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Relationship between hypoplastic right coronary artery and coronary artery anomalies

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Abstract. – OBJECTIVES: The frequency of hypoplastic right coronary artery (HRCA) and its contribution to coronary artery anomalies (CAAs) has not been thoroughly studied. Here we aimed to investigate whether a casual relationship exists between the presence of HRCA and CAAs.

MATERIALS AND METHODS: We retrospectively reviewed coronary angiography records of 7500 patients. The images were carefully assessed for coronary artery (CA) anatomy and CAAs. Overall, we compared CAAs at the presence and absence of HRCA and evaluated potential association between HRCA and CAAs. Besides, we grouped HRCA patients according to the presence of CA disease (CAD) into two groups and compared their CAAs.

RESULTS: While the percentage of HRCA was 6.2%, it was 3.34% for CAAs. The percentage of CA with anomalous origin (CAAO) at the presence of HRCA was significantly higher than the presence of normal right coronary artery (NRCA) ($p < 0.01$). Similarly, the percentage of absent left main coronary artery (ALMCA) was also considerable increased in HRCA patients with respect to the patients with NRCA ($p < 0.01$). The percentage of CAAO was notably higher in the CAD (-) than CAD (+) patients with HRCA ($p < 0.01$). Likewise, the prevalence of ALMCA was also noticeably higher in the CAD (-) than CAD (+) patients with HRCA ($p < 0.01$).

CONCLUSIONS: HRCA is a clinically significant and frequently encountered congenital variation. The present observations indicate that the presence of HRCA is closely associated with a high prevalence of CAAO, particularly with increased rate of ALMCA.

Key Words:
Hypoplastic right coronary artery, Coronary artery anomaly.

Introduction

Coronary artery anomalies (CAAs) are inborn anomalies mostly encountered incidentally during coronary angiography. Most of CAAs are benign in nature and cause no detrimental deterioration in the supply of cardiac musculature[1-3]. Nevertheless, CAAs can rarely prevent blood flow to myocardium, causing myocardial infarcts and sudden cardiac death[4-7]. CAAs are isolated anomalies accompanied in general with no additional cardiac pathologies. Insufficient amount of data is available regarding the underlying causes of CAAs and their relationship with various other cardiac diseases.

Hypoplastic coronary artery disease (HCAD) is described as the presence of one or more congenitally underdeveloped epicardial CA, which is characterized with a great decrease in the diameter or length[8,9]. The term of HRCA is generally used when the RCA supplies only to the right ventricle and ends before reaching the crux of the heart and prior to giving off the posterior descending artery (PDA) and posterolateral artery (PLA). HRCA was described for the first time in 14 years-old girl in 1937 by Whiting[10]. Naming of this type congenital anomaly of the RCA is not well established; several terms are used to define it. These terms include hypoplastic RCA, rudimentary RCA, or diminutive RCA[10-13]; we arbitrarily preferred to use hypoplastic right coronary artery (HRCA) throughout the manuscript.

Moreover, HRCA is encountered with relatively higher frequency during coronary angiography. However, few studies exist in the literature investigating the incidence of HRCA in general population[14], the role of its presence on CAAs. We therefore, planned to determine the frequency of HRCA, examine its involvement in the beginning, route and ending of CAAs, established whether it has an association with various other CAAs.

Materials and Methods

We retrospectively reexamined the digital angiography records of 7500 patients underwent

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coronary angiography at the Department of Cardiology, Medical School of Eskisehir Osmangazi University, Eskisehir, Turkey between February 2007 and December 2010. The angiographic images were carefully evaluated for the view of CA anatomy and CAAs by a qualified interventional cardiologist. Variations in CA anatomy together with normal and abnormal origin, course, and termination of CA were further reworked by an experienced anatomist. Anomalous origin, course (myocardial bridging-MB), and termination (fistula) of CA were recorded for further analyses and comparisons. We used the classification system defined by Angelini to classify CAAs[2].

The right coronary artery was considered as HRCA when the RCA supplies only to the right ventricle and ends before reaching the crux of the heart and prior to giving off the PDA and PLA. On the whole, we compared CAAs at the presence and absence of HRCA and evaluated the effect of HRCA on the origin, course, and termination of CAAs. Additionally, we categorized HRCA patients with reference to the presence of coronary artery disease (CAD) into CAD (+) and CAD (-) groups and compared their CAAs. The CAD is defined as more than 50% luminal compression of one or more major epicardial CA.

We excluded the patients with following conditions: (1) the patients received previous CA bypass surgery; (2) the patients having one or more completely occluded major epicardial CA; (3) The patients with digital angiography records holding poor quality to assess. The abbreviations used are listed and explained in Table I.

Table I. Descriptions of the abbreviations used in the text.

Abbreviation	Description
ALMCA	Absent left main coronary artery
CA	Coronary artery
CAA	Coronary artery anomaly
CAAO	Coronary artery with anomalous origin
CAD	Coronary artery disease
CAF	Coronary artery fistula
Cx	Circumflex artery
HRCA	Hypoplastic right coronary artery
MB	Myocardial bridge
NRCA	Normal right coronary artery
PDA	Posterior descending artery
PLA	Posterolateral artery

Statistical Analysis

The SPSS statistical software package (SPSS, version 16.0 for windows; SPSS Inc., Chicago, IL, USA) was used to perform all the statistical calculations. Continuous variables were expressed as mean±SD, categorical variables were defined as percentages. 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.

Results

The review of the angiography records of 7500 patients revealed that the mean age of the patients was 57.4±12.6 years (range: 18-102 years). Seventy-two percent of the patients were males, 28% were females, and 64.4% of the patients contained the CAD. We detected HRCA in 466 (6.2%) patients. A representative picture of HRCA is illustrated in Figure 1. The frequency of CAAs and their classification in relation to their types are summarized in Table II. Among the 7500 angiographic population we detected 251 patients (3.34%) with CAAs. We sorted out the CAAs with regard to their anomalous origin, unusual course (myocardial bridge-MB), and abnormal termination (coronary artery fistula-CAF). Among 251 CAAs, there were 121 CA with anomalous origin (CAAO) (1.61%), 98 MBs (1.3%), and 32 CAFs (0.43%). Among the CAAO, the most common anomaly was ALMCA (58.7%), second most frequent anomaly was the split RCA (12.4%), and third most common abnormality was the RCA originating from the LSV (7.5%). As for the frequency of CAAs among the entire study population, most prevalent anomaly was the CAAO (1.61%); and among which, ALMCA was the most frequent anomaly (0.95%). The percentage of MBs and CAFs were 1.3% and 0.43%, respectively (Table II).

Moreover, we determined that a total of 466 (6.2%) patients had HRCA. We investigated the existence of a possible association between the occurrence rate of the CAAs and the presence of HRCA by comparing the patients having HRCA and the patients with NRCA. The prevalence of total CAAs was considerably increased in the presence of HRCA with respect to the patients with NRCA (9.87% vs. 2.91%, $p < 0.001$). The prevalence of the MBs and CAFs were similar between the patients with HRCA and NRCA ($p > 0.05$). By contrast, the number

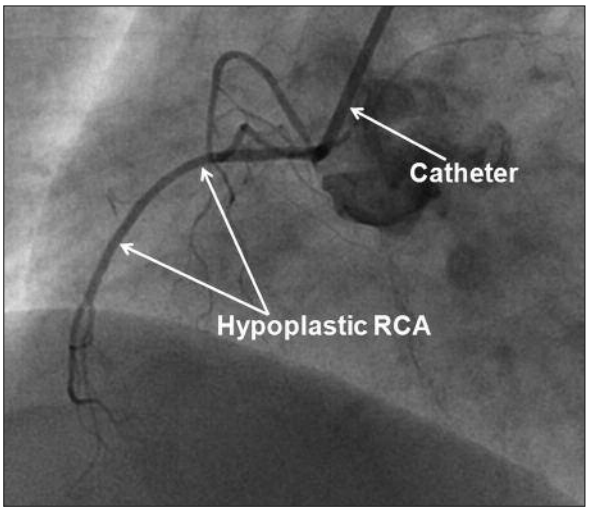

Figure 1. A representative coronary angiography image illustrating a hypoplastic right coronary artery (HRCA). Note that HRCA shows an incomplete development, characterized with notable decrease in its diameter and in its length.

of CAAO was markedly higher in HRCA patients than the patients with NRCA (8.37% vs. 1.16%, $p < 0.001$). Among the CAAO, ALMCA were notably higher in the existence of HRCA than the presence of NRCA (7.73% vs. 0.50%, $p < 0.001$). The percentage of MBs and CAFs were similar in HRCA and NRCA patients ($p > 0.05$) (Table III).

We also noted the presence of the CAD in 466 HRCA patients and found that 247 of them were CAD (+) while 219 of them were CAD (-). The total number of CAAs in CAD (-) patients was significantly higher than CAD (+) patients (15.07% vs. 5.26%, $p = 0.005$). Similarly, the frequency of the CAAO was significantly increased in CAD (-) patients in comparison to the CAD (+) patients (14.15% vs. 3.24%, $p < 0.001$). Likewise, among the CAAO, the occurrence rate of absent LMCA was also markedly amplified in the CAD (-) patients with regard to the CAD (+) patients (12.78% vs. 3.24%, $p < 0.001$). The percentage of MBs and fistulas were similar in CAD (+) and CAD (-) patients ($p > 0.05$) (Table IV).

Discussion

Hypoplastic right coronary artery (HRCA) is a congenital anomaly with presently unexplained underlying factors. In the present study we evaluated the frequency of HRCA and its effect on the elements of CAAs. CAAs are seldom anomalies discovered incidentally during coronary angiography. Earlier studies reveal that the frequency of CAAs varies between 0.6-5.6%[1,3,15-19]. We distinguished 251 (3.34%) CAAs among the angiographic records of 7500 patients. This frequency for CAAs is higher than previous investigation except for the study reported by Angelini et al[19]. We used the classification system defined by Angelini to classify CAAs[2].

Table II. The frequency of CAAs and their classification in relation to their types.

	Number	Frequency among the sites of anomalous origin (n = 251)	Frequency among the present entire angiographic population (n = 7500)
The sum of anomalous CA	251	100%	3.34%
Anomalous origin	121	–	1.61%
Absence of LMCA	71	58.7%	0.95%
RCA from LSV	9	7.5%	0.12%
RCA from Cx	1	0.8%	0.01%
Cx from RSV or RCA	19	15.7%	0.25%
LAD from RSV or RCA	5	4.1%	0.07%
Split RCA	15	12.4%	0.2%
Single CA	1	0.8%	0.01%
Myocardial bridge	98	–	1.3%
Fistula	32	–	0.43%

Abbreviations: CAA: coronary artery anomaly, CA: coronary artery, LMCA: the left main coronary artery, RCA: the right coronary artery, LSV: the left sinus of Valsalva, Cx: the circumflex artery, RSV: the right sinus of Valsalva, LAD: the left anterior descending artery.

Table III. Frequency of coronary artery anomalies with regard to the presence and absence of HRCA.

	HRCA (n = 466)	NRCA (n = 7034)	*p* value
The sum of anomalous CA (n, %)	46 (9.87)	205 (2.91)	< 0.001
Anomalous origin (n, %)	39 (8.37)	82 (1.16)	< 0.001
Absence of LMCA (n, %)	36 (7.73)	35 (0.50)	< 0.001
RCA from LSV (n, %)	2 (0.43)	7 (0.1)	0.1
RCA from Cx (n, %)	0 (0)	1 (0.01)	0.94
Cx from RSV or RCA (n, %)	0 (0)	19 (0.27)	0.3
LAD from RSV or RCA (n, %)	0 (0)	5 (0.07)	0.72
Split RCA (n, %)	1 (0.21)	14 (0.2)	0.62
Single CA (n, %)	0 (0)	1 (0.01)	0.94
Myocardial Bridge (n, %)	3 (0.64)	95 (1.35)	0.13
Fistula (n, %)	4 (0.86)	28 (0.40)	0.13

Abbreviations: HRCA: hypoplastic right coronary artery, NRCA: normal right coronary artery, CA: coronary artery, LMCA: the left main coronary artery, RCA: the right coronary artery, LSV: the left sinus of Valsalva, Cx: the circumflex artery, RSV: the right sinus of Valsalva, LAD: the left anterior descending artery.

