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Research Article

Prevalence and characteristics of coronary artery anomalies detected by coronary CT angiography in Romanian population

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Abstract. Purpose: The aim of this study is to determine the prevalence of different types of coronary artery anomalies (CAA) in a Romanian population. Methods: We retrospectively reviewed images of 913 consecutive patients who were referred for coronary CT angiography (CCTA) between January 2015 and March 2018. All the CT scans were performed using 64-slice multi-detector CT (MDCT) and the obtained images were postprocessed on a dedicated workstation. Results: We report a total of 99 CAAs, with an overall prevalence of 10.3% in our study group. Myocardial bridges were the most common variants, with a prevalence of 7.23% in the examined population. 26 patients were diagnosed with anomalies of origin and course, 7 of them having malignant variants, including one case of adult-type ALCAPA syndrome. Conclusion: Our results show a relatively high incidence of CAA in Romanian population. Therefore, we consider radiologists should be aware of them and CCTA should be used as a diagnostic tool to give morphological information useful for proper management of these patients.

Key Words: cardiac, CT-Angiography, coronary artery anomalies, prevalence, Romania

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Introduction

Coronary artery anomalies (CAAs) include a wide array of variants with diverse cardiovascular manifestations. Some of them are insignificant, some variants may or may not be symptomatic and some are associated with serious cardiovascular events like myocardial ischemia or even sudden death (Angelini 2007). They are present at birth, but most of them are accidentally discovered. Even if the anomalies are asymptomatic, knowledge of their presence is important to cardiac surgery to avoid inadvertent damage to a vessel (Angelini 2007).

Angelini et al. proposed a set of criteria for assessment of coronary arteries anomalies based on a statistical definition of what constitutes the normal range, defining a coronary artery anomaly as a morphological feature (number of ostia, proximal course, and termination) rarely encountered.

For the diagnosis of CAAs it is necessary thorough familiarity with the anatomic pattern and clinical significance of each anomalous condition.

Until recent years, invasive coronary angiography (ICA) was considered to be the "golden standard" for identifying CAAs. The largest study by Yamanaka and Hobbs (1990) reported an incidence of 1.3% of CAAs depicted by ICA.

With the new advances in computer tomography, coronary anomalies can be more accurately detected on CCTA, this non-invasive method offering the opportunity to make multi-planar and 3D reconstructions in order to assess the origin and course of coronary arteries (Kim et al 2006).

In comparison with ICA studies, the prevalence of coronary anomalies reported in studies based on CCTA is higher, ranging between 0.7% and 18.4% (Cademartiri et al 2008).

The aim of this study is to evaluate the prevalence of coronary artery anomalies detected by 64- MDCT coronary angiography in a population of Romanian patients.

Materials and Methods

Study population

This single centre cross-sectional study was conducted using data from the radiological database of Hiperdia - Affidea Imaging Centre, Cluj-Napoca, Romania. Institutional review board approval was obtained for this study. We retrospectively

reviewed 913 consecutively patients who underwent CCTA between January 2015 and March 2018 in our institution. The indications for CCTA were: atypical angina, typical angina with an inconclusive stress test, patients with high-risk for major cardiac events. The exclusion criteria for CCTA were: renal failure, significant arrhythmias, documented contrast allergy, pregnancy.

Ethical approval

The study was conducted according to the Declaration of Helsinki. It was approved by the institutional Ethical Committee. Informed consent was obtained from all individual participants included in this study.

Scan protocol

All CCTA scans were performed with a 64-sliced multi-detector CT (Sensation 64, Siemens, Forchheim, Germany). The scanning parameters were: slices/collimation 64/0.6 mm, tube voltage 120 kv, 850 mAs, gantry rotation time 330 ms, pitch 0.2, effective slice thickness 0.75 mm and reconstruction increment 0.4 mm. Patients with a heart-rate > 70 bpm received premedication with oral beta-blockers 1 hour prior the examination. Short-acting nitroglycerine sublingual spray was administered to all patients for coronary vasodilatation.

First, a non-contrast enhanced scan was performed in order to assess the coronary artery calcium score (CACS). This scan was followed by the coronary computed tomography angiography (CCTA) to evaluate the coronary artery lumen and to characterize the atherosclerotic plaques. A bolus of 80 ml of iodinated contrast medium was administered intravenously at 5 ml/sec, followed by 40 ml of saline injected at the same rate.

