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RESEARCH

Diagnosis, risk assessment, and surgical planning of coronary artery anomalies by CT angiography

Koroner arter anomalilerinde BT anjiyografi ile tanı, risk analizi ve cerrahi planlama

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Abstract

Purpose: This study evaluates the role of coronary computed tomography (CT) angiography in diagnosis and management of coronary artery anomalies and explores demographic variations.
Materials and Methods: A retrospective analysis of 2,786 patients undergoing Coronary CT angiography from November 2018 to October 2023 identified 53 cases (21 females, 32 males) of coronary artery anomalies. Anomalies were classified by origin, course, and structure. Imaging was performed using a dual-source CT scanner.
Results: Coronary artery anomaly prevalence was 1.82%. The most common anomaly was a high take-off origin of the right coronary artery (41.5%). Left main anomalies were more frequent in males, while malignant courses occurred only in females (19%). Additional findings included coronary stenosis and diverticula. Coronary CT angiography provided critical 3D visualization for preoperative planning and revealed gender-specific differences, emphasizing the need for tailored approaches.
Conclusion: Coronary CT angiography is an indispensable tool for diagnosing and characterizing coronary artery anomalies. Its non-invasive imaging allows for detailed preoperative evaluation, improving clinical and surgical outcomes. This study underscores the importance of addressing demographic variations and highlights the need for standardized protocols and further multicenter research.

Keywords:. Coronary artery anomalies, coronary imaging, coronary CT angiography, coronary surgery

Öz

Amaç: Bu çalışma, Koroner bilgisayarlı tomografik anjiyografinin koroner arter anomalileri tanı ve tedavisindeki rolünü değerlendirmekte ve demografik özelliklere göre farklılıkları incelemeyi amaçlamaktadır.
Gereç ve Yöntem: Kasım 2018 ile Ekim 2023 tarihleri arasında Koroner BT anjiyografi uygulanan 2.786 hastanın retrospektif analizinde 53 koroner arter anomali olgusu (21 kadın, 32 erkek) tespit edildi. Koroner anomaliler orijin, seyir ve yapılarına göre literatürle uyumlu şekilde sınıflandırıldı. Görüntüleme, çift dedektörlü BT anjiyografi kullanılarak gerçekleştirildi.
Bulgular: Koroner arter anomali prevalansı %1,82'dir. En sık görülen anomali, yüksek çıkışlı sağ koroner arter orijiniydi (%41,5). Sol ana arter anomalileri erkeklerde daha sık görülürken, malign seyir sadece kadın hastalarda (%19) görüldü. Ek bulgular arasında koroner stenoz ve divertikül yer aldı. Koroner BT anjiyografi, ameliyat öncesi planlama için kritik 3B görüntüleme sağladı ve cinsiyete özgü farklılıkları ortaya çıkararak, bireyselleştirilmiş tedavi yaklaşımlarının gerekliliğini ortaya koydu.
Sonuç: Koroner BT anjiyografi, koroner arter anevrizmalarının teşhis ve karakterizasyonu için önemli bir araçtır. Non-invaziv görüntüleme, ayrıntılı ameliyat öncesi değerlendirmeye olanak tanıyarak klinik ve cerrahi sonuçları iyileştirir. Bu çalışma, demografik farklılıkların ele alınmasının önemini vurgulamakta ve standart protokollere ve daha fazla çok merkezli araştırmaya olan ihtiyacı vurgulamaktadır.

Anahtar kelimeler: Koroner arter anomalileri, koroner görüntüleme, koroner BT anjiyografi, koroner cerrahi

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INTRODUCTION

The prevalence of coronary artery anomalies (CAA) has been reported to range between approximately 0.3% and 1% in the general population[1]. Anomalous origin of the coronary arteries represents one of the leading causes of sudden cardiac death in young individuals[2]. Although most CAAs are clinically silent, a small but important subset may be hemodynamically significant, resulting in myocardial ischemia, infarction, congestive heart failure, or sudden cardiac death[3-6].

