

Major Coronary Artery Anomalies in a Pediatric Population: Incidence and Clinical Importance

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- OBJECTIVES** We sought to prospectively determine the incidence and clinical significance of major coronary artery anomalies in asymptomatic children using transthoracic two-dimensional echocardiography.
- BACKGROUND** Anomalous origins of the left main coronary artery (ALMCA) from the right sinus of Valsalva or anomalous origins the right coronary artery (ARCA) from the left sinus are rarely diagnosed in children and can cause sudden death, especially in young athletes. Because most patients are asymptomatic, the diagnosis is often made post mortem. No study to date has prospectively identified anomalous coronary arteries in asymptomatic children in the general population.
- METHODS** After serendipitously identifying an index case with ALMCA, we examined proximal coronary artery anatomy in children with otherwise anatomically normal hearts who were referred for echocardiography. In those diagnosed with ALMCA or ARCA, we performed further tests.
- RESULTS** Within a three-year period, echocardiograms were obtained in 2,388 children and adolescents. Four children (0.17%) were identified with anomalous origin of their coronary arteries, and angiograms, exercise perfusion studies and/or stress tests were then performed. One ARCA patient had decreased perfusion in the right coronary artery (RCA) perfusion area and showed ventricular ectopy on electrocardiogram (ECG) at rest that diminished but did not resolve with exercise. A second patient with ALMCA had atrial tachycardia immediately after exercise, with inferior and lateral ischemic changes on ECG and frequent junctional and/or ventricular premature complexes both at rest and recovery.
- CONCLUSIONS** This study demonstrates that although anomalous origins of coronary arteries are rare in asymptomatic children, the prevalence is greater than that found in other prospective studies. Ischemia can occur with both ALMCA and ARCA even though patients remain asymptomatic. Because of the high risk of sudden cardiac death, aggressive surgical management and close follow-up are necessary. (J Am Coll Cardiol 2001;37:593-7) © 2001 by the American College of Cardiology
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Anomalous origins of the left main coronary artery (ALMCA) from the right sinus of Valsalva or anomalous origins the right coronary artery (ARCA) from the left sinus of Valsalva are rare congenital anomalies with a combined incidence ranging from 0.17% in autopsy studies to 1.2% in patients angiographically evaluated (1,2). Sudden death occurs with both anomalies, most notably in young athletic individuals (3-5). The diagnosis is often first made post mortem because most of these patients are asymptomatic

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(6), with cardiovascular symptoms (e.g., chest pain, exertional dyspnea, syncope or dizziness) occurring in only 18% to 30% of patients (7,8). These anomalies can be detected by

transthoracic two-dimensional echocardiography (TTE), which offers a safe, noninvasive way of examining the proximal coronary artery anatomy (9).

Indeed, few studies to date have prospectively identified ALMCA or ARCA in children and adolescents (9-12). Those that have done so identified patients either because they were symptomatic (9,10) or because they were athletes required to undergo preparticipation echocardiographic screening (11,12). No studies have identified anomalous coronary arteries in asymptomatic children and adolescents in the general population. Therefore, our study was designed to prospectively determine the incidence and clinical significance of major coronary artery anomalies in otherwise asymptomatic children and adolescents by using TTE.

METHODS

Patients. An index case with ALMCA was serendipitously identified and reported at our institution using TTE (13). Subsequently, between February 1997 and December 1999,

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Abbreviations and Acronyms

ALMCA	= anomalous origin of left main coronary artery
AOCA	= anomalous origin of a coronary artery
ARCA	= anomalous origin of right coronary artery
CABG	= coronary artery bypass graft
ECG	= electrocardiogram
LAD	= left anterior descending artery
LCA	= left circumflex artery
LMCA	= left main coronary artery
RCA	= right coronary artery
TTE	= transthoracic two-dimensional echocardiography

we examined proximal coronary artery anatomy in 2,388 patients with otherwise anatomically normal hearts who were referred for echocardiography to the Cardiology Clinic at Children's Hospital and Medical Center in Seattle, Washington. This includes patients referred for evaluation of innocent murmurs as well as for functional assessments.

Two-dimensional echocardiogram. Transthoracic two-dimensional echocardiography examinations were performed on all patients, using a Hewlett-Packard Sonos 5500 imaging system with a 5.0 MHz transducer (Hewlett Packard, Andover, Massachusetts). Patients were examined when they were calm and in the supine, left or right decubitus position. The left main coronary artery (LMCA), right coronary artery (RCA), their ostia and their initial branches were first visualized from the left parasternal short-axis view at the level of the aortic root. The transducer was then angled superior and leftward to view the LMCA and its initial branches or rightward to demonstrate the RCA. Patients with poor acoustic windows precluding definitive identification of coronary artery origins are extremely rare and represent <2% of the total population. These patients were excluded from the study.