After the acquisition, the images were transferred to a dedicated workstation for post-processing, which included multiplanar reconstructions (MPR), maximum intensity projections (MIP) and volume rendering images (VRT). All CCTA images were assessed by an experienced radiologist who was blinded to the study.

Results

Among the 913 enrolled patients, a total of 94 patients were identified with coronary anomalies and a total of 99 coronary anomalies were found, given the fact that 5 patients had more than one type of anomaly. The values correspond to an overall prevalence of 10.3% of coronary anomalies in the population examined. The baseline clinical characteristics are shown in Table 1.

We classified the CAA according to anatomical criteria (Table 2) and to hemodynamic relevance (Table 3).

According to the anatomical criteria, we found 26 (25.26%) anomalies of origin and course (AOC), 72 (72.72%) anomalies of intrinsic coronary arterial anatomy (AICA) and 1 (1.02%) anomalous anastomosis.

Anomalies of intrinsic coronary arterial anatomy

Among the AICAs, myocardial bridges (MB) were the most common abnormalities (Fig.1). The majority of them involved the left anterior descending (LAD) artery (95.45%), two of them the obtuse marginal artery (OM), while one involved the first diagonal artery.

Table 1. Baseline clinical characteristics of the patients with coronary anomalies

Variable	Value
Age ˜	53.38±16.23
Male sex*	59 (62.7%)
Hypertension*	72 (76.6%)
Dyslipidemia*	61 (64.9%)
Diabetes mellitus*	9 (9.6%)
Obesity*	33 (35.5%)
Smoking*	42 (44.7%)
Clinical presentation*	
Typical angina	35 (37.2%)
Atypical angina	34 (36.2%)
No chest pain	25 (26.6%)
Patients who underwent stent implantation	0(0%)
Patients who underwent coronary artery bypass grafting (CABG)	3 (3.2%)

˜ Results are presented as mean±SD

* Results are presented as number (%)

Anomalies of origin and course

The most common anomaly of origin was a "high take-off", being identified in 7 cases, 6 of them having a right coronary artery (RCA) with a higher origin near the right coronary sinus (RCS) (Fig. 2). A commissural origin was found in 2 patients, in both cases involving the RCA.

A single coronary artery, originating from the left sinus of Valsalva, was detected in one 64-old male patient.

Separate origin of the left anterior descending artery and circumflex artery (CX) from the left sinus of Valsalva (split left main) was seen in 1 patient.

In 2 patients, RCA arose from the opposite sinus of Valsalva with a separate ostium than the left main artery (LM), both of them having malignant interarterial course (Fig. 3).

Ectopic origin of LM from RCS was more frequent, being found in 5 cases. Two of them had a common origin between LM and RCA, with the left main trunk taking a further long retroaortic course (Fig. 4). In the other three patients, a malignant course of LM was seen.

Two cases of absent LM were observed, with LAD and CX arising from RCS, having a common origin with RCA. In one patient, LAD had an anomalous course anterior to the pulmonary outflow (Fig. 5), while in the second patient LAD had an interarterial, malignant course. CX was localized retroaortic in both cases.

In two patients, only the CX artery had an abnormal origin, arising from RCS, but with a benign, retroaortic course.

Our study reports one case of anomalous left coronary artery arising from the pulmonary artery (ALCAPA) with the left main having its origin directly from the pulmonary trunk (Fig. 6).

Discussion

The overall prevalence of CAAs in our study was 10.3%, including all types of coronary anomalies. To the best of our knowledge, this is the first study to investigate the prevalence of coronary

