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Original Article

Anomalous origins and branching patterns in coronary arteries – An angiographic prevalence study

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ABSTRACT

Introduction: The objectives under study were to validate percentages of presence of anomalous origins, branching patterns, presence of clinical abnormalities, for example, cameral fistulas, myocardial bridging, ectasia in coronary arteries. The cardiac dominance and the normal and diseased coronaries among the above-mentioned parameters were also analysed. The study was done among a west coastal population of Kerala and Karnataka.

Materials and methods: The angiograms were obtained from the Department of Interventional Cardiology, K.S. Hegde Medical Academy and Hospital, Karnataka after obtaining the ethical clearance. Five hundred angiograms of patients who presented with the clinical symptoms, ECG and ECHO abnormalities were studied prospectively. Informed consent was obtained. Recanalized normal looking coronary arteries were excluded. The parameters were assessed and categorized as per the sequence in the objectives of the study mentioned above.

Results: Presence of anomalous origins was seen in 20 cases and difference in branching pattern in 31 cases. The presence of ramus intermedius branch was seen in 51 cases, cameral fistulas in 5 cases, myocardial bridging in 29 cases and ectasia in coronary arteries in 8 cases. Cardiac dominance was seen as right in 405 cases, left in 44 cases and co-dominant in 29 cases. 298 patients had diseased coronaries among the study group. 22 cases were excluded.

Discussion and conclusion: Discussion and comparisons with various studies and possible explanations are provided about the obtained result outcomes.

The present study concludes that coronary artery appears to be normal even if anomalous origin and branching patterns are present.

1. Introduction

A coronary angiography guides a cardiologist to determine an anatomic variant in the coronary artery. This in turn depends on the observer's perceptive thresholds of defining a variant. Coronary anomalies may occur with prevalence of 1–5% in patients who undergo a coronary angiography proceedure.[1–3] An appropriate identification and classification of coronary anomalies is required to determine the propensity of clinical conditions particularly in young and healthy individuals. Conditions may include fixed or dynamic myocardial ischemia and sudden cardiac death.[4] Owing to failure to detect significant anatomic abnormalities by conventional exercise stress testing or intravascular Doppler flow studies, the credential recording of precise ischemia risk for these anomalies is lacking.[5]

The left main coronary artery (LMCA), which takes its origin from left aortic sinus, bifurcates into left anterior descending (LAD) artery and left circumflex (LCx) artery branches. There will be separate ostia of the LAD and LCx barely and the LAD mostly presents an anterior origin than the LCx, if serrate ostias are present. LMCA trifoliates into LAD, LCx and ramus intermedius, which arises between the LAD and LCx arteries in few patients. Depending on its anterior or posterior course along the lateral aspect of the left ventricle, ramus is analogous to either a diagonal branch or an obtuse marginal branch. LAD gives origin to sepal and diagonal branches.[6]

Number and size of diagonal branches may fluctuate from one to three. An acquired atherosclerotic occlusion is questionable if diagonals are not visualised. In most patients (80%), the left

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coronary artery (LAD) courses around the left ventricular apex and adjourn along the diaphragmatic aspect of the left ventricle designated as type III LAD. Right coronary artery (RCA) originates from the right anterior aortic sinus. If the ostium of the RCA is not easily located, the most common reason will be the ostium has a more superior and anterior origin than anticipated.[6]

Presence and absence of myocardial ischemia form the basis for categorising coronary artery anomalies. An abnormal communication between a coronary artery and a cardiac chamber (right or left ventricle) or a major vessel is a coronary anomaly denominated as coronary artery fistula. Major vessels included can be vena cava, pulmonary vein or pulmonary artery.[7,8]

Three major coronary arteries customarily sequel along the epicardial surface of heart. Occasionally, short moieties of coronary artery douche into myocardium for a vacillating distance, termed as myocardial bridging. This has a prevalence of 5–12% of patients and is usually confined to the left anterior descending artery (LAD).[9] When the significance of prevalence of myocardial bridging by coronary angiogram was analysed, it has been found out that even though tunnelling provides an atheroprotective locale, atherosclerosis will become an axiomatic phenomenon in a proximal bridged segment. Bridging alters the micro- and macro-coronary mechanics and also lures and inveigles atherosclerosis at the same time.[10] Ectasia of a coronary artery is a lesion characterised by a greater diameter than the reference diameter in one or more areas of a coronary artery. These findings help to clinch the value of new devices and drugs for the treatment of patients with ischemic coronary artery disease (CAD).[11]