Additional tests/procedures. Patients identified as having either ALMCA or ARCA underwent additional tests, including 12-lead electrocardiograms (ECG) at rest, 24-h ECGs and treadmill exercise tests with myocardial scintigraphy using intravenous administration of technetium-99m-Sestamibi. The youngest patient did not undergo the treadmill exercise/myocardial scintigraphy test. After completing the above procedures, all patients underwent cardiac catheterization and angiography to confirm the diagnosis. To date, all but the youngest patient have had coronary artery bypass grafts (CABG).

RESULTS

Within an approximately three-year period, 2,388 asymptomatic children and adolescents (age 0 to 21 years) with otherwise anatomically normal hearts had echocardiograms. Four (0.17%) were identified with anomalous origin of their coronary arteries: two with ALMCA and two with ARCA. The two patients with ALMCA were 15 and 18 years of

age, and the two with ARCA were 2^{1/2} weeks and 12 years of age. All patients were male and three of the four were athletes, with one being a highly competitive swimmer. The reasons for referral to a cardiologist were irregular rhythm (two patients), evaluation of a murmur (one patient) and to rule out Marfan syndrome (one patient). None of the four patients had a family history for any unexplained sudden cardiac death; one patient had a family history of mitral valve prolapse.

Anomalous LMCA. In both patients with ALMCA, the LMCA coursed between the aorta and pulmonary artery before branching into the left anterior descending (LAD) and left circumflex artery (LCA) (Figs. 1 and 2).

The 18-year-old had a normal ECG at rest and a normal treadmill exercise/sestamibi perfusion study. The 15-year-old patient's ECG showed sinus bradycardia and intermittent junctional/ventricular premature complexes at rest. The ectopy was suppressed during exercise, but during recovery he experienced two nonsustained runs of rapid atrial tachycardia with a rate of 230 beats per minute and evidence on ECG of inferolateral ischemic changes. The patient remained asymptomatic when this ectopy occurred. There were no pathological ST segment changes during sinus rhythm. Both patients underwent CABG procedures and treadmill tests after surgery were normal in both patients. Echocardiography and Doppler studies demonstrated patent grafts at one-year follow-up.

Anomalous RCA. In both patients with ARCA, the RCA coursed between the aorta and main pulmonary artery (Fig. 3). The 2^{1/2}-week-old patient returned at 1^{1/2} months of age for a 12-lead ECG, which was normal; he was then seen for follow-up at 35 months for a repeat ECG and cardiac catheterization, both of which were normal. The 12-year-old patient's ECG at rest showed uniform ventricular ectopy with a left bundle configuration consistent with right ventricular origin; the ectopy diminished but did not resolve with exercise. There was also abnormal repolarization of the lateral chest leads with T-wave inversion and ST elevation. The treadmill exercise/sestamibi perfusion study demonstrated inferior wall ischemia of moderate intensity in the RCA perfusion area. The patient remained asymptomatic during this test. The patient subsequently underwent a CABG. A post-surgical treadmill/sestamibi study revealed ventricular ectopy at rest that was suppressed with exercise. The sestamibi scan showed normal uptake in the previously noted exercise-induced ischemic regions.

False negative. During the study period a 16-year-old male with known reactive airway disease presented with a single episode of exertional syncope, which was originally thought to be caused by exercise-induced asthma. An echocardiogram was performed that evaluated proximal coronary artery anatomy, and no abnormality was identified. Four months later, the child died suddenly; autopsy revealed an ALMCA. Because this patient did have symptoms, he was not included in our calculations of incidence in the "normal" population.