Surgical intervention is generally recommended for patients with ischemic symptoms, documented ischemia, or high-risk anatomical features such as malignant coronary courses. In selected cases, certain anatomical configurations may warrant surgical correction even in asymptomatic individuals. Accurate delineation of coronary anatomy is therefore essential for appropriate risk stratification and surgical decision-making.

Coronary computed tomography angiography (CCTA) is a non-invasive, operator-independent imaging modality that provides high spatial and temporal resolution images of the coronary arteries. Its ability to offer a comprehensive three-dimensional visualization of coronary anatomy makes CCTA particularly valuable in the evaluation of CAAs, especially in patients with complex or high-risk anatomical patterns requiring detailed preoperative assessment[7-9].

Despite the increasing use of CCTA, there remains no clear consensus regarding the optimal surgical management of coronary artery anomalies, and the available literature is limited, particularly with respect to geographic and demographic variability. Moreover, data addressing regional prevalence patterns and their implications for surgical planning remain scarce, leading to potential gaps in patient-centered and region-specific clinical guidance[9,10].

This study aims to evaluate the prevalence and anatomical characteristics of coronary artery anomalies detected by coronary computed tomography angiography and to assess their clinical and surgical relevance. We hypothesized that CCTA provides reliable anatomical delineation that may influence surgical planning and perioperative risk assessment, particularly when regional and demographic characteristics are taken into account.

MATERIALS AND METHODS

Study design and population

This study was designed as a retrospective, single-center observational study conducted between November 2018 and October 2023, including a total of 2,786 patients (1,159 females and 1,627 males) who underwent coronary computed tomography angiography (CCTA) at our hospital due to suspected coronary artery disease, chest pain, or other indications such as coronary risk factors or electrocardiogram abnormalities. Among these, 53 patients (21 females, 39.6%; 32 males, 60.4%) were identified with coronary artery anomalies. This study population reflects unique regional characteristics, allowing for insights into geographic and demographic variations in CAA prevalence.

Procedure

Ethical approval (Selcuk University Faculty of Medicine, Local Ethics Committee, Approval Date and No: 16.04.2024 & 2024/220) was obtained from the local ethics committee. Additionally, permission forms were obtained from the responsible physicians for using the information of the patients in the study population.

All patients were instructed to fast for a minimum of 6 hours prior to the procedure to minimize the risk of aspiration resulting from vomiting, which may occur due to contrast media sensitivity. Arterial blood pressure was recorded. An antecubital intravenous line was established, preferably using an 18 G IV catheter prior to the patient's entry into the procedure room. Breath-holding exercises were performed before the procedure to ensure that patients could hold their breath for approximately 15–20 seconds.

The patients were positioned lying on their backs on the examination table. ECG electrodes were placed carefully over bony prominences to reduce muscle artifacts. In the final stage, just three minutes before the scanning procedure, 5 to 10 mg of isosorbide dinitrate (Isordil®) was administered to aid in the dilation of the coronary arteries.

Coronary computed tomography

CCTA examinations were conducted using a dual-source, 128 × 2-section DSCT scanner (Somatom Definition Flash®, Siemens Healthcare, Forchheim, Germany). This scanner features two X-ray tubes at a 95° angle and a 128-channel, two-detector row.

First, a topogram image was obtained to determine the scanning area. Following that, a single cross-sectional image was taken at the level of the left atrium, as indicated by the topogram, for the "bolus-tracking" program. The left atrium was manually marked to guide the scanning process.

The scanning area was defined between the carina level and the heart's diaphragmatic surface. A non-ionic contrast medium (Opaxol 350 mg/mL, 1.0 mL/kg body weight) was administered at a rate of 4.5–6 mL/s using an automatic injector system synchronized with ECG recording. After administering the contrast medium, 40 mL of saline (NaCl) was injected at a speed of 6 mL/s with the automatic injector. Once the predicted contrast level was reached, scanning was initiated using Sure Start®, automatically launched and completed during a single breath-hold. Repetitive images were captured from the marked left atrial lumen using the "bolus-tracking" technique. The procedure was completed without complications in all patients.

In this study, the device automatically determined the optimal kilovolt (kV) values using the Care kV option based on the topogram images, adjusting for the patient's body mass index (BMI). The automatic milliampere-seconds (mAs) values were established with the CareDose 4D option. CT acquisition parameters included slice collimation of 2×128×0.6 mm with a z-flying focal spot and a gantry rotation time of 270 ms. Images were reconstructed with a slice thickness of 0.75 mm and a 0.4 mm increment using a medium smooth tissue iterative reconstruction kernel (I26f). Sinogram affirmed iterative reconstruction (SAFIRE) was applied, with the strength set to 3 for all patients.

Table 1. Classification of coronary artery anomalies

Category	**Definition and Subtypes**
Coronary Artery Origin Anomalies	High take-off anomaly: The right coronary artery (RCA) or left main coronary artery (LMCA) originates from the ascending aorta more than 5 mm above the sinotubular junction.
	Low take-off anomaly: Coronary arteries are located deep within the aortic sinus, increasing the risk of iatrogenic complications during aortic valve surgery.
	LMCA origin anomaly: The LMCA originates from an abnormal location, such as the right coronary sinus or the non-coronary sinus.
	LAD origin anomaly: The left anterior descending artery (LAD) arises anomalously, often from the right coronary sinus.
	LCx origin anomaly: The left circumflex artery (LCx) originates from an unusual position, typically from the right coronary sinus or an aberrant branch.
	RCA origin anomaly: The RCA originates anomalously, often from the left coronary sinus.
	LAD and LCx origin anomaly: Both the LAD and LCx arteries have abnormal origins, often sharing a single ostium or originating from the opposite sinus.
	Single coronary artery: A rare anomaly where a single coronary ostium arises directly from the aortic trunk, mimicking a typical RCA/LMCA distribution or bifurcating atypically.
	Anomalous origin of coronary artery from pulmonary artery (ALCAPA/ARCAPA): The LMCA originates from the pulmonary artery (ALCAPA), or the RCA originates from the pulmonary artery (ARCAPA).
	Extra-aortic and extra-pulmonic origins: Coronary arteries arise from non-aortic structures, such as the brachiocephalic trunk, internal mammary artery, subclavian artery, or bronchial artery.
Coronary Artery Course Anomalies	Malignant course: Defined as an interarterial course where the coronary artery travels between the aorta and pulmonary artery, increasing the risk of compression and ischemia.
Intrinsic Coronary Artery Anomalies	Diverticula: Small outpouchings or dilatations within the coronary artery wall, often congenital in origin.
	LMCA agenesis: Absence of the LMCA, with separate ostia for the LAD and LCx arteries arising directly from the aorta.
	Coronary ectasia: Abnormal dilatation or enlargement of the coronary artery, exceeding its normal diameter.

Image analysis

The patient data were transferred to the workstation (syngo.Via, Siemens, Erlangen, Germany) for evaluation. The workstation automatically identified the optimal diastolic phases. The coronary arteries were examined in detail using the least artifact-affected axial images of each coronary artery, along with reconstructed images obtained through multiplanar reconstruction, maximum intensity projection, and 3D volume-rendered techniques.

Definition of coronary anomalies

Coronary anomalies are categorized into three primary groups: anomalies of origin, anomalies of course, and intrinsic coronary artery anomalies. These encompass variations such as high take-off origins, anomalous pulmonary connections, malignant courses, and structural abnormalities[11]. High take-off of the right coronary artery and left main coronary artery was defined as an origin located more than 5 mm above the sinotubular junction, according to previously published anatomical criteria. A detailed classification of coronary artery anomalies is provided in Table 1.

Statistical analysis

All statistical analysis were conducted using SPSS version 29.0, with a significance level set at $p < 0.05$. Continuous variables are reported as mean ± standard deviation, while categorical variables are presented as percentages. The prevalence of CAAs and the impact of CCTA on surgical planning and decision-making were analyzed using chi-square tests.

RESULTS

Among the 2,786 patients who underwent coronary computed tomography angiography (CCTA), coronary artery anomalies (CAAs) were identified in 53 individuals (1.82%), including 32 males (60.4%) and 21 females (39.6%). The mean age was 48.34 ± 12.25 years, with no significant difference between sexes ($p > 0.05$). Chest pain was the most common presenting symptom (75.5%), followed by exertional dyspnea (11.3%) and palpitations (9.4%), highlighting the clinical utility of CCTA in evaluating both specific and nonspecific cardiac complaints.

The most frequent anomaly was high take-off origin of the right coronary artery (RCA), observed in 41.5% of cases, followed by left circumflex artery (LCx) origin anomalies (32.1%), left main coronary artery (LMCA) anomalies (18.9%), and combined left anterior descending (LAD) and LCx anomalies (18.9%). Isolated LAD origin anomaly was least common (5.7%). Rare variants included single coronary artery, anomalous origin from the opposite sinus of Valsalva, and pulmonary artery origin anomalies (Table 2).

Sex-based differences were observed. LAD origin anomalies occurred exclusively in females (14.3%), whereas LMCA anomalies were more prevalent in males (28.1%). RCA and LCx anomalies showed similar distribution between sexes. Malignant interarterial courses were detected only in female patients (19.0%), representing a statistically significant difference ($p = 0.02$).Associated cardiac findings included significant coronary stenosis (9.4%), LMCA agenesis (9.4%), intracoronary stents (5.7%), diverticula (3.8%), apical aneurysm (1.9%), and prior coronary artery bypass grafting (1.9%). Extracardiac findings were common, most frequently pulmonary nodules (17.0%), atelectasis (13.2%), and aortic dilatation (9.4%). These findings underscore the added diagnostic value of CCTA in comprehensive preoperative assessment (Table 3).

Table 2. Gender distribution of coronary artery anomalies

Anomaly Type	Subcategories	Female (n,%)	Male (n,%)	Total (n,%)
Anomalies of Origin	LMCA Origin Anomaly	1 (4.8%)	9 (28.1%)	10 (18.9%)
	LAD Origin Anomaly	3 (14.3%)	0 (0.0%)	3 (5.7%)
	LCx Origin Anomaly	7 (33.3%)	10 (31.3%)	17 (32.1%)
	RCA Origin Anomaly	10 (47.6%)	12 (37.5%)	22 (41.5%)
	LAD & LCx Anomaly	4 (19.0%)	6 (18.8%)	10 (18.9%)
Anomalies of Course	Malignant course	4 (19.0%)	0 (0.0%)	4 (7.5%)
Intrinsic Coronary Artery Anomalies	Diverticula	0 (0.0%)	2 (6.3%)	2 (3.8%)
	LMCA Agenesis	2 (9.5%)	3 (9.4)	5 (9.4%)
	Coronary Ectasia	0 (0.0%)	1 (3.1%)	1 (1.9%)

LMCA: Left main coronary artery, LAD: Left anterior coronary artery; LCx: Left Circumflex coronary artery, RCA: Right coronary artery

Table 3. The role and impact of coronary CT angiography (CCTA) in surgical planning

CCTA Finding	Impact	Clinical Importance
Detection of Malignant Anomalies	Guides the surgical strategy	Surgical intervention is essential in malignant courses due to compression risks
3D Anatomical Visualization	Enables clear evaluation of abnormal coronary artery courses by surgeons	Accurate assessment of high-risk anatomical structures, such as interarterial courses
Discrepancies with Conventional Angiography	Identifies details missed by conventional methods, informing surgical decision-making	Provides definitive diagnosis for anomalies like ostial origin abnormalities or double ostium missed by conventional methods
Detection of Non-Cardiac Findings	Integration of non-cardiac conditions (e.g., pulmonary nodules, atelectasis) into surgical planning	Perioperative risk management and need for a multidisciplinary approach due to comorbid conditions
Dominant Circulation Type	Assists in determining surgical bypass strategy based on right or left dominant circulation	Evaluation of circulation patterns is critical for preserving myocardial perfusion