Complex anatomy of the coronary artery system can accurately be depicted by 64-slice computed tomographic angiography (CTA). The coronary artery system was right-dominant in 76%, left-dominant in 9.1% and co-dominant in 14.8% of the cases. Myocardial bridging was observed in 37% when reviewed retrospectively, suggesting this modality to be useful in detecting coronary artery variants and is a persuasive alternative to conventional coronary angiography in their diagnosis.[12]

The right coronary artery (RCA) is dominant in 85% of patients and non-dominant in 15% of patients in which the left circumflex (LCx) artery is the dominant vessel. The remaining patients have an RCA that gives rise to the PDA, with the LCx artery providing all the posterolateral branches (balanced or co-dominant circulation).[6] Left coronary dominance and atherosclerotic involvement of left anterior descending artery (LAD) are neither related nor is left coronary dominance associated with atherosclerotic involvement of LAD ostium and ischemic myocardial infarction.[13]

The study was aimed at finding out the prevalence of anomalous origin and branching patterns of coronary arteries, among a west coastal population of Kerala and Karnataka. The objectives of the study were to validate percentages of presence of anomalous origins, branching patterns, presence of clinical abnormalities, for example, cameral fistulas, myocardial bridging, ectasia in coronary arteries, and to assess the percentage of prevalence of ramus intermedius branch of coronary artery among the study population. The cardiac dominance and the normal and diseased coronaries among the above-mentioned parameters were also analysed.

2. Materials and methods

2.1. Study design

A cross-sectional study was conducted.

2.2. Study setting

After procuring the ethical clearance through proper channels, coronary angiogram reports of 500 patients, who had presented with the clinical symptoms, electrocardiograph (ECG) and echocardiogram (ECHO) abnormalities, were studied prospectively. This study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a prior approval by the institution's human research committee.

Reports were obtained for analysis from the department of Interventional Cardiology, K.S. Hegde Medical Academy and Hospital, Karnataka. Informed consent was obtained from the patients.

2.3. Study subjects

Patients who visited the cardiology outpatient department as a part of their routine cardiac checkups were selected as study subjects, if they underwent a coronary angiography procedure due to variation in the normal cardiac parameters. The selection criteria to be enrolled for a coronary angiography procedure were strictly subjected to the guideline protocols. The age group of the study population was up to 75 years because after the cut-off age of 75, the approach was conservative. Benefits from invasive as well as from surgical procedures were marginal in patients above 75 years or more. This is because of the poor prognosis of them with an average 1-year mortality rate of 33–35%.[14]

2.3.1. Inclusion criteria

The criterion is strictly subjected if the patients are of Indian origin and from the respective state were included in the study. For the history of the patient, origin was enquired and was cross-checked with patient details from respective files. All patients who underwent an angiogram procedure were selected for the study purpose after obtaining their consent.

2.3.2. Exclusion criteria

Patients with previous history of a coronary artery bypass grafting (CABG) and recanalized normal looking with or without in-stent restenosis coronary arteries were excluded. Twenty-two such cases were excluded.

2.4. Sample size and its calculation

Five hundred samples were estimated statistically for conducting the study.

2.4.1. Sample size determination

The minimum sample size required is 490 cases. The sample size was taken as 500 as the samples can be up to 10% more than of the estimated sample size.

Level of significance = 5%
Effect size = 0.031
Power of the test = 80%
Prevalence = 5%[9]

The sample size was estimated by consulting a statistician and using the statistical software G* Power 3.0.10.

2.5. Sampling technique

Convenience sampling was done as all eligible cases who fulfilled the inclusion criteria during the definite time period of the study were selected as samples. Patients were approached at the cath lab prior to angiogram procedure.

2.6. Angiography procedure

Quantitative coronary angiography (QCA) was performed using the automated coronary analysis package of the Innova 2100 IQ Cath at a AW4.4 workstation. Coronary angiograms were

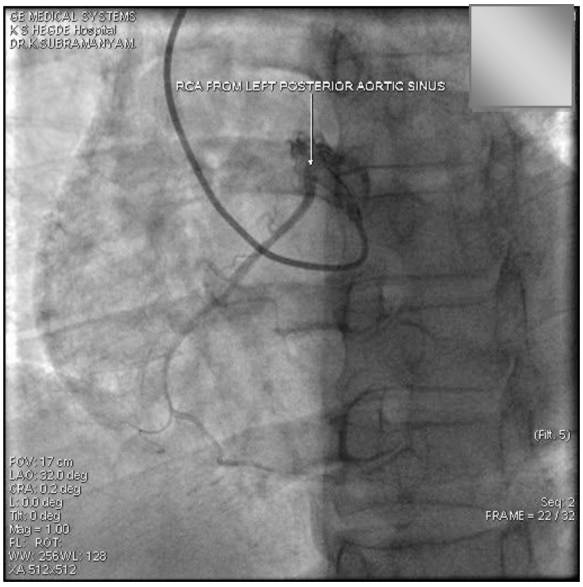

Fig. 1. Right coronary artery (RCA) originating elsewhere rather than right anterior aortic sinus.

subsequently viewed on a volume viewer software package of GE Medical Systems USA for digital angiographic films. Angiographic views were selected by minimising foreshortening of the involved coronary segments and by separating them from adjacent intervening structures. All angiograms were reviewed by two cardiologists using double blinding method of randomisation for subsequent quantitative analysis.

2.7. Data collection

Angiogram reports were analysed by classifying them into the following parameters: presence of anomalous origins, branching pattern anomalies, presence of clinical abnormalities, presence of ramus intermedius branch of coronary artery and distribution of diseased segments among ramus branch, cardiac dominance pattern and distribution of diseased segments among each pattern and normal and diseased coronary among the study population.

Presence of anomalous origins was further sub-classified into high anterior origin of right coronary artery (RCA), anomalous origin of coronary artery from the opposite sinus (ACAOS), single origin for left anterior descending artery (LAD) and RCA, anomalous origin of left main coronary artery (LMCA) from the pulmonary artery (ALCAPA), absence of LMCA (LAD and left circumflex artery (LCx)) having separate origin, single coronary artery and high origin of LAD.

Branching pattern anomalies were further sub-classified into early bifurcation of right coronary artery (RCA) to posterior descending artery (PDA) and posterior left ventricular artery (PLV), dual PDA, dual left anterior descending artery (LAD), type II left anterior descending artery (LAD), early diagonal from LAD.

Presence of clinical abnormalities assessed in the study included (a) cameral fistulas, (b) myocardial bridging and (c) ectasia in coronary arteries.

2.8. Statistical analysis

Chi-square test was used to analyse the association between the variables mentioned in the objectives.

3. Results

3.1. Study population

Out of coronary angiogram reports of 478 patients, 4.18% ($n = 20$) showed presence of anomalous origins (Figs. 1 and 2A and B). Difference in branching pattern was observed in 6.49% ($n = 31$) (Figs. 3–6). Clinical abnormalities and cameral fistulas were seen in 1.05% ($n = 5$) (Fig. 7A and B), myocardial bridging in 6.07% ($n = 29$) (Fig. 8A and B) and ectasias in coronary arteries were delineated in 1.67% ($n = 8$) (Fig. 9) cases. Total of 19.46% ($n = 93$) patients were found to have anomalous coronaries when the results were computed. Percentage of prevalence of diseased coronaries among the anomalous origins was found to be 37.63% ($n = 35$) (Table 1).

Among the study population, ramus intermedius branch was noticed in 10.67% ($n = 51$) cases and percentage of prevalence of diseased coronaries among ramus segments was 49.01% ($n = 25$) (Table 2). Cardiac dominance was seen as right in 84.73% ($n = 405$), left in 9.21% ($n = 44$) and co-dominant in 6.07% ($n = 29$) and the percentage of prevalence of diseased coronaries was found to be 63.46%, 61.36% and 48.28%, respectively (Table 3). Among the study group, 62.34% ($n = 298$) patients had diseased coronaries whereas 37.66% ($n = 180$) patients had non-critical coronary arteries (Table 4).

According to the sub-classifications mentioned in the methodology about the presence of anomalous origins, the following percentages of prevalence were noted. High anterior origin of right

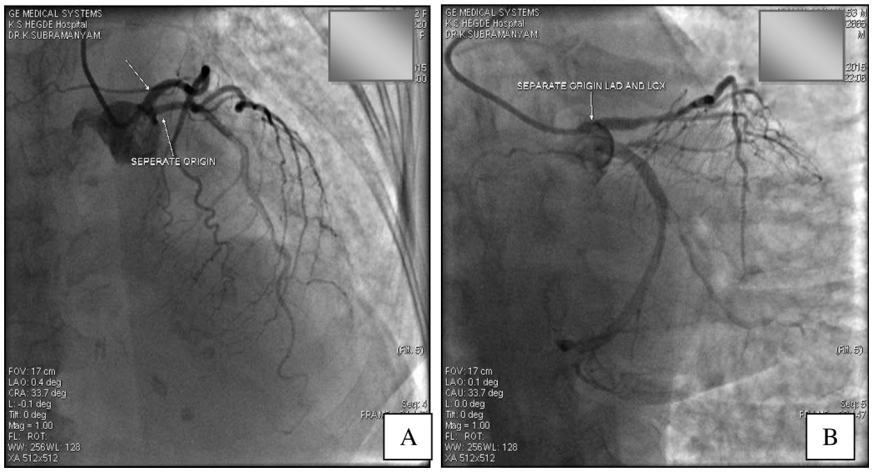

Fig. 2. Absence of LMCA (left main coronary artery): left anterior descending (LAD) and left circumflex artery (LCx) having separate origin (A and B).

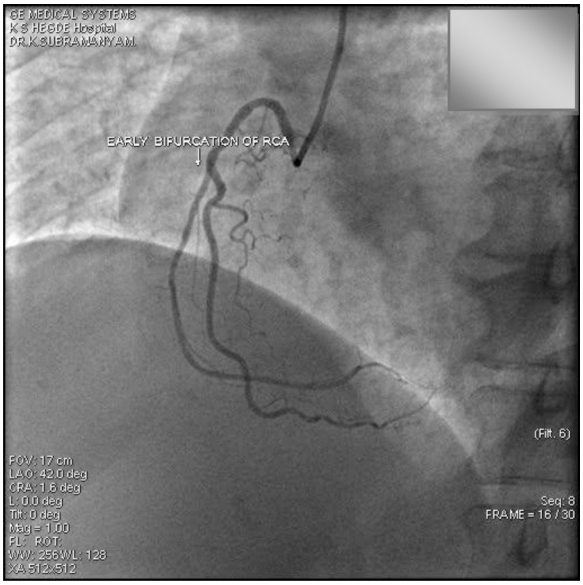

Fig. 3. Early bifurcation of right coronary artery (RCA) to posterior descending artery (PDA) and posterior left ventricular branch (PLV).

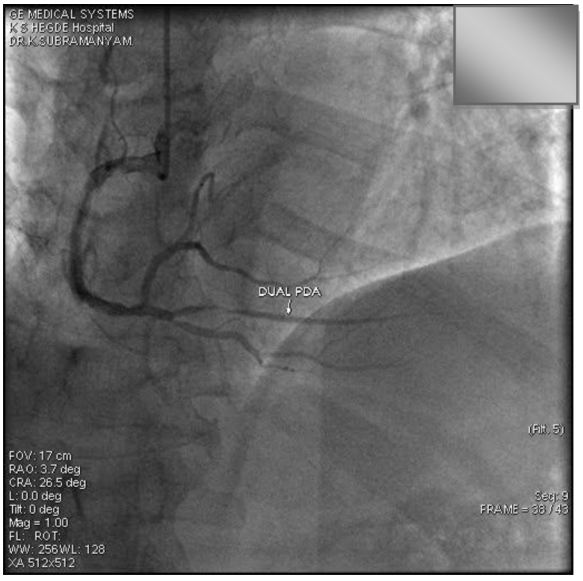

Fig. 4. Dual posterior descending artery (PDA).

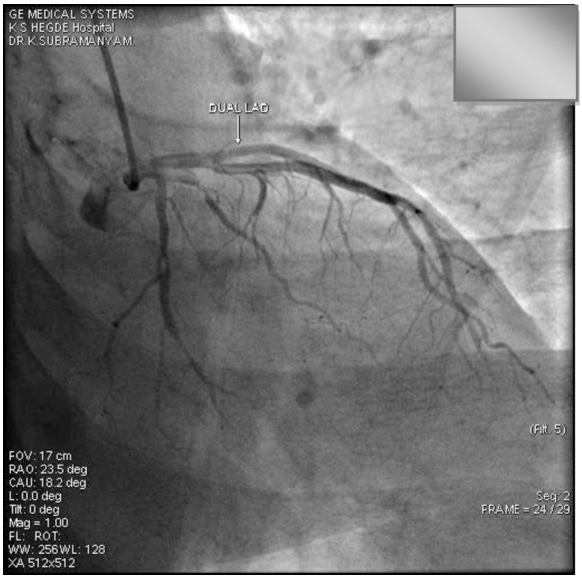

Fig. 5. Dual left anterior descending artery (LAD).

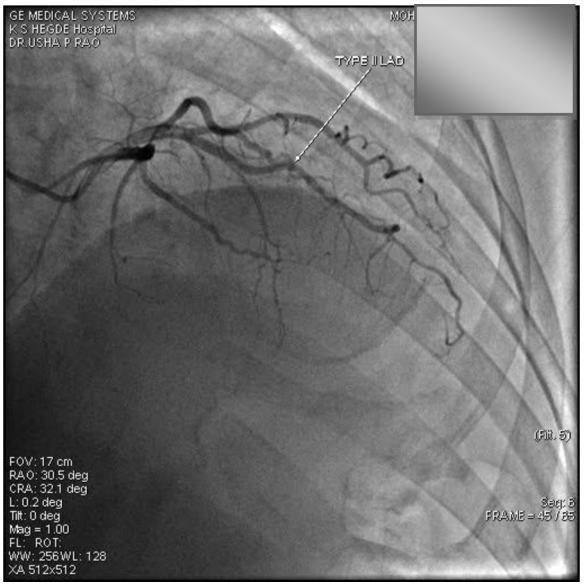

Fig. 6. Type II left anterior descending artery (LAD).

coronary artery (RCA) was seen in 2 cases (0.42%) and anomalous origin of coronary artery from the opposite sinus (ACAOS) was observed in 13 (2.72%) cases (Fig. 1). Among these, all cases were showing right coronary artery (RCA) originating elsewhere rather than right anterior aortic sinus. This indicates that anomalous

Table 1
Anomalous origins of coronary artery and its contribution to coronary artery stenosis with percentages.

Particulates	Number	Percentage
Normal	385	80.54%
Anomalous origin	93	19.46%
Total	478	100%
Normal among anomalous	58	62.37%
Diseased among anomalous	35	37.63%
Total	93	100%

Table 2
Normal and diseased coronary among the study population.

Particulate	Number	Percentage
Normal	180	37.66%
Diseased	298	62.34%
Total	478	

Table 3
Percentage of prevalence of ramus intermedius branch of coronary artery and distribution of diseased segments among ramus branch.

Particulates	Number	Percentage
Normal	427	89.33%
Ramus branch	51	10.67%
Total	478	100%
Diseased among ramus segments	25	49.01%
Non-diseased among ramus segments	26	50.98%
Total	51	100%

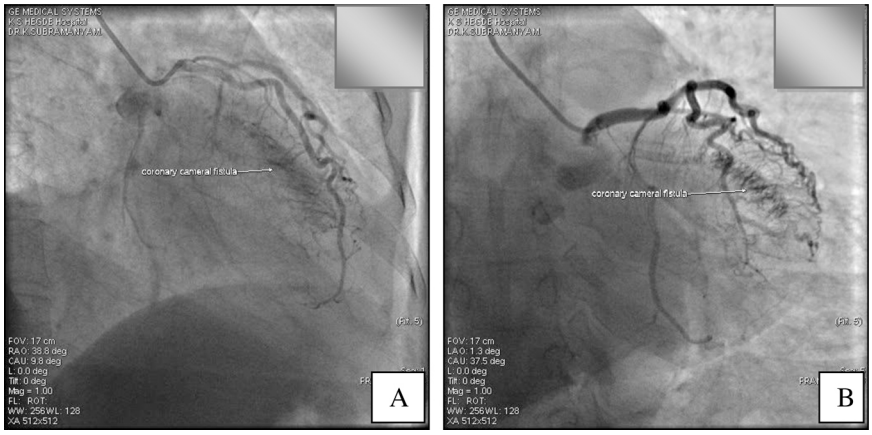

Fig. 7. Systolic (A) and diastolic (B) phase of cameral fistula.

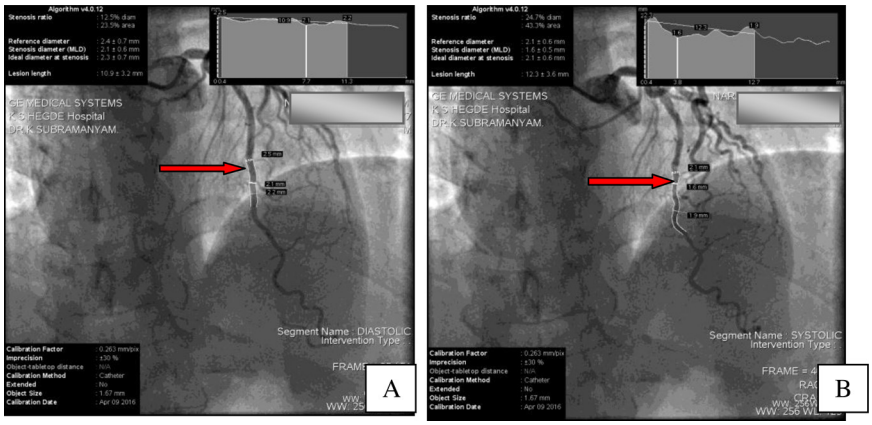

Fig. 8. Diastolic (A) and systolic (B) phase of bridging.

origins of right coronary were more than the left coronary artery. Absence of left main coronary artery (LMCA), that is left anterior descending artery (LAD) and left circumflex artery (LCx) having separate origin, were noticed in 2 (0.42%) (Fig. 2A and B) cases and high origin for LAD was seen in a (0.21%) case. Single origin for left anterior descending artery (LAD) and right coronary artery (RCA), anomalous origin of left main coronary artery (LMCA) from the pulmonary artery (ALCAPA) and single coronary artery cases were not observed.

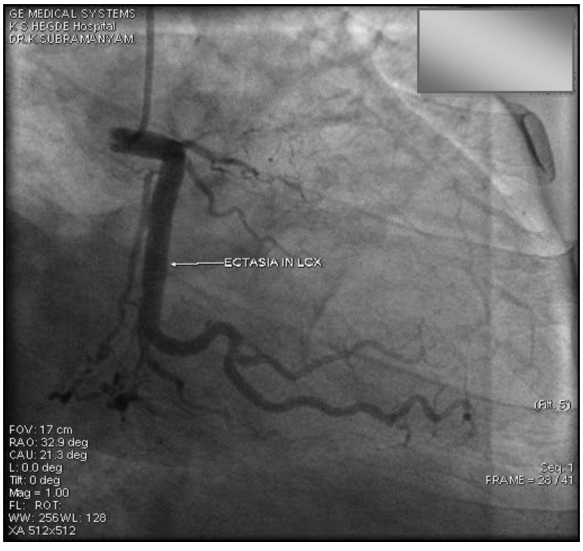

Fig. 9. Ectasia in coronary arteries (left circumflex artery).

Among the branching pattern anomalies and its sub-classifications, early bifurcation of RCA to posterior descending artery (PDA) and posterior left ventricular artery (PLV) were noted in 3 (0.63%) cases (Fig. 3), dual PDA was seen in a (0.21%) case (Fig. 4), dual left anterior descending artery (LAD) in 4 (0.84%) cases (Fig. 5), type II LAD in 16 (3.35%) cases (Fig. 6) and early diagonal from LAD in 7 (1.47%) cases. Among the branching pattern differences, the left coronary artery has more involvement than its counter partner on right side.

Chi-square test is statistically significant ($p \leq 0.05$). Here, we observe an association between A and B. This indicates that a coronary artery appears normal even if anomalous origin and branching patterns are present, provided the anomalous origins are not from the pulmonary artery.

Table 4
Cardiac dominance pattern and distribution of diseased segments among each pattern percentages.

Particulate	Number	Percentage	Diseased coronaries	Percentage
Right-dominant	405	84.73%	257	63.46%
Left-dominant	44	9.21%	27	61.36%
Co-dominant	29	6.06%	14	48.28%
	478		298	62.34%

4. Discussion

Even though coronary artery anomalies remain asymptomatic, its prevalence shows a wide variation. Coronary anomalies are regarded as coincidental findings during a diagnostic coronary angiography. The significance of confirming and recognising coronary artery anomalies and its clinical importance is vital in patients who undergo coronary interventions or cardiac surgery.

Presence and absence of myocardial ischemia form the basis for categorising coronary artery anomalies. Split right coronary artery (RCA), ectopic RCA (either from right or left cusp), fistulas, absence of left main coronary artery, left circumflex artery (LCx) arising from right or left cusp, low origin of RCA and other anomalies are included in the category which cause myocardial ischemia.[15] Coronary arteries with anomalous origins can cause unstable hemodynamics with turbulent blood flow patterns and vascular endothelium damages.[16] Besides atherosclerotic coronary disease, all these can predispose to myocardial ischemia.

Fujimoto et al. reported the prevalence of anomalous origin of a coronary artery (AOCAs) as 1.52% in 5868 consecutive patients by multidetector computed tomography (MDCT).[17] Namgung and Kim observed that the prevalence of coronary anomalies in a single centre of Korea was 1.16% among 8864 patients. Of these, 90 (87.4%) patients had origin and distribution anomalies.[18] Yildiz et al. analysed the angiographic data of 12,457 consecutive adult patients which were collected retrospectively for coronary artery anomalies. Anomalous coronaries were found with an incidence of 0.9%.[19]

The anomalous coronary artery from the opposite sinus (ACAOS) is characterised with the origin of left coronary artery (LCA) either from the proximal right coronary artery (RCA) or from right aortic sinus. This can be associated with sudden death during or shortly after exercise in young persons.[20] A most common anomaly in our study among the anomalous origins was the origin of coronary artery from the opposite sinus (ACAOS) in 13 (2.72%) cases (Fig. 1). Right coronary artery (RCA) originating elsewhere rather than right anterior aortic sinus was the only ACAOS identified. Namgung and Kim reported that in their studies, the most common anomaly was an anomalous origin of the right coronary artery (RCA) in 39.8% while, it was only 12.5% in the studies of Yuksel et al. and 0.84% in the study reports of Opolski et al.[18,21,22] The present study has fewer incidence prevalences than the comparative studies. But among the anomalous origin of RCA, all cases were taking its origin from right posterior aortic sinus, which is different from the above-mentioned study.

Secondly, the separate origin of left anterior descending artery (LAD) and left circumflex artery (LCX) was the prevailing anomaly in the present study with a percentage of 0.42%. This anomaly causes no hemodynamic impairment and is considered to be benign. The appearance of an avascular area at the site of the left main coronary artery (LMCA) distribution should raise a suspicion to the separate origin of LAD and LCX. Its incidence is very variable because of the great operator dependence.