Table 2. Prevalence of coronary artery anomalies based on anatomical criteria

Type of coronary anomaly	N	% of total CAAs	% of total number of patients
I. Anomalies of origin and course			
a.Absent left main trunk (split origin of LM)	1	1.01	0.1
b. Anomalous location of coronary ostium within aortic root or near proper aortic sinus of Valsalva			
High	7	7.07	0.76
Commisural	2	2.02	0.2
c. Anomalous location of coronary ostium at improper sinus (ACAOS)			
RCA that arises from left anterior sinus with anomalous course: between aorta and pulmonary artery	2	2.02	0.2
LAD that arises from right anterior sinus, with anomalous course: between aorta and pulmonary artery	1	1.01	0.1
LAD that arises from right anterior sinus, with anomalous course: anterior to pulmonary outflow	1	1.01	0.1
CX that arises from right anterior sinus with anomalous course: retroaortic	5	5.05	0.54
LCA that arises from right anterior sinus with anomalous course: retroaoartic	2	2.02	0.2
LCA that arises from right anterior sinus with anomalous course: between aorta and pulmonary artery	3	3.03	0.32
d. Anomalous location of the coronary ostium outside normal "coronary" sinuses: pulmonary artery (ALCAPA)	1	1.01	0.1
e. Single coronary artery	1	1.01	0.1
II. Anomalies of intrinsic coronary arterial anatomy			
a. Coronary ectasia	2	2.02	0.2
b. Intramural coronary artery (muscular bridge)	66	66.66	7.22
c. Double LAD	4	4.04	0.43
III. Anomalous anastomotic vessels	1	1.01	0.1

Abbreviations: LM: left main coronary artery, LAD: left anterior descending artery, CX: circumflex artery, RCA: right coronary artery

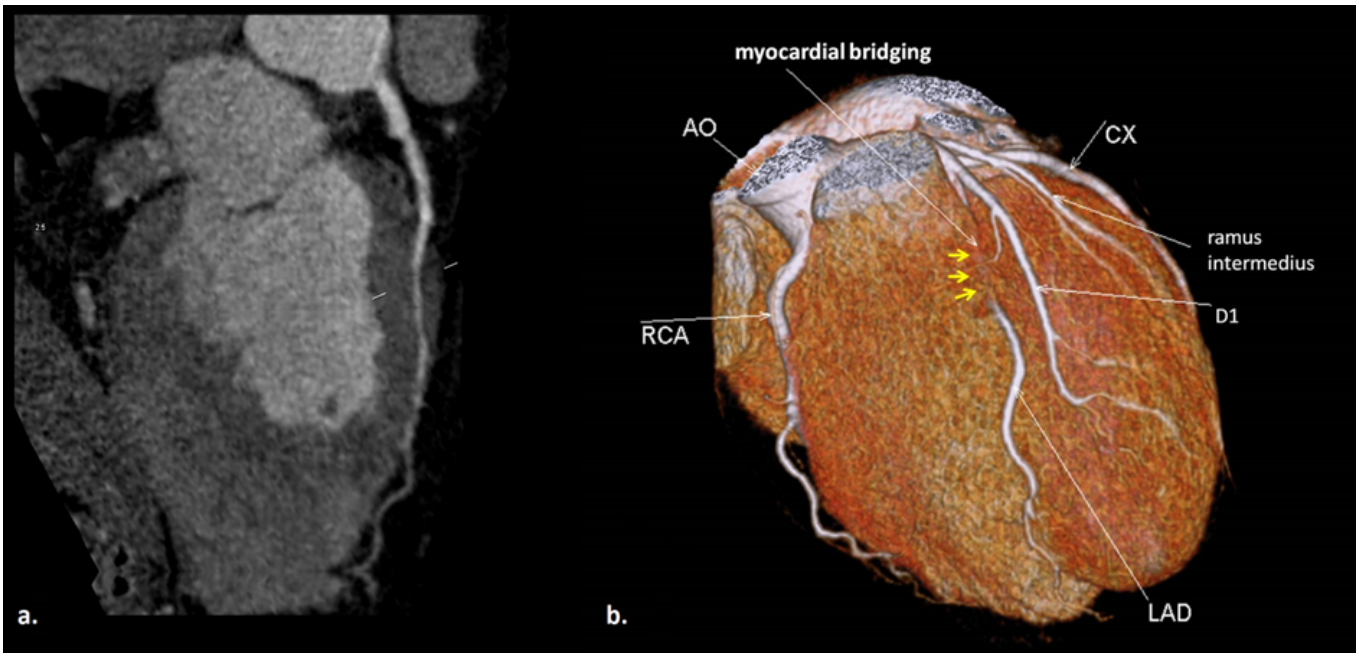

Fig. 1 – Multiplanar reconstruction (MPR) image (a) and volume rendered image (VRT) (b) showing a deep myocardial bridge of the mid-segment of LAD.

