SPSS Statistics for Windows (version 21).

Results

The study included 95 heart specimens (mean age of donors at death \pm standard deviation, 76.9 ± 13.2 years;

range 34–99 years) with 48 male (78.0 ± 11.7 years; range 41–99 years) and 47 female (75.8 ± 14.6 years; range 34–96 years).

The prevalence of normal coronary artery variations is summarized in **Table 1**. The right dominance was the most common type of the coronary arterial system. The left and codominant patterns were found in 5% and 2%, respectively (**Figure 1**). One coronary orifice in each aortic cusp (dual aortic origin) was the most common. The most frequent variation was one in the left aortic cusp and 2 in the right aortic cusp. The extra orifice in the right cusp was noted as the origin of the conal artery (**Figure 2**).

The data of branching patterns of the LCA were collected from 93 specimens, because 2 were incomplete due to student dissection. The left main trunk normally bifurcated into AIA and CxA in 32 cases (34%). The most common

Table 1. Anatomic variations of coronary arteries, n (%)

Dominant pattern (n = 95)	
Right	88 (93)
Left	5 (5)
Codominance	2 (2)
Coronary orifices (n = 95)	
Dual aortic origin	65 (68)
One orifice in the left and 2 orifices in the right aortic cusps	28 (29)
One orifice in the left and 3 orifices in the right aortic cusps	1 (1)
Two orifices in the left aortic cusp	1 (1)
Branching pattern of LCA (n = 93)	
Bifurcation	32 (34)
Trifurcation	53 (57)
Quadrifurcation	8 (9)
Conal artery (n = 95)	
One branch	31 (33)
With a separate orifice	7 (7)
From RCA	24 (25)
Two branches	53 (56)
Two with separate orifices	1 (1)
One separate orifice and one RCA	17 (18)
From RCA	35 (37)
Three branches	11 (12)
One separate orifice and 2 RCAs	4 (4)
From RCA	7 (7)
RPDA (n = 95)	
Absence	52 (55)
From RCA	43 (45)

LCA, left coronary artery; RCA, right coronary artery; RPDA, right posterior diagonal artery

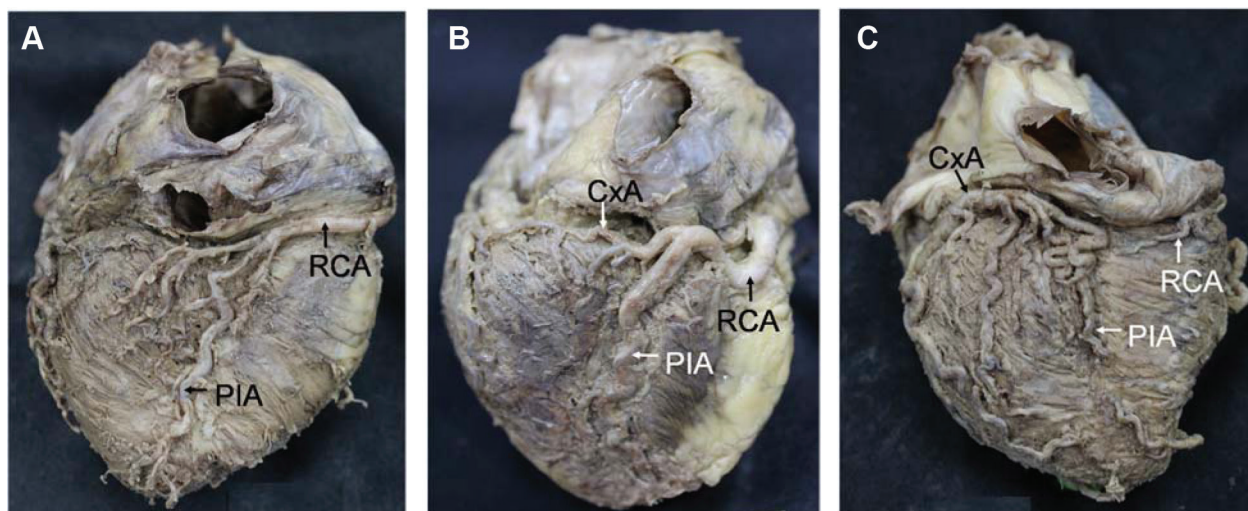


Figure 1. (A) Right dominance. (B) Codominance. (C) Left dominance.

CxA, circumflex artery; PIA, posterior interventricular artery; RCA, right coronary artery

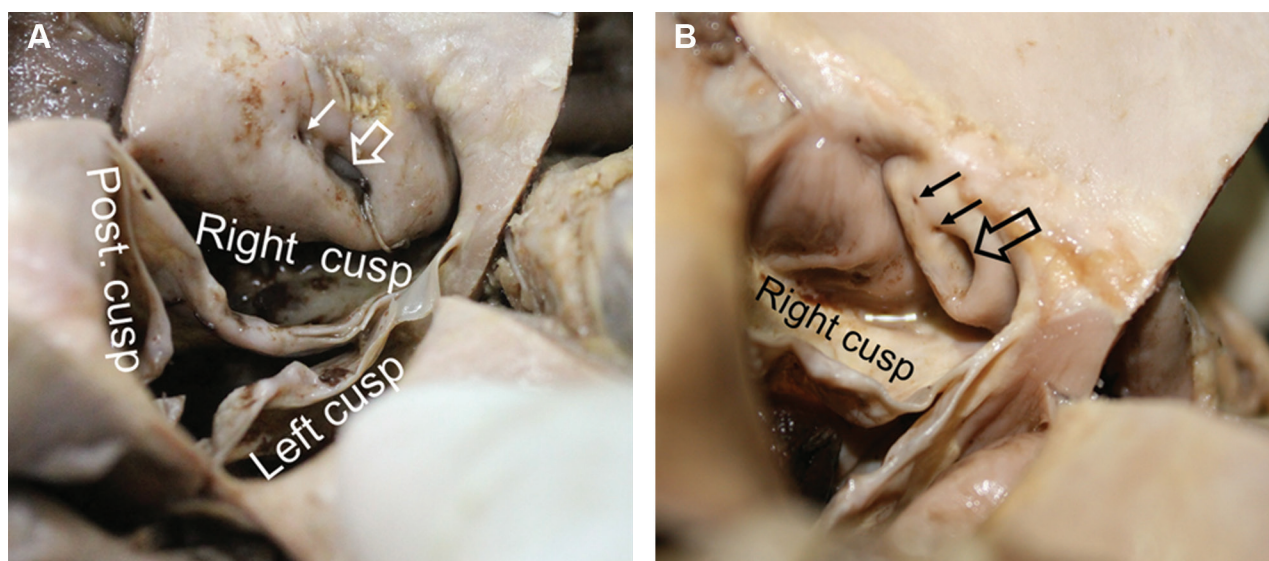


Figure 2. (A) Two orifices in the right cusp. (B) Three orifices in the right cusp. Extra orifice (arrow) aside from RCA (open arrow) was conal artery. RCA, right coronary artery

type was trifurcation. MA was the additional branch. In all specimens, the first branch of the RCA was the conal artery. This artery most frequently had 2 branches (56%) and most branches originated from the RCA (**Table 1**; **Figure 3**).

The RPDA was found in 43 specimens (45%). All RPDA's arose from the RCA after giving the right marginal artery. In 3 specimens, RPDA branched from the RCA at the acute margin of the right ventricle (**Figure 4**). Most of the RPDA occurred in a right dominant pattern. The prevalence of abnormalities of coronary arteries including the anomalous origin of RCA from the left aortic cusp (**Figure 5A**), and the myocardial bridge

are summarized in **Table 2**. The RCA in this anomalous case coursed interarterially between the aorta and the pulmonary trunk to continue into the coronary sulcus (**Figure 5B**).

