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Multimodality Imaging in Individuals With Anomalous Coronary Arteries

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ABSTRACT

Anomalous coronary arteries (ACA) represent a congenital disorder with an anomalous location of the coronary ostium and/or vascular course. Although most individuals with ACA are asymptomatic and remain undiagnosed, some ACA variants are clinically significant leading to symptoms and even adverse cardiac events. Currently, disease prevalence, pathophysiological mechanisms, risks of sudden cardiac death, and the optimal assessment and treatment strategies among subtypes of ACA remain largely unknown. Consequently, there is a lack of guidelines regarding imaging, sport restriction, and treatment options in individuals with ACA at all ages. Cardiac imaging techniques may play a pivotal role in the assessment of individuals with ACA and may offer guidance toward an optimal treatment strategy. This state-of-the-art review highlights current challenges and future perspectives with a special focus on the role of noninvasive multimodality imaging in patients with ACA. (J Am Coll Cardiol Img 2017;10:471–81)
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Anomalous coronary arteries (ACA) represent a congenital disorder hallmarked by an anomalous location of the coronary ostium and/or vessel course. The prevalence of ACA in the general population is estimated at 1% (1-4). Most patients with ACA remain undiagnosed because of a lack of symptoms, but a minority becomes symptomatic and experiences adverse cardiac events. Interarterial course (IAC), slit-like ostium, intramural course, acute take-off angle with tangential vessel course, and proximal narrowing of the anomalous vessel are considered high-risk anatomic features (**Central Illustration**) that have been associated with an increased risk of myocardial ischemia, ventricular arrhythmias, heart failure, and sudden cardiac death (SCD) (5-9). Patients with these features are at a higher risk for SCD when engaged in strenuous exertion (5-9). Autopsy series showed that, after hypertrophic cardiomyopathy, ACA is the second most common cause of sports-related SCD in young athletes during or shortly after strenuous exercise and accounts for up to one-third of SCD in military recruits in the United States (10,11). However, some reports had suggested that such risk of SCD was overestimated because of reporting bias from those presented with a fatal event (12,13). A more accurate representation of the risk of SCD has been hampered by a lack of mandatory reporting of SCD in most countries, inconsistencies in conduction of autopsy, and variable methods used to verify the cause of death.

Besides young athletes with ACA, substantial interest has emerged in older patients with this condition. With increased use of noninvasive imaging in evaluation of coronary artery disease (CAD) in middle-aged and older individuals, an increase in incidental ACA can be expected. Given a lack of evidence-based guidelines in recommending optimal diagnostic strategies, sports restriction, and treatment options in patients with ACA, cardiologists, cardiac imaging specialists, and cardiac surgeons are often ill-equipped in counselling their patients. At present, recommendations are limited and inconsistent, ranging from an immediate surgical approach to watchful waiting with sports restriction. Cardiac imaging of ACA may offer additional information

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ABBREVIATIONS AND ACRONYMS

ACA = anomalous coronary arteries

ACAOS = anomalous coronary arteries of the opposite sinus of Valsalva

CAD = coronary artery disease

CMR = cardiac magnetic resonance imaging

CTA = computed tomography angiography

IAC = interarterial course

MPI = myocardial perfusion imaging

PET = positron emission tomography

SCD = sudden cardiac death

SPECT = single-photon emission computed tomography

TTE = transthoracic echocardiography

needed for decision-making and guidance of optimal treatments.

CHALLENGES IN CHARACTERIZING ACA

The coronary arteries were historically considered to be embryological outgrowths of the aortic root. However, more than 3 decades of evidence had suggested that coronary endothelial precursors self-organize in the subepicardial space and form a vascular plexus that only in later stages of embryological development connects to the aorta (14). The underlying mechanism of ACA evolvement remains largely unknown. Some evidence exists that genes (e.g., Tbx1 gene), coronary arteriovenous growth coordination, aortic root and CXCL12/CXCR4 signaling axis, vascular density around the aortic trunk, modulated by hypoxic domains and local vascular endothelial growth factor availability are involved in the correct connection between the distal coronary artery parts and the proximal aortic root parts (4). One of the clinically important ACA variants, namely ACA of the opposite sinus of Valsalva (ACAOS), is divided into right-ACAOS (anomalous right coronary vessel originating from the left coronary sinus) and left-ACAOS (the anomalous left coronary artery originates from the right coronary sinus). Right-ACAOS are more prevalent than left-ACAOS (15), but it has been reported that only left-ACAOS may lead to SCD, given the much larger amount of myocardium it supplies (16). However, SCD occurrence in patients with right-ACAOS has been reported (4,17), specifically those with an IAC between the aorta and the pulmonary artery, which is considered a "malignant" variant given the potential of extracoronary compression by the adjacent great arteries. On the contrary, an anomalous course between the right ventricular outflow tract and the aorta (also known as subpulmonic or intraseptal course) is not considered malignant and is usually not associated with high-risk anatomic features, such as a slit-like ostium (18). A retroaortal (i.e., between the left atrium and behind the aorta) or pre-pulmonal (i.e., ventral of the pulmonary artery) course of the anomalous vessels and those originating from the noncoronary sinus are considered benign variants (19). Aside from IAC and the slit-like ostium, other proposed high-risk anatomic features include an acute take-off angle (<45°) with a tangential course of the anomalous vessel, an intramural course (of the anomalous vessel within the tunica media of the aortic wall), an elliptic luminal vessel shape (defined as height/width ratio of >1.3), and proximal vessel narrowing (hypoplasia) of the anomalous vessels (>50% narrowing of the cross-section vessel area compared to the distal part) (20–22).

Besides great vessel compression of the ACA based primarily on anecdotal evidence, other hypotheses regarding the underlying mechanism of SCD in patients with ACA exist. Increased cardiac output during exercise may cause valve-like obstruction of the slit-like ostium because of vessel expansion, and coronary flow is further impeded if acute angulation of the arterial take-off coexists. However, with increased pressure and volume during systole, associated aortic dilation and torsion may lead to asymmetrical lateral compression of the proximal and narrowed intramural vessel segments (4,5,23). Strenuous physical exercise, which results in shortened diastolic filling time and tachycardia, could lead to ischemia and arrhythmia. Whether coronary spasm may play an additional aggravating role is unclear. Others proposed that restriction of flow through the relatively noncompliant commissural area of the anomalous vessel originating from the opposite coronary cusp may be a contributing factor (24–26). Supported by limited clinical evidence at present, another hypothesis includes repetitive myocardial ischemia leading to cumulative patchy fibrosis, serving as a substrate for lethal arrhythmias (4,6,27).

Several ACA morphologies are considered clinically benign: these include high take-off of coronary arteries from the aorta, duplication of coronary arteries, absent left main stem with separate ostium for left anterior descending coronary artery and left circumflex coronary artery (5), or intramyocardial course (myocardial bridges) of the epicardial portion of the coronary artery (3). A very rare but mostly lethal coronary anomaly presenting primarily in early infancy is the anomalous origin of the coronary artery from the pulmonary artery (also called Bland-White-Garland syndrome) (28). In this anomaly, extensive collaterals develop between the right and left coronary arterial systems and over time the flow reverses causing myocardial ischemia and congestive heart failure (28). Because ACA with anatomic high-risk features is believed to confer a greater risk for adverse cardiac events, exact anatomic depiction as offered by multimodality noninvasive imaging may be helpful for further risk stratification (10,29–32). In the rest of this review, we focus on the more common variants of ACAOS.