Table 3. Prevalence of coronary artery anomalies based on haemodynamic relevance

Type of coronary anomaly	N	% of total CAAs	% of total number of patients
I. Non-hemodynamic significant CAA	86	86.7	9.4
Absent left main trunk (split origin of LMCA)	1	1.01	0.1
High take-off	7	7.07	0.76
Commissural origin	2	2.02	0.2
ACAOS with retroaortic course			
·LAD with anomalous course anterior to pulmonary outflow	1	1.01	0.1
·CX with retroaortic course	5	5.05	0.54
·LCA with retroaortic course	2	2.02	0.2
Single coronary artery	1	1.01	0.1
Muscular bridge without systolic stenosis	60	60.6	6.57
Double LAD	4	4.04	0.43
Anomalous anastomotic vessel	1	1.01	0.1
Coronary ectasia	2	2.02	0.2
II. Hemodynamic significant CAA	13	13.1	1.4
ACAOS with interarterial course			
· RCA with interarterial course	2	2.02	0.2
· LAD with interarterial course	1	1.01	0.1
· LCA with interarterial course	3	3.03	0.32
ALCAPA	1	1.01	0.1
Muscular bridge with systolic stenosis	6	6.06	0.65

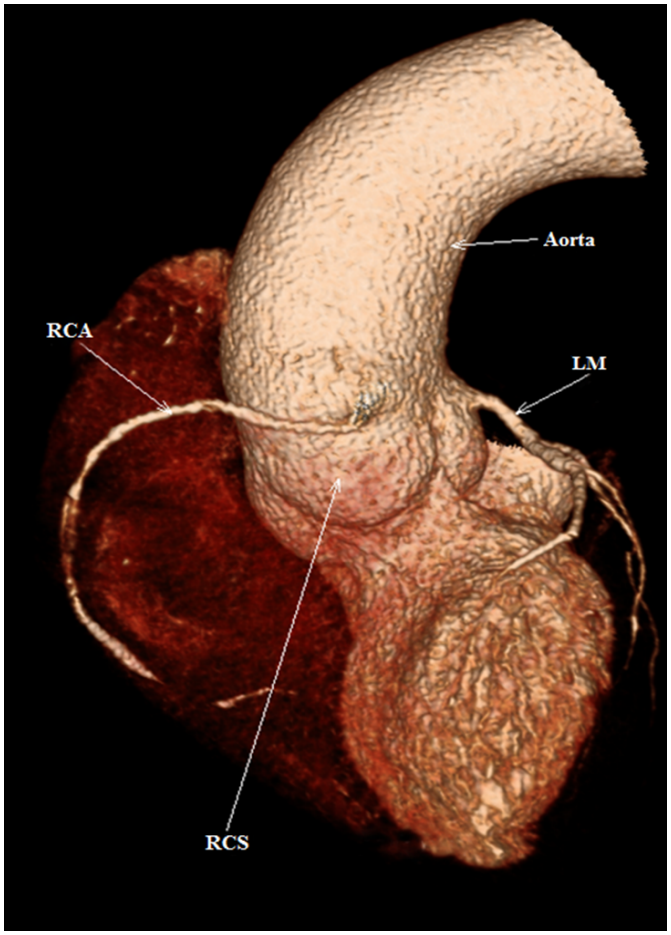

Fig. 2 - VRT image of a high-take off of RCA originating above RCS, at the sino-tubular junction