A myocardial bridge was found in 62% (59 of 95 specimens). Most bridges comprised ventricular myocardium except one that was the right atrial wall (**Figure 6**). In these cases, after giving the right marginal artery, the RCA traveled into the right atrium wall above the coronary sulcus and emerged from the atrial wall to terminate in the right ventricle before reaching the posterior interventricular sulcus. The PIA, in this case, was derived from the CxA. The number of myocardial bridges in each specimen ranged from 1 to 4. The most

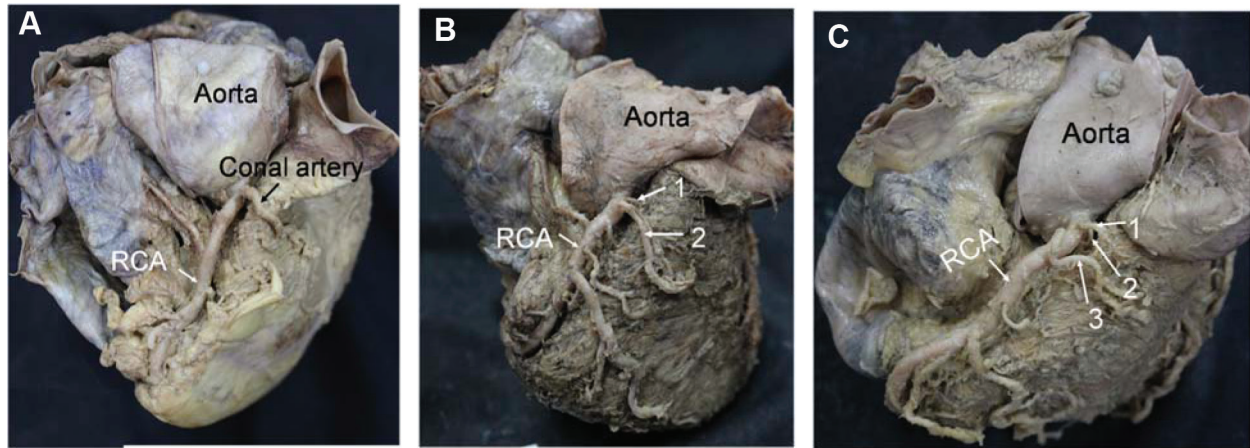


Figure 3. (A) One conal artery from the aorta. (B) Two conal arteries, one from aorta (1) and another from RCA (2). (C) Three conal arteries, one from aorta (2), 2 from RCA (1, 3).
RCA, right coronary artery

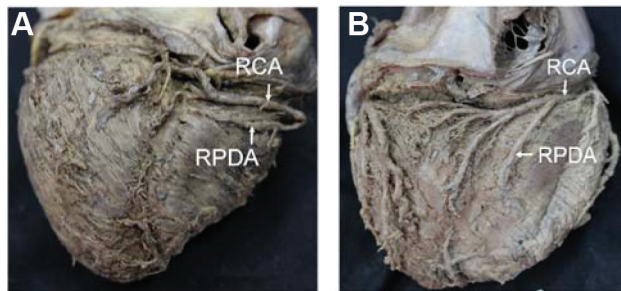


Figure 4. (A) RPDA branched from RCA at acute margin; (B) RPDA branched from RCA after giving the marginal artery.
RCA, right coronary artery; RPDA, right posterior diagonal artery

common location of the myocardial bridge was situated at the AIA. The locations and number of myocardial bridges are shown in **Table 2** and **Figure 7**.

Discussion

Identification of the dominant pattern of coronary arteries has clinical importance particularly from the functional impact of myocardial ischemia [3]. The prevalence of right dominance had been reported to be 40%–80% [3, 6–8], left dominance 6.8%–18.57% [7, 9, 10], and codominance 10%–42.5% [8, 11, 12]. In the present study, the prevalence of right dominance was slightly higher than that reported previously, but left and codominance were considered to be lower. However, the codominant type was reported to be absent [6]. The inconsistency could be explained by the definition of the codominant type [7]. Moreover, dissection might not always yield the same result as radiology when evaluating the anatomy of the coronary artery [3].