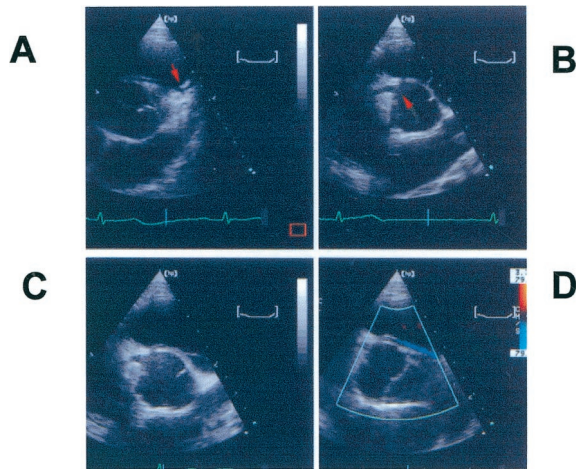


Figure 1. Origin of the LMCA from the right sinus of Valsalva is shown in **B** and **C**. Arrow in **A** points to branching of the LMCA into the LAD and LCA. Abnormal direction of blood flow is shown by color Doppler (blue) in **D**. LAD = left anterior descending artery; LCA = left circumflex artery; LMCA = left main coronary artery.

DISCUSSION

Prevalence. The principal goal of this study was to determine the prevalence rate of anomalous origin of a coronary artery (AOCA) in an otherwise normal pediatric population. Anomalous origin of the LMCA and RCA from the contralateral sinuses of Valsalva is rarely diagnosed in children and adolescents (1,2). Sudden death, especially in young athletic individuals, is frequently the initial manifestation of these abnormalities (4,8). The current study yielded the largest and youngest population of asymptomatic patients prospectively identified with this abnormality. The data indicate that the prevalence of these abnormalities corresponds to that found in large autopsy studies (1), but is greater than that found in prospective studies of athletes (11,12). This discrepancy may be caused by some bias in

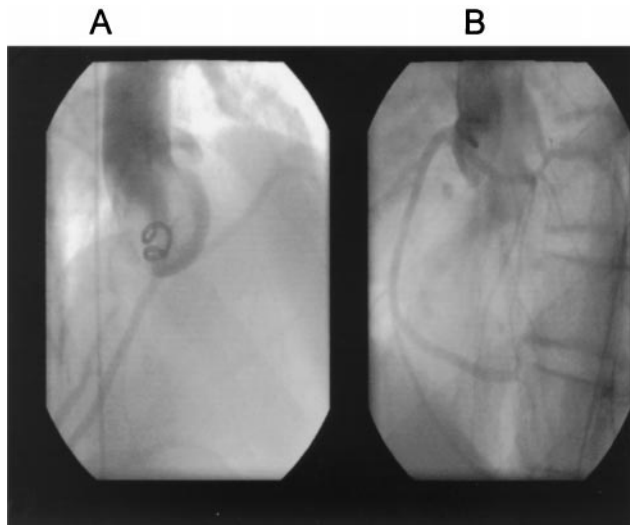


Figure 2. Angiograms of the LMCA and RCA both originating from the right sinus of Valsalva (**A** is LAO view; **B** is cranial RAO view). LAO = left anterior oblique; LMCA = left main coronary artery; RAO = right anterior oblique; RCA = right coronary artery.

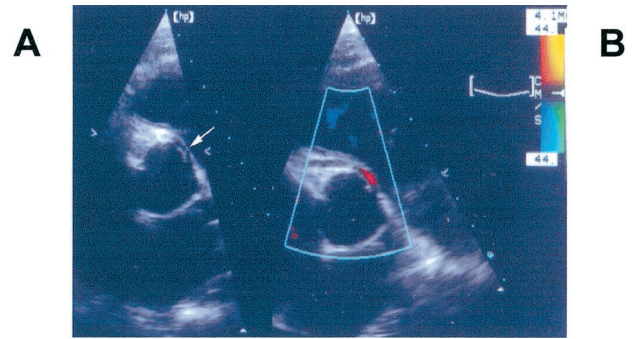


Figure 3. Arrow in **A** shows the origin of the RCA from the left sinus of Valsalva. Abnormal direction of blood flow is shown by color Doppler (red) in **B**. RCA = right coronary artery.

patient selection caused by echocardiography referral patterns in our study. Although asymptomatic children and adolescents made up this study population, these patients were nevertheless referred to cardiology and may not truly represent the “normal” pediatric population. Thus, the prevalence for our study group might be higher than in the general population. Alternatively, differences in prevalence rate might result from improvements in echocardiographic and Doppler resolution that have occurred over the past several years, as well as direction of routine studies towards identification of coronary artery origins. This prevalence data might affect future cost analyses of screening athletes for risk of sudden cardiac death.

Imaging. Although other imaging tools such as angiography (14) and magnetic resonance angiography (15,16) can be used to identify anomalous vessels, TTE remains the imaging modality of choice. It provides an excellent, non-invasive tool to diagnose anomalous coronary arteries in young individuals because the ability to visualize the origin and proximal segments of the coronary arteries is very high (17) provided careful attention is paid to coronary anatomy. Indeed, using TTE we were able to prospectively identify all four of our cases even though they were asymptomatic and were referred to our cardiology clinic for other reasons (i.e., irregular rhythm, murmur, possible Marfan). However, the results emphasize that identification of coronary artery origins should be a routine portion of any echocardiographic examination. This point is highlighted by data reported in a retrospective review of patients diagnosed with coronary artery origin anomalies at autopsy. Two patients in that series had undergone echocardiograms without prospective identification of coronary artery origins (18).

False negatives do occur when using TTE. These might be caused by incorrect interpretations or inability to fully identify coronary artery origins because of poor acoustic windows. Previous prospective studies of asymptomatic patients have not really addressed the possibility of false negatives within their study populations (11,12). An accurate determination of the false negative rate would be exceedingly difficult to perform.

Pathophysiology of sudden death. After identifying these abnormalities in asymptomatic patients, the clinical import

of these findings required consideration. Recent autopsy studies indicate that symptoms, such as exertional chest pain or syncope are the principal indicators AOCA prior to death (18). Sudden death probably occurs because of a reduction in blood flow in the anomalous vessel, resulting in myocardial ischemia and/or infarction (19,20). Although the exact pathophysiology of this decreased blood flow is not fully understood, several mechanisms have been proposed. The anomalous vessel may be compressed between the aorta and pulmonary trunk (21,22), especially during exercise-induced distention of the sinus of Valsalva (23). Kinking or torsion of the aberrant vessel may also occur as it courses between the great vessels (24). An acute angle of origin of the anomalous artery with respect to the ostium may form a "slit-like" opening that could become further compressed or occluded during systole (3,25). Sudden cardiac death occurs most frequently when the anomalous vessel courses between the aorta and pulmonary trunk (3,26,27). This high-risk anatomy was present in all four identified patients. In particular, narrowing of the coronary ostia may have contributed to the exercise-induced ischemia noted in the adolescent with ARCA.

Clinical evaluation and management. Retrospective review of data obtained from the recent autopsy series revealed that all cardiovascular exams performed in those patients were normal (18). These examinations included 12-lead ECGs, stress ECGs with maximal exercise test and echocardiograms without identification of coronary artery origins. The prospective data obtained in asymptomatic patients seemingly conflict with results from the autopsy study. However, exercise stress tests in the current study were performed to evaluate the functional importance of known abnormalities, and the results do not contradict the contention that those tests have limited diagnostic use. Nevertheless, the positive findings during stress testing do indicate that after identification of an ALMCA or ARCA, the patient should undergo further evaluations including cardiac catheterization, 12-lead ECG at rest, 24-h ECG and exercise stress testing with myocardial scintigraphy. These studies provide baseline information relevant to follow-up after surgical management of these anomalies. Thus, the resolution of a perfusion defect was documented in one patient.

Some authors have suggested that surgical management of these abnormalities is mandatory in any young patients with these coronary artery abnormalities (18). The high-risk anatomy associated with sudden death, the ischemic findings and the young age and high activity levels formed the basis for an aggressive approach, which included CABG from the internal mammary artery in three of the four patients. Duration of CABG patency in this age group is unknown; therefore, close follow-up and repeated evaluation will be necessary. Change to a sedentary lifestyle in children or adolescents, as recommended in at least one other study (12), does not seem a viable option. Reversal of exercise-induced perfusion defects and graft patency at one year demonstrates the efficacy of this surgical procedure. The youngest patient represents a clinical challenge, as he

has not shown any signs or symptoms of ischemia and is yet too young to perform stress testing. The ischemia noted in the adolescent who has a similar ARCA, yet displays no symptoms, highlights the need for regular evaluation in this very young patient.

Conclusions. This study confirmed that anomalous origin of coronary arteries is rare in children, but the prevalence is probably greater than has been found in other prospective studies (11,12). Identification of coronary artery origins should be included as part of any echocardiographic exam. The data indicate that ischemia can occur with both ALMCA and ARCA even in the absence of cardiovascular symptoms. When premonitory symptoms such as exertional chest pain and syncope occur, AOCA should be suspected. Although directed echocardiography can generally confirm the diagnosis, this exam's sensitivity has not been fully established. Negative findings with regard to coronary artery abnormalities in a patient referred for cardiovascular symptoms do not preclude the performance of further evaluation. Coronary artery bypass grafting plays an important role in management of patients with confirmed ALMCA or ARCA.

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