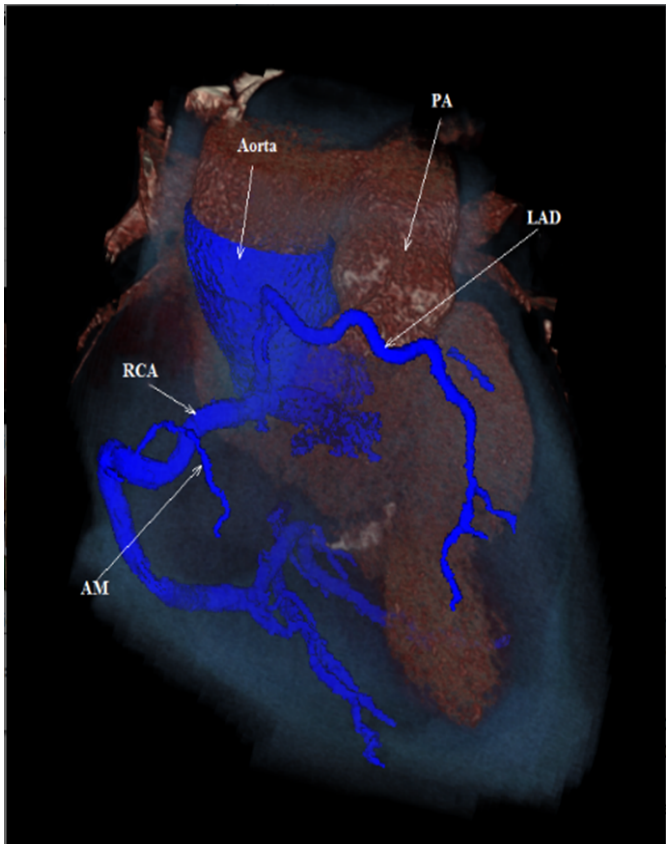

Fig. 5 - VRT image reveals absence of LM, with LAD and CX arteries arising from the right coronary sinus, with a common origin with RCA. LAD has a prepulmonic course

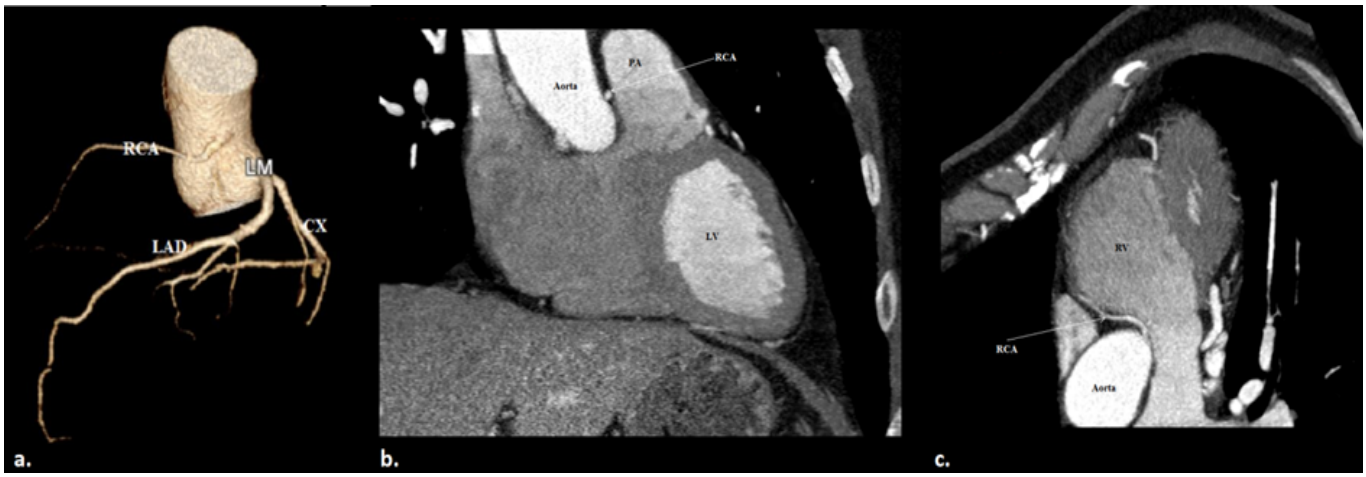

Fig. 3 - VRT image shows RCA originating from LCS (a). Multiplanar reconstruction (MPR) images of the same patient reveal a interarterial course of RCA (b,c)