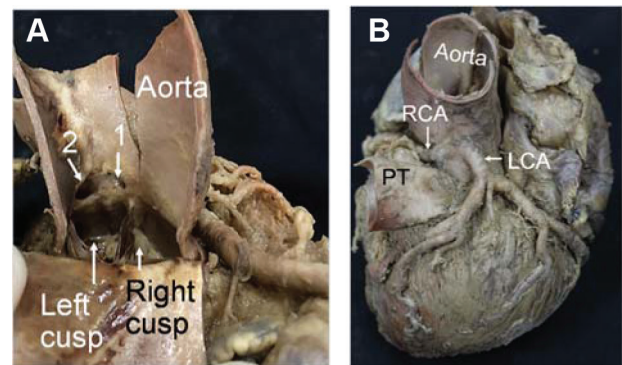


Figure 5. (A) Two orifices in the left aortic cusp: RCA (1) and LCA (2). (B) Interatrial course of RCA between PT and aorta.
LCA, left coronary artery; PT, pulmonary trunk; RCA, right coronary artery

In 94.7%–100%, the 2 coronary orifices were typically located in both aortic cusps [3, 13, 14]. However, additional orifices can be found in the right aortic cusp. Most of these orifices belonged to conal arteries in 33%–51% [15], and some of them belonged to the sinoatrial node artery (0.4%) [7]. The prevalence of 2 and 3 orifices in the right aortic cusp was 22%–28.81% and 0.2%, respectively [7, 10]. In the present study, there was a lower prevalence of dual aortic origin, whereas the prevalence of 2 orifices within the right cusp was similar to that reported previously [7, 10]. Moreover, the occurrence of 3 orifices in the right cusp was higher [7]. The presence of multiple orifices might cause problem and should be considered while performing the right ventriculotomy [7].

Left main trunk bifurcated into the AIA and the CxA in 50%–93.3% [6, 11, 16]. Eventually, the trunk might be terminated by trifurcation in 6.7%–46% [5, 10, 15] and quadrifurcation in 4%–10% [6, 8, 11]. In the present study, the prevalence of bifurcation was lower. Conversely, there were high percentages

Table 2. Prevalence of coronary artery anomalies, n (%)

Anomalous origin of RCA	
RCA from the left aortic cusp	1 (1)
Myocardial bridge	
One site	42 (44)
AIA	3
RPDA	2
PIA	2
LMA	1
Two sites	11 (12)
AIA/AIA	5
AIA/DA	1
AIA/MA	1
AIA/RPDA	1
PIA/DA	1
PIA/MA	1
PIA/LMA	1
Three sites	5 (5)
AIA/AIA/RPDA	1
AIA/DA/PIA	1
AIA/AIA/MA	1
AIA/AIA/PIA	1
AIA/AIA/RCA	1
Four sites	1 (1)
AIA/AIA/AIA/LMA	1

AIA, anterior interventricular artery; LMA, left marginal artery; DA, diagonal artery, MA, median artery; PIA, posterior interventricular artery; RCA, right coronary artery; RPDA, right posterior diagonal artery

of trifurcation and quadrifurcation. The uncertain definition of the MA could explain these different percentages. Angelini et al. determined this artery by its distribution between the diagonal branch and left marginal artery. It may originate from the left main trunk, or proximal part of the AIA or the CxA [5], whereas some authors [6, 7, 16] as well as ourselves defined the origin of MA as only from the left main trunk. The existence of an MA might be important as a collateral vessel in cases of AIA and CxA occlusion [6, 16]. However, this artery could cause a problem while inserting a catheter and could lead to misdiagnosis [7].

The conal artery is an important in collateral circulation between the right and left coronary arteries [17]. It supplies the conus arteriosus and anterior, middle, and superior part of the ventricle [18]. The prevalence of this artery is reported as the first branch of RCA in 96%–100% [7, 10, 19]. The conal artery can originate from its own orifice in 18%–46.67% [7, 17, 19] or as a branch from the RCA in 53.34%–76% [10, 17, 19]. The number of branches

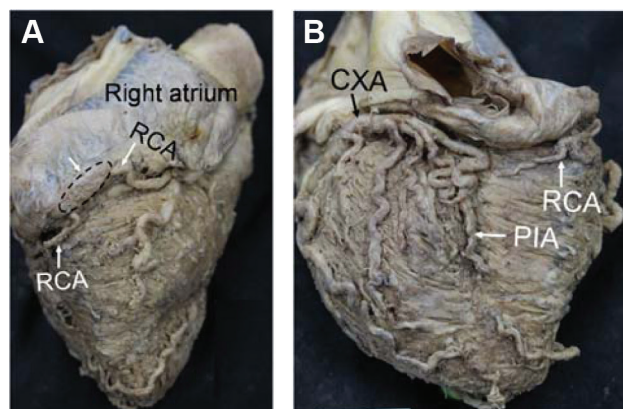


Figure 6. (A) Myocardial loop. (B) Left dominant pattern in this case. CxA, circumflex artery; PIA, posterior interventricular artery; RCA, right coronary artery

varied from 1 to 3; 20%–94% of conal arteries were observed as a single branch. The double and triple branches were reported in 1%–46.67% and 6.66%, respectively [17, 19]. In the present study, the prevalence and origin of conal artery were similar to those reported previously.

The artery that could be noticed before the branching of the PIA was the RPDA. This artery irrigated the inferior part of the posterior interventricular sulcus and adjacent areas. The prevalence of RPDA was 22.1% and 14% in the right dominant type [10, 20]. The RPDA originated from the RCA in 84–86.8% and from the right marginal artery in 13.2%–16% [10, 20]. Moreover, Ortale et al. reported the prevalence of this artery in all dominant circulations [11]. In the present study, there was a high percentage of RPDA and the origin in all specimens was from the RCA. The RPDA was found in both the right and codominant types.

The anomalies of coronary arteries that have hemodynamically significance are abnormalities of the origin from the opposite sinus or pulmonary artery, myocardial bridge, and coronary fistula [21]. These might be involved life-threatening symptoms; arrhythmia, myocardial infarction, or sudden death [7]. The atypical origin of the RCA from the left sinus and from the pulmonary artery was considered to be malignantly anomalous. It has been proven that a decrease in coronary artery circulation might produce acute myocardial ischemia, arrhythmia, and sudden death [22]. This reduction in blood flow might be caused by an acute takeoff angle from the origin and the pressure effect from the interatrial course [23]. The prevalence of anomalous origin of the RCA from left sinus was observed to be 0.03–0.92% [7, 24], which was lower than that found in the present study.

The myocardial bridge comprises myocardial fibers that spread over a segment of coronary arterial branch. The bridge was determined as an atypical course that produces