The increased frequency of CAAs might be explained with the use of current classification approach and methodology. (1) We considered all the coronary arteries with anomalous origin, unusual course, or/and aberrant termination as CAA[2]. However, few of the previous reports regard these three types of anomalies as CAA[18,19]. (2) Our methodology for retrieving the data was different than most of the previous investigations. While majority of previous works determined the type of CAA using angiographic records[1,3,17,18], we generated the current data through reviewing the angiographic movies. Determination of CAAs from angiographic reports contains certain disadvantages that include:

1. Because CAAs infrequently exist, the physician reporting them may fall short to precisely distinguish and define them in the records;
2. Since majority of the CAAs are habitually benign in nature, the specialist may not record them always;
3. In the majority of the available researches, angiographic records are assessed by different cardiologists whose standards for the classification of the CAAs may well deeply fluctuate, thereby generating in conflicting statistics regarding the CAAs. All of these factors can influence the frequency calculated for CAAs for the present and studies elsewhere.

Table IV. The frequency of CAAs in HRCA patients with respect to presence and absence of CAD.

	CAD (+) (n = 247)	CAD (–) (n = 219)	*p* value
The sum of anomalous CA (n, %)	13 (5.26)	33 (15.07)	0.005
Anomalous origin (n, %)	8 (3.24)	31 (14.15)	< 0.001
Absence of LMCA (n, %)	8 (3.24)	28 (12.78)	0.001
RCA from LSV (n, %)	0 (0)	2 (0.91)	0.28
RCA from Cx (n, %)	0 (0)	0 (0)	–
Cx from RSV or RCA (n, %)	0 (0)	0 (0)	–
LAD from RSV or RCA (n, %)	0 (0)	0 (0)	–
Split RCA (n, %)	0 (0)	1 (0.46)	0.53
Single CA (n, %)	0 (0)	0 (0)	–
Myocardial bridge (n, %)	2 (0.81)	1 (0.46)	0.45
Fistula (n, %)	3 (1.21)	1 (0.46)	0.27

Abbreviations: HRCA: hypoplastic right coronary artery, NRCA: normal right coronary artery, CA: coronary artery, LMCA: the left main coronary artery, RCA: the right coronary artery, LSV: the left sinus of Valsalva, Cx: the circumflex artery, RSV: the right sinus of Valsalva, LAD: the left anterior descending artery.

The appearence of HRCA has relatively higher frequency met during coronary angiography. Different designations are used to refer to congenitally underdeveloped RCA[10-13]. Most commonly used designations in the literature are hypoplastic RCA, diminutive RCA, non dominant RCA, and rudimentary RCA. We researched PubMed for these terms using the link of http://www.ncbi.nlm.nih.gov/pubmed. Our PubMed research turned out a total of 277 papers. Majority of them were case reports and we found no data regarding the association between HRCA and CAAs in the rest of the papers. Therefore, to our knowledge this is the first study attempting to find out if a potential relationship exists between the presence of HRCA and features of CAAs.

In our investigation the percentage of HRCA was 6.2%. Our comparison turned out no marked difference for the frequency of MBs and CAFs between the patients with HRCA and NRCA. The percentage of CAAO was significantly higher in the patients with HRCA than the patients with NRCA. Moreover, the occurrence rate of ALMCA was fifteen folds increased in HRCA patients with respect to the presence of NRCA. This marked increase suggests that there might be a relationship between the existence of HRCA and the presence ALMCA. Since the circumflex artery (Cx) well develops at the presence of HRCA, the left coronary artery system becomes dominant as expected, where left anterior descending artery (LAD) and the Cx supply to entire left ventricle[20]. In such condition, the separate origin of the LAD and the Cx, thus arising directly from the aorta, might ensure better blood supply to the heart musculature. In the case of the stenosis in the LAD or the Cx, the other one can be source of alternative collateral circulation. In other words, we assume that the presence of ALMCA at the existence of HRCA can be an embryological adaptive response to guarantee blood flow to the heart. The rate of ALMCA in the patients with HRCA was 8.4%. This is a considerably higher percentage. Therefore, while the presence of HRCA during the right coronary system angiography should prompt specialist for the potential existence of ALMCA, the attendance of absence of LMCA during the left coronary system angiography should alert expert for the occurrence of accompanied HRCA.