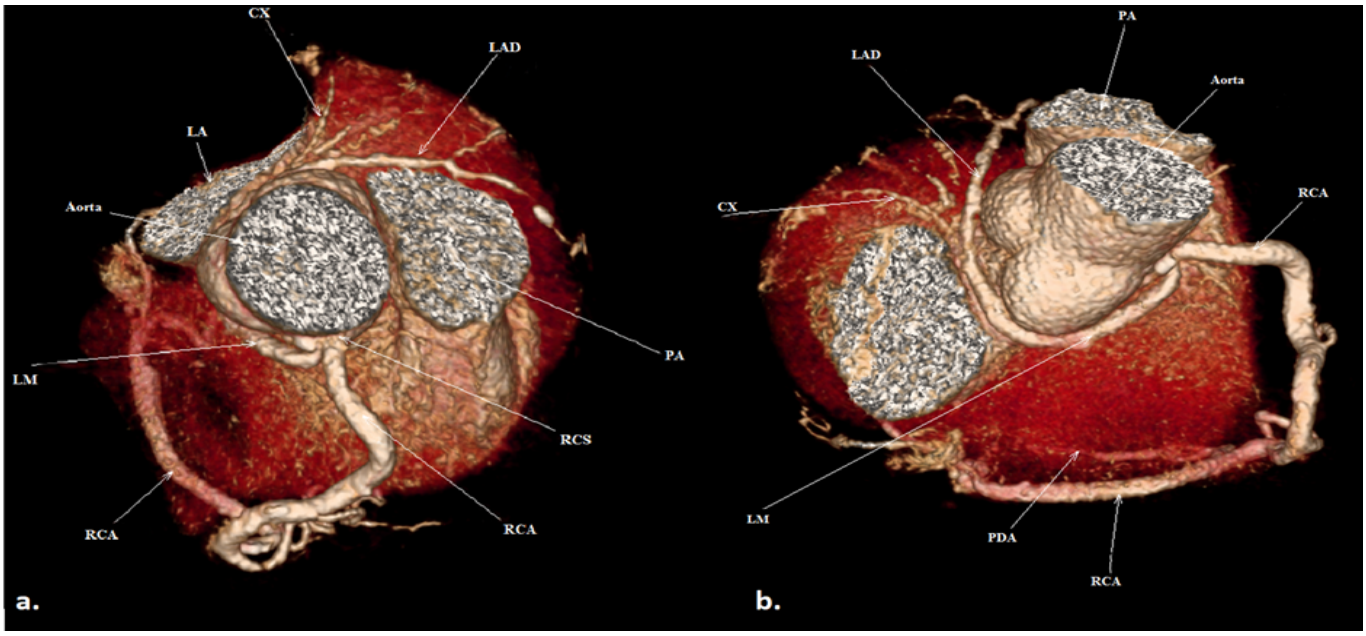

Fig. 4 - VRT images showing origin of LM from RCS, separately from RCA (a), with a further retraoaortic course (b)

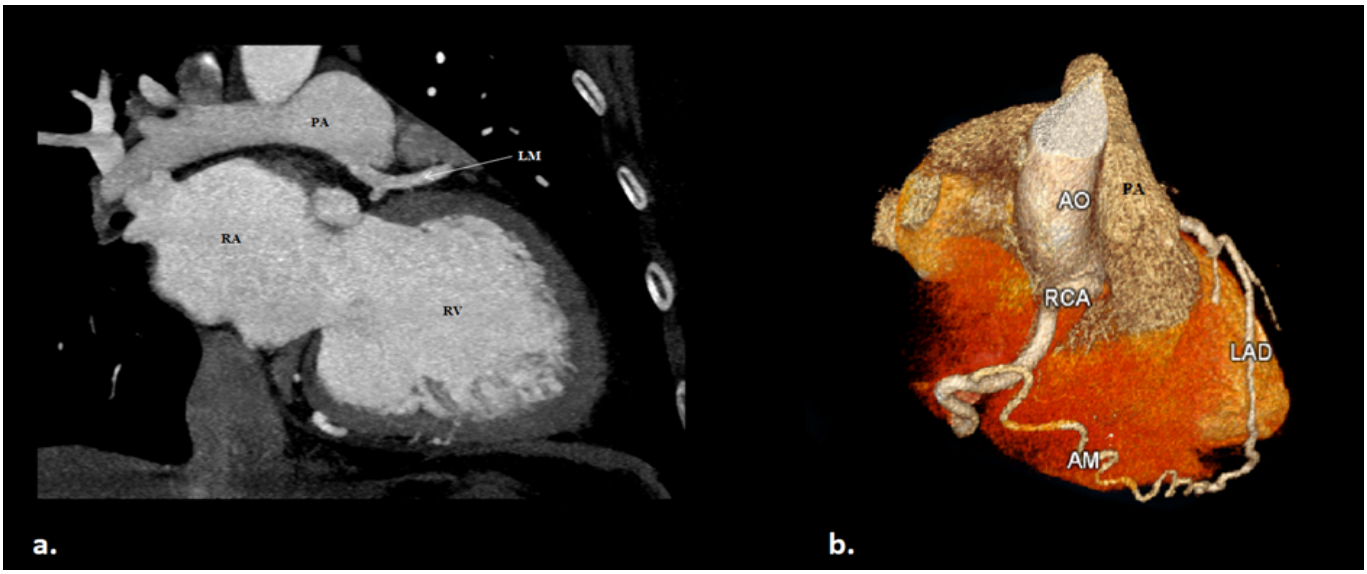

Fig. 6 - MPR (a) showing LM arising from pulmonary trunk and VRT image (b) for the same patients revealing a tortuous, dilated RCA and an anomalous anastomosis between acute marginal artery and distal LAD

anomalies in the general Romanian population. Our results are similar to those described in other studies from different countries (Tongut et al 2016, Andreini et al 2010).

According to Angelini (2007), there are four main categories in which coronary artery anomalies are divided.

The ostium anomalies are usually benign, but they can lead to difficulties when cannulating the vessels during interventional procedure and they can be associated with aberrant courses of the coronary arteries (Kim et al 2006, Zeina et al 2009). In our study, the most frequent anomaly from the anomalies of origin and course was the "high take-off" anomaly, being encountered in 0.76% of the study population and 7.14% of the anomalies, prevalence higher than others found in literature (Tongut et al 2016, Grani et al 2016, Graidis et al 2015, Namgung et al 2014). A single coronary artery was found in one patient, with a benign course, representing 0.1% of the study group and 1.02% of the anomalies, consistent with the results of other major studies (Tongut et al 2016, Grani et al 2016, Yildiz et al 2010).

Regarding the anomalous coronary arteries that are originating from the opposite aortic sinuses (ACAOS), there are five possible trajectories: retrocardiac, retroaortic, interarterial (between the aorta and the pulmonary artery), intraseptal and prepulmonic (pre-cardiac) (Angelini 2007). The interarterial course is commonly described as "malignant course", because of the greater risk for sudden death (Shriki et al 2012). The potential mechanisms that can cause ischemia are: coronary hypoplasia, lateral compression, the length of the stenotic segment or the distensibility of the aortic wall (Angelini et al 2003).

If RCA arises from the left anterior sinus with interarterial course, the hemodynamic significance of this anomaly differs according to the location of the anomalous RCA ostium. A high interarterial course is more susceptible to be compressed, especially during systole, when the pulsations from the aorta and pulmonary artery are increased - scissors-like mechanism On the other hand, during the systole, the right ventricular outflow tract is contracted and the RCA ostium localized below the pulmonary valve is less susceptible to be compressed (Lee et al 2012). The prevalence of typical angina and major adverse cardiac events was found significantly higher in patients with a high interarterial course than in those with a low interarterial course (Husaini et al 1983). The incidence of this variant varies among different populations, the highest incidence being reported in Indians (0.46%) and the lowest in Germans (0.04%) (Hillis et al 2011). Our study reports an incidence of 0.2%.

Another AOC anomaly that is considered malignant is LAD that arises from the right anterior sinus with interarterial course, the risk for sudden death being increased in patients that present intramural coronary artery segments (Fujimoto et al 2011). The prevalence of this anomaly is reported to be between 0.09% and 0.11% (Page et al 1974). According to our results, the Romanian population has a relatively high incidence of it: 0.1%. Moreover, we report a higher incidence of another malignant anomaly: LM arising from RCS with interarterial course, which has a prevalence of 0.32% in our study group.

Among the benign ACAOS, the most frequent anomaly in this study was CX with retroaortic course, with an incidence of 0.54%. This is in accordance with other studies that reported a frequency of 0.4 – 0.8% (Harmeet et al 2015). Another possible variant is LM arising from RCS with a retroaortic course. This anomaly was observed in 0.67% of the patients in the series by Angelini et al. (1999). However, our results show a lower frequency: 0.2%. In some cases, these anomalies can be considered malignant, when the aortic root is dilated and it repeatedly compresses the retroaortic segment, when there is a slit-like ostia or an unusual angling of its course (Aydin et al 2004).

Another variant of benign ACAOS is LAD that arises from RCS with a course anterior to the pulmonary outflow, with an incidence of 0.1% in our population.

In this study we identified one 38-year old female with an anomalous origin of the left coronary artery from the pulmonary trunk (ALCAPA syndrome). ALCAPA is a rare and serious congenital coronary anomaly, affecting 1 of 300.000 newborns (Dodge-Khatami et al 2002). There are two types of ALCAPA syndrome: infantile and adult (Heermann et al 2017). In recent literature, there are several studies that reported similar prevalence of adult type ALCAPA, with less than 0.1% cases diagnosed at CCTA (Grani et al 2016, Graidis et al 2015, Tariq et al 2012). The adult type is characterized by development of tortuous, compensatory collaterals between the right and left coronary tree associated with a dilated RCA (Heermann et al 2017), these typical features being also detected in our patient. Patients with this CAA can be asymptomatic or they can present cardiac symptoms, revealing an underlying subclinical chronic ischemia (Heermann et al 2017). This was the situation of our patient, which was known with minimal EKG changes on periodical treadmill test and she reported acute chest pain .The worsening of the symptoms occurs as a result of the decompensation of the collateral circulation and coronary steal phenomenon (Dodge-Khatami et al 2002).

The most frequent anomaly observed in our study was myocardial bridging (MB). This is a congenital anomaly defined as a segment of a major epicardial coronary artery that passes intramurally, through the myocardium beneath a muscular layer (Angelini 2007). In the majority of cases, it is considered to be a benign anomaly, but in rare situations it can be the cause of major cardiac events (Heermann et al 2017). Because of these potentially fatal consequences, diagnosing MB is clinically important, especially in patients with no coronary atherosclerosis (La Grutta et al 2009).

There is a great discrepancy between the incidence of MB reported on autopsy studies (15-85%) and the number of MB diagnosed using conventional catheter angiography (0.5-16%) (Shi et al 2004). With the introduction of MDCT, the prevalence of MB has become higher, ranging from 3.5%-58% (Erol and Seker 2012). Our study reports an incidence of 7.23% MBs, which is in accordance with results from previous studies made using 64-slices MDCT (Cademartiri et al 2008, Andreini et al 2010, Girzadas et al 2009). In our study population, MBs were detected mainly in the mid-segment of LAD (75.7%), a finding similar to other researches (Erol and Seker 2012, Kim et al 2010).

Depending on the thickness of the covering muscular layer, MBs can be classified in superficial (< 1 mm) or deep (> 1 mm) (Konen et al 2007). Among the 66 MBs, the majority of them were superficial, with 40% being reported as deep. An important finding in this study is that all patients with hemodynamic significant stenosis in the tunneled segment had a deep MB. Therefore, it is a priority to identify deep bridges since the

likelihood of ischemia increases with the depth (Ishikawa et al 2011, Nakanishi et al 2012).

Furthermore, recent studies had reported a positive correlation between the presence of MB and atherosclerotic changes in the segment proximal to the bridge (La Grutta et al 2009, Ishikawa et al 2011). We observed that 25% of the patients who had MB and positive calcium scoring had significant stenosis in the proximal segments due to atheromatous plaques and another 20% had a reduction of the lumen in the proximal segment with about 40%. Considering these results, we agree that MB can represent a potential causing factor for atherosclerotic changes. From our group of 66 subjects with MB, 39 had zero calcium scoring. Among them, 66% were symptomatic and in these cases, where the atherosclerotic disease hasn't been demonstrated, we can consider that their symptoms were attributed to the coronary anomaly.

Duplication of LAD is another anomaly of intrinsic anatomy, but with a much lower incidence of about 0.3 - 1% in the general population (Kim et al 2006). It consists of two LADs, a short one and a long one, which occupy the anterior interventricular sulcus (AIS). Spindola-Franco et al. (1983) first described the variants of dual LAD in 1983 and classified them into four types. In recent years, another two types of duplication of LAD have been described in the literature (Manchanda et al 2010, Maroney&Klein 2011). In our research, we found an incidence of 0.43% of double LADs, this anomaly being reported in 4 patients, with 3 patients having type IV double LAD, a result contrary to that of Spindola-Franco et al (1983) who categorized this anomaly as the rarest.

Our research has several limitations. Firstly, we used a retrospective approach to select the cases. Also, the sample size for this study is relatively small and this is the first study to evaluate coronary anomalies in the Romanian population. Therefore, larger studies are needed to confirm these results.

Conclusion

In conclusion, our study shows a relatively high incidence of coronary anomalies in the Romanian population. Taking these results into consideration, we believe that identifying CAAs should be a healthcare priority, especially in symptomatic young patients without risk for atherosclerosis disease. CCTA represents an alternative diagnostic method with high sensitivity useful for the right management of the patients.

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