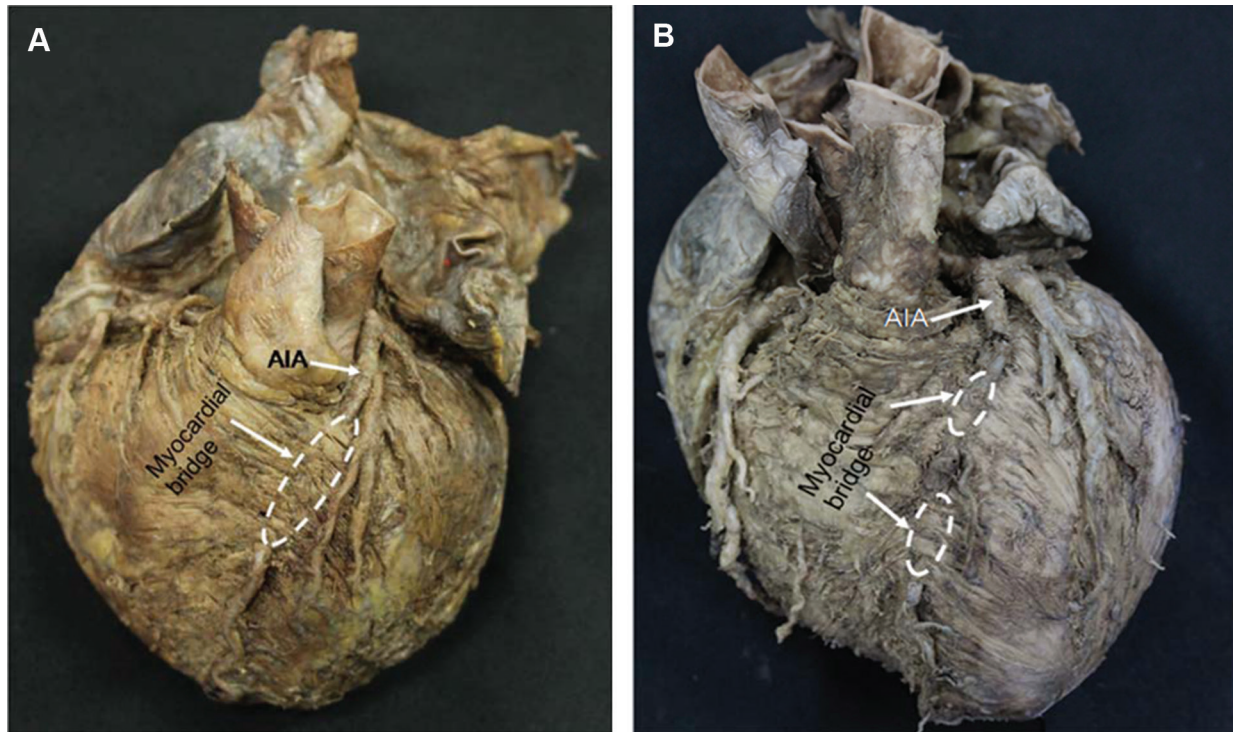


Figure 7. (A) One site of the myocardial bridge on the AIA. (B) Two sites on the AIA. AIA, anterior interventricular artery

compression of vessels during systole. Although it may be asymptomatic in most patients during a functional stress test, a myocardial bridge might be associated with atypical angina, especially in cases with a long and deep segment [24, 25]. The prevalence of the myocardial bridge in angiography was 0.15–25% and 5–86% in autopsy reports [6, 8, 24]. Occasionally, a myocardial bridge was found at more than one site. The prevalence of single, double and triple sites of myocardial bridge were 33.33%, 8.30%, and 3.33%, respectively [26]. The middle third of the AIA followed by the left marginal artery were observed to be the most common locations [8, 15]. In the present study, the prevalence resembled that reported at autopsy. In addition, a myocardial loop formed by the atrial myocardium on the RCA was found in one specimen. This abnormality had a minimal effect on the coronary diameter. Therefore, to our knowledge prevalence of the loop has not been mentioned in any literature [25].

Conclusions

The prevalence of right dominance, of the coronary artery, the RPDA, the atypical origin of the RCA from the left sinus and the prevalence of a myocardial bridge were found higher than that reported previously, whereas the dual aortic origin from both cusps and the prevalence of the bifurcated left main trunk

were found lower than that reported previously. Therefore, physicians should be aware of variations and abnormalities of coronary arteries when inserting catheters.

Author contributions. NK and CV substantially contributed to the concept and design of the study and analyzed and interpreted the data collected substantially by NK who drafted the manuscript. VC critically revised the manuscript. Both authors approved the final version submitted for publication and take responsibility for statements made in the published article.

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Conflict of interest statement. The authors have each completed and submitted an International Committee of Medical Journal Editors Uniform Disclosure Form for Potential Conflicts of Interest. None of the authors disclose any conflict of interest.

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