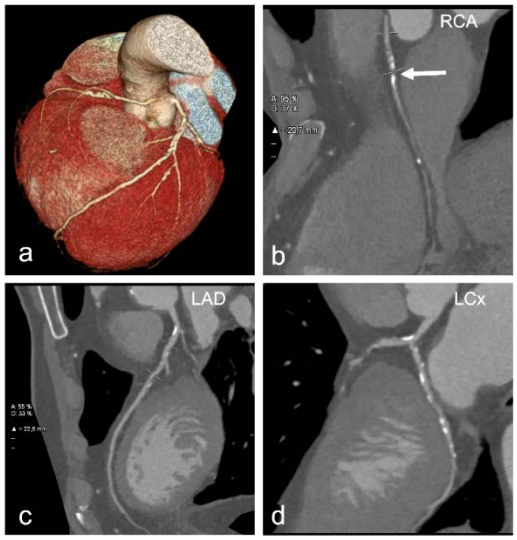

Figure 1. Anomalous origin of the RCA in a 63-year-old female patient. The RCA originates from Valsalva's left sinus in the 3D volume-rendered image (a). Multiplanar reconstruction images (b, c, d) demonstrate a mixed plaque (arrow) causing severe stenosis (70–99%) in the proximal RCA. Additionally, calcified plaques causing mild-to-moderate stenosis are seen in the LAD and LCx coronary arteries.

RCA: Right Coronary Artery; LAD: Left Anterior Descending Coronary Artery; LCx: Left Circumflex Coronary Artery.

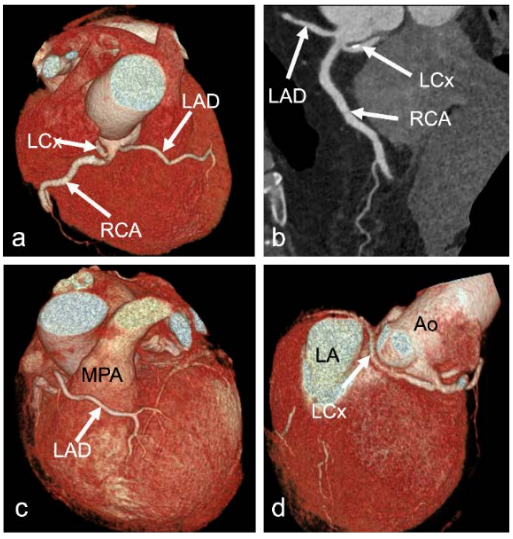

Figure 2. Malignant course of the RCA in a 46-year-old female patient. In the 3D volume-rendered image (a), the RCA originates from the left sinus of Valsalva. Multiplanar reconstruction images (b, c) illustrate the RCA's interarterial course (arrow) between the aorta and the pulmonary artery.

Ao: Aorta; MPA: Main Pulmonary Artery.

Right coronary dominance was observed in 83% of patients, followed by left dominance (13.2%) and codominance (3.8%). In nine patients who underwent invasive coronary angiography, significant stenosis was confirmed in five cases. In two patients, anomalous coronary origins detected by CCTA were angiographically confirmed, including a high take-off RCA with severe proximal stenosis and a malignant RCA course between the aorta and pulmonary artery (Figures 1–2). A single coronary artery anomaly was also clearly visualized by CCTA (Figure 3).

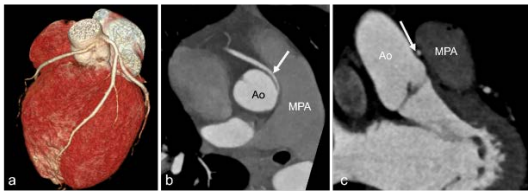

Figure 3. Single coronary origin anomaly in a 61-year-old male patient. In the 3D volume-rendered (a) and multiplanar reconstruction (b) images, the RCA, LAD, and LCx coronary arteries are observed originating from a single short stem in the right sinus of Valsalva. Additionally, the 3D volume-rendered images (c, d) demonstrate the LAD coursing anterior to the main pulmonary artery to reach the anterior surface of the interventricular septum. The LCx follows a retroaortic course, continuing between the aorta and the left atrium, extending into the left atrioventricular groove.

Ao: Aorta; MPA: Main Pulmonary Artery; LA: Left Atrium.

DISCUSSION

The present study provides a comprehensive evaluation of the prevalence, anatomical characteristics, and clinical relevance of coronary artery anomalies (CAAs) detected by coronary computed tomography angiography in a large single-center cohort. The overall prevalence of CAAs (1.82%) observed in our population is slightly higher than that reported in previous series, which may be partly attributed to methodological differences, particularly the lower cut-off value used to define high take-off coronary origins[12]. This approach allows the identification of borderline anatomical variations that may otherwise be overlooked, but which can still carry clinical or surgical relevance in selected patients.

Consistent with existing literature, high take-off origin anomalies especially involving the right coronary artery represented the most frequent anomaly in our cohort[12]. Although high take-off origin is often considered a benign variant, its recognition is clinically important, as it may complicate catheter engagement during invasive angiography and increase the risk of inadvertent injury during aortic or coronary interventions. Moreover, when accompanied by significant coronary stenosis or unfavorable angulation, this anomaly may acquire greater clinical significance, emphasizing the need for precise anatomical delineation prior to intervention.

One of the most notable findings of the present study is the exclusive occurrence of malignant interarterial coronary courses among female patients. Malignant coronary anatomy, defined by a course between the aorta and pulmonary artery, is widely recognized as a high-risk feature associated with myocardial ischemia, infarction, and sudden cardiac death, particularly during exertion[13,14]. While congenital coronary anomalies are generally reported more frequently in males, our findings suggest that certain high-risk morphologies may demonstrate sex-related differences in prevalence or clinical expression. These observations raise the possibility that genetic, hormonal, or anatomical factors may influence the development or manifestation of malignant coronary courses and highlight the importance of sex-specific analyses in future studies.

The clinical management of patients with coronary artery origin anomalies remains controversial and highly individualized. Treatment options range from conservative follow-up and medical therapy to exercise restriction and surgical intervention. Most authors agree that surgery should be considered in symptomatic patients or in those with objective evidence of myocardial ischemia[15]. However, the optimal management of asymptomatic patients particularly those with anomalous right coronary artery origin remains less clearly defined, underscoring the need for detailed anatomical assessment to support individualized risk stratification.

An additional strength of CCTA highlighted in this study is its ability to detect concomitant cardiac and extracardiac findings. The relatively high prevalence of non-cardiac thoracic abnormalities, such as pulmonary nodules, atelectasis, and aortic dilatation,

underscores the added diagnostic value of CCTA beyond coronary anatomy alone. These findings may influence perioperative risk assessment, prompt further diagnostic evaluation, or necessitate multidisciplinary management, particularly in patients considered for surgical intervention.

Compared with conventional invasive coronary angiography, CCTA offers superior three-dimensional assessment of complex coronary anatomy and is less limited by technical challenges related to ostial cannulation or overlapping vascular structures[16,17]. While invasive angiography remains essential for functional assessment and revascularization planning, CCTA serves as a complementary modality that often provides critical anatomical information not readily obtainable through catheter-based techniques. In our cohort, CCTA was particularly valuable in characterizing malignant coronary courses and single coronary artery anomalies, which directly influenced clinical and surgical decision-making.

Finally, the predominance of right coronary dominance observed in this study is consistent with previous reports and further emphasizes the importance of evaluating dominance patterns when assessing coronary anomalies. Coronary dominance may have implications for myocardial perfusion and surgical risk, particularly in patients undergoing coronary artery bypass grafting or complex aortic procedures[18,19].

This study is limited by its single-center design, relatively small number of patients with coronary anomalies, and lack of long-term clinical follow-up. The retrospective design and absence of a predefined power analysis represent inherent methodological limitations; however, inclusion of the complete available cohort reduces selection bias and reflects real-world clinical practice.

In conclusion, detailed anatomical evaluation of coronary artery anomalies using coronary computed tomography angiography is essential for accurate diagnosis and surgical planning. Future prospective, multicenter studies with larger cohorts are needed to further elucidate the clinical implications of these anomalies and optimize patient-specific management strategies.

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