Roughly two third of the present study population consisted of the patients with coronary artery disease (CAD). The percentage of CAD was remarkably higher in the patients with NRCA than the patients with HRCA. We propose a couple of factors that might offer a reason to this interesting finding. One explanation can be the fact that ischemia, even myocardial infarcts can develop in the presence of HRCA without accompanying a CAD in musculature of the right ventricle[21,22]. In turn, this might have increased the number of coronary angiography. The other possible cause can be the lost of relatively more patients with HRCA owing to the occlusion of the Cx or the LAD providing larger area of the left ventricle myocardium. However, actually we have no evidence to confirm these propose. Further studies remain to be done to investigate the relationship between HRCA and adverse effects of CAD to help illuminate these points.

Moreover, we also scrutinized if a potential relationship exists between CAAs and the occurrence of CAD in the patients with HRCA. Our analysis revealed a four folds increase in the frequency of absence of LMCA in the absence of CAD in comparison to the presence of CAD, suggesting that the presence of HRCA appears to provide a protective effect against the development of CAD. Normally, the LMCA gives off the LAD and the Cx after arising from the aorta. Coronary blood flow creates turbulence harming the endothelial cells at the bifurcation of the LAD and the Cx; consequently, easing the development of atherosclerotic lesion. In reality, relatively augmented progression of atherosclerotic lesion at the bifurcation sites of the vessels is well established[23,24]. Conversely, the LAD and Cx arise directly from the aorta at the presence of ALMCA and more laminar flow is achieved throughout arterial wall. Consequently, in this case the proximal sites of the LAD and Cx can be protected from the blood flow turbulence. The presence of ALMCA perhaps enables a better coronary blood flow, thereby reducing arterial wall damage and so the development of CAD. However, we encountered no data verifying our deductions in the literature we reviewed. The paper of Yamanaka and Hobbs[3], the largest study performed until now regarding the CAAs, does not find a correlation between ALMCA and CAD. Another reason for the observation of fewer ALMCA in the CAD patients might be the presence of an atherosclerotic lesion that is located at the aorta-ostial junction of one of the major epicardial coronary artery and can mask the absence of LMCA. Exclusion of the patients with totally occluded one or more major epicar-

dial artery and the patients with previous bypass graft surgery from the present study can be another factor reducing the percentage of ALMCA in the CAD patients.

The presence of HRCA can create complication during the angiography. Angiography catheter can entirely obstruct ostium of HRCA and avert coronary artery blood flow. Taking the first pose as non-selective during the RCA angiography can help prevent the occurrence of this complication. Further, the use of a thinner catheter (5 French) with side hole for the angiography of the RCA is also functional for reducing impediment**.** In brief, the selection of suitable catheter not only optimizes procedural success but also reduces the complications at the presence of HRCA[25]. Sometimes, HRCA can provide significant collateral circulation to the left coronary system. Most of these collaterals underlie the myocardium and majority of them cannot be visualized during angiography[26]. Therefore, it should be kept in mind that the collateral of HRCA to the left coronary system can become very critical in the case of severe narrowing in the left coronary system.

Conclusions

Complete familiarity with coronary artery anatomy, variations, and anomalies is critical for not only optimizing interventional approaches but also reducing potential complications during the procedure. HRCA is a congenital variation wit relatively higher frequency and clinical importance. The presence of HRCA appear to have an association with CAAO, particularly with the ALMCA; therefore, the presence of HRCA should alert the specialist for the potential presence of ALMCA.

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