Most common anomaly detected in the studies by Sohrabi et al. was separate ostia of the left anterior descending artery and left circumflex artery. This was found in 42 patients (53.16%) with the angiographic incidence of 0.69%, which appears to be more than the present study prevalence.[23] Şengül et al. encountered the separate origins of left anterior descending artery (LAD) and circumflex artery (Cx) in 28 patients (2.7%), with the angiographic incidence of 0.15% among 17.606 patients in their studies.[24] Accordingly, our study prevalences were more than this comparative study. Ghadri et al. found that the non-appearance of the left main artery percentages was ranging from 36% and 30.4% correspondingly by invasive coronary angiography (ICA).[25]

High take-off is defined as the coronary artery originating at higher points than the junctional zone between the sinus and the tubular part of the ascending aorta. High anterior origin of the right coronary artery is a common anomaly reported but is of no hemodynamic significance.[6] Fujimoto et al. reported the high take-off of left anterior descending artery (LAD) prevalence as 0.60% among 89 patients with anomalous origin of coronary artery (AOCAS). Still, the reported percentages were less for the high origin of left anterior descending artery (LAD) as 0.21%.[17] The present study lines up with the above-mentioned study of having an incidence of a high origin of LAD.

In type II left anterior descending artery (LAD), artery fails to reach the diaphragmatic surface, tether either at or before the cardiac apex. Erol and Seker mentioned about dual LAD as well as type I LAD prevalences in their studies as 1.38%. The type I is short, in which LAD originates from the left coronary artery (LCA) and ends high in the anterior interventricular groove.[26] Dual LAD is a rare coronary anomaly. In the present study, dual (LAD) was seen in 4 (0.84%) cases and type II LAD in 16 (3.35%) cases.

Kacmaz et al. state that the draining site of the fistula has a greater clinical and physiologic importance. The most common sites are the right ventricle (45% of cases), right atrium (25%) and the pulmonary artery (15%). Least common sites (<10%) are from left atrium or left ventricle.[27] Xu et al. identified a prevalence of 2.48% for coronary artery fistulas in their studies.[28] Namgung and Kim found coronary artery fistulas among 12.6% patients in their studies.[18] Şengül et al. stated that 20.7% cases had coronary artery fistulae in their case study.[24] In the present study, cameral fistulas were found in 1.05% cases and all the observed cameral fistulas were confirmed to right coronary artery (RCA) only.

Marcos-Alberca et al. observed that myocardial bridging is a very common finding even in normal subjects, but is considered clinically significant only when associated with chest pain and myocardial ischemia.[29] Tripathy et al. observed myocardial bridging only in a left anterior descending branch of left coronary artery (LAD) with a percentage of 3.5% in their studies.[30] The present study has a prevalence of myocardial bridges of 6.07%, which is more compared to the above-mentioned study.

Donkol and Saad assessed the incidence and location of myocardial bridging. The prevalence was found as 22.5% with most of the intra-muscular segments of the superficial type. All bridges were confirmed to the mid left anterior descending (LAD) artery (24.6%).[31] The present study has a prevalence of myocardial bridges of 6.07%, which is less compared to the above-mentioned study.

Cardiac dominance was seen as right in 84.73% (n = 405), left in 9.21% (n = 44), co-dominant in 6.07% (n = 29) and the percentage of prevalence of stenotic coronaries was found to be 63.46%, 61.36% and 48.28%, respectively in the present study. Kosar et al. stated that the coronary artery system was right-dominant in 76%, left-dominant in 9.1% and co-dominant in 14.8% of the cases among the study population they assessed.[12] Though the present study prevalence for right and left dominance patterns is almost similar to the comparative study, the co-dominant prevalences are higher in the present study.

Left coronary dominance and atherosclerotic involvement of left anterior descending artery (LAD) are neither related nor associated with atherosclerotic involvement of LAD ostium and ischemic myocardial infarction concluded by Ghaffari et al.[13] The present study lines up with this finding as the disease prevalence is same for all dominance patterns.

Suryanarayana et al. stated that there is no evidence of predisposition of anomalous coronary arteries to significant coronary artery disease in comparison to normal coronary arteries.[32] The present study also concludes that coronary artery appears to be normal even if anomalous origin and branching patterns are present.

5. Conclusion

Coronary artery appears to be normal even if anomalous origin and branching patterns are present. Greater awareness of their existence, clinical significance and treatment options will lead to better management of this entity. Although coronary artery anomalies are rare, they may cause difficulties during coronary interventions or cardiac surgery and may occasionally result in sudden cardiac death. The present study has a limitation; no case of an anomalous origin from the pulmonary artery was found. The contribution of the same to artery stenosis, hence, could not be assessed.

Conflicts of interest

The authors have none to declare.

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