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Anomalous Aortic Origin of a Coronary Artery: A Report From the Congenital Heart Surgeons Society Registry

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Abstract

Background: Anomalous aortic origin of a coronary artery (AAOCA) is a common congenital heart lesion that may be rarely associated with myocardial ischemia and sudden death in the young. Evidence-based criteria for managing young patients with AAOCA are lacking. The Congenital Heart Surgeons Society (CHSS) established a multicenter registry of patients with AAOCA aged $\leq$30 years to develop these criteria. **Methods:** All institutional members of the CHSS are eligible to enroll patients. Patients were enrolled retrospectively if diagnosis of AAOCA occurred between January 1, 1998, and January 20, 2009, and prospectively from January 20, 2009 forward. The first phase of analysis explored possible associations between demographics, symptoms, coronary anatomy, and management using correlation analysis and logistic regression. **Results:** As of June 2012, 198 patients were enrolled from CHSS member institutions (median age at diagnosis = 10.2 years; 64% male). Data were extracted from clinical records. Fifty-four percent were symptomatic at presentation (most commonly chest pain, N = 78). The AAOCA was diagnosed at autopsy in two patients who presented with sudden death (one with anomalous aortic origin of the left coronary artery [AAOLCA]; one with a single ostium above a commissure giving rise to both left and right coronary arteries). Imaging reports documented anomalous aortic origin of the right coronary artery (AAORCA) in 144 patients, AAOLCA in 51 patients, and AAOLCA/AAORCA in 1 patient. Surgery or autopsy without surgery was performed in 106 patients (71 AAORCA [67%]; 31 AAOLCA [29%]; and 4 AAORCA/AAOLCA [4%]) at a median age of 12.6 years. Overall, 52% of patients with AAORCA versus 67% with AAOLCA had surgery. Most surgical operative reports described an intramural segment of the coronary artery with anomalous origin. Surgery correlated with symptoms, older age, and presence of an intramural segment in the setting of AAOLCA. **Conclusions:** Management decisions, including surgical referral, are associated with patient symptoms and coronary morphology. Information derived from annual follow-up of surgically and nonsurgically managed patients enrolled in the registry will eventually form the basis for development of evidence-based protocols to address the spectrum of risk and inform clinical decision making in this heterogeneous population of young patients.

Keywords

coronary artery anomaly, congenital heart disease, coronary artery imaging, congenital heart surgery

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Introduction

Anomalous aortic origin of a coronary artery (AAOCA) with interarterial, intramural, or intraconal course is a common congenital heart anomaly. In the most common variants, the right coronary artery arises from the left sinus of Valsalva (ie, anomalous aortic origin of the right coronary artery [AAORCA]) or the left main coronary artery arises from the right sinus (anomalous aortic origin of the left coronary artery [AAOLCA]). In some instances, all of the coronary arteries have a single origin,

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Abbreviations and Acronyms

AAOCA	Anomalous aortic origin of a coronary artery
AAOLCA	anomalous aortic origin of the left coronary artery
AAORCA	anomalous aortic origin of the right coronary artery
CHSS	Congenital Heart Surgeons Society
CT	computed tomography
MRI	magnetic resonance imaging
SCD	sudden cardiac death

in which case either the right or the left coronary artery has an anomalous origin and proximal course. If the single origin is ectopic (above an aortic valve commissure), then both coronaries have an anomalous origin. Occasionally, one or both coronary arteries may arise from the "noncoronary" sinus. Both AAOLCA and AAORCA have been associated with sudden cardiac death (SCD). The risk of SCD is believed to be greater in association with AAOLCA,[1] but there have been case reports of SCD associated with other types of AAOCA including AAORCA and single origin of the coronary arteries.[2] The probability of SCD is greatest during or just after exercise, notably among healthy children and young adults with the vast majority of these deaths occurring in adolescent athletes. In the United States, AAOCA is the second leading cause of SCD from structural heart disease in young athletes who were thought to be previously healthy, after hypertrophic cardiomyopathy. The true prevalence of AAOCA is unknown. The largest study in children using echocardiography found the incidence of AAOCA to be 0.17% in those with otherwise structurally normal hearts.[3]

The cause and mechanisms of ischemia and sudden death in AAOCA are a subject of debate. Based on autopsy studies, SCD is hypothesized to occur from transient mismatch of coronary blood flow and myocardial oxygen demand resulting in myocardial ischemia and/or ventricular tachyarrhythmias. Limitation of coronary blood flow is thought to be related to the functional consequences of abnormal anatomy of the origin and proximal segment of the anomalous vessel. Several specific mechanisms have been hypothesized.[4,5] These mechanisms, which remain matters of speculation and controversy, include an acute angle take-off from the aorta creating a "slit-like" orifice that easily collapses, the presence of an ostial ridge, an intramural proximal intussusception of the ectopic artery at the aortic wall, hypoplasia of the intramural segment, a proximal intramural course that is compressed within the aortic wall, and/or an interarterial course resulting in compression between the great arteries. These mechanisms are proposed to explain the increased risk of ischemia with exercise when there is significantly greater cardiac output and oxygen demand placed on the heart. Individual mechanisms may be associated with specific varieties of AAOCA, and any one mechanism or several in combination may account for the reduction in coronary blood flow that leads to SCD. This hypothesis is consistent with the theory that some variants of AAOCA are more "malignant" than others. Importantly, different theoretical mechanisms to explain diminished coronary blood flow are addressed in specific ways by various surgical techniques used in the management of patients with AAOCA.

At present, treatment of AAOCA is controversial and varies among clinicians. Recommendations may include observation alone, exercise restriction, medication, and/or surgical repair. There is no consensus as to how patients identified as having AAOCA should be evaluated.[6] Although the diagnosis is most often made or confirmed by echocardiography, the specific roles and diagnostic utility of computed tomography (CT) scan, cardiac magnetic resonance imaging (MRI), and other imaging modalities are as yet unresolved matters; evaluation is generally performed in accordance with preferences of individual physicians or centers.

Many practitioners agree that surgical intervention is indicated if a patient of any age presents with signs and/or symptoms consistent with myocardial ischemia.[7-9] There are very little data concerning long-term outcomes following surgical procedures of various types. The optimal management of asymptomatic patients who are serendipitously diagnosed with AAOCA remains an unresolved matter. The follow-up and ongoing surveillance of those patients who undergo surgery is also controversial. Avoidance of sports participation is often recommended for asymptomatic children found to have AAOCA, without consideration of subtypes or details of anatomy.[10] Is such a lifestyle altering decision warranted or even realistic? We do not have risk models to predict the risk of SCD in these patients. In addition to general risk models, there is a need to develop finely adjusted risk models that include details of the patient's coronary anatomy, presenting symptoms, and analysis of clinical diagnostic tests. Such risk models are crucial to assist clinicians in weighing the risks of surgery against the risks of nonoperative management. Ultimately, analysis of a large body of evidence accumulated at multiple institutions will be the best way to bring about a transition, whereby AAOCA moves from being an incompletely understood anomaly for which treatment is largely anecdotal (or even idiosyncratic) to one where evidence-based guidelines exist to assist physicians in the evaluation and management of their patients.

By enrolling patients in the Congenital Heart Surgeons Society (CHSS) AAOCA Registry, we continue to build on what is now the largest clinical database of children and young adults with AAOCA in North America. Systematic follow-up of surgically and nonsurgically treated patients with AAOCA and the accumulated data will reflect the combined clinical experience with AAOCA at centers across North America. All patients are managed at the discretion of their physicians. Care is individualized and is not based upon a research protocol. The large body of data gathered over time will be analyzed to determine associations between clinical events, diagnostic studies, and treatment choices. These previously unobtainable data will help us to develop the predictive models that are so urgently needed.

Methods

The design and implementation of the registry are described previously.[11] Patients diagnosed with AAOCA between January 1,

1998, and January 20, 2009, at participating CHSS member institutions were retrospectively enrolled in the registry and prospective enrollment commenced on January 21, 2009. Inclusion criteria consist of a diagnosis of AAOCA made at a participating institution, age at diagnosis of less than 30 years, and either a structurally normal heart or a concomitant cardiac abnormality that has been hemodynamically insignificant and does not require a surgical or catheter intervention procedure (eg, patent ductus arteriosus, atrial septal defect, restrictive ventricular septal defect, mild pulmonary valve stenosis, or bicuspid aortic valve without stenosis). Exclusion criteria include coronary artery atresia or aneurysm, myocardial bridging, coronary-cameral fistula, anomalous coronary artery arising from the pulmonary artery, or any hemodynamically significant structural heart disease. Institutional review boards or ethics committees at each participating center reviewed and approved the protocol. Informed consent was obtained before enrollment into the registry.

Upon entry into the registry, patient demographics, records of symptoms, imaging reports and studies, operative records, and autopsy reports were obtained from the medical record and abstracted into a database at the CHSS Data Center. Features of coronary anatomy obtained from imaging reports and operative records were disaggregated into individual components to be amenable for classification and analysis. In order to succinctly and completely describe the course of the coronary arteries, a descriptive scheme was devised, which may be adapted for use both by imaging specialists and by surgeons, since they view the anatomy from either the caudal or cranial perspective, respectively (Figures 1 and 2). In addition to the origin and course of the coronary vessels, the relationship between coronary ostia is described using a four-level grading system as follows: two separate orifices (nonconfluent) arising from the same sinus (grade 1); two confluent orifices (located immediately adjacent to each other) within the same sinus (grade 2); single orifice within the sinus, immediate bifurcation within the aortic wall to give rise to two major coronary arteries (grade 3); or a single orifice within the sinus, giving rise to a common trunk that bifurcates into two major coronary arteries outside the aorta (grade 4). Furthermore, we made determinations based on the text of the imaging, surgical, and autopsy reports as to the presence or absence of slit-like orifice, high ostial take-off, acute angulation, interarterial course, intramyocardial course, intramural course, or intraconal course. We have called the disaggregated coronary morphology data "atomized" data. When multiple operations were performed on a single patient, as occurred in three patients, we used the first available surgical atomization. In a few cases, the only report of coronary morphology was made at autopsy. Since the origins of the coronary arteries are viewed at autopsy through the opened aortic root, we decided to use the surgical view scheme for atomized autopsy data.

Often, patients have undergone multiple imaging studies during initial evaluation in order to completely assess all aspects of coronary morphology. In some instances, these studies would not be productive of data pertaining to all aspects of coronary morphology, due to either omission or a limited study; at other times, multiple studies might provide inconsistent data regarding a specific component of the coronary morphology. In order to address the issue of missing or contradictory data within the imaging reports, we devised an algorithm to gather the most recent imaging data, and backfill any missing data with progressively earlier studies until all data fields were filled or no further studies were available. The authors believed that this algorithm would most accurately reflect the aggregated diagnostic impression used for triage to observation or surgery.

Patient demographics, symptoms, and coronary morphology were initially explored using Pearson's correlation. Two-variable comparisons were examined if there were sufficient numbers available for comparison in each cell of the 2×2 table. A modification of the Pearson's correlation coefficient called Cramer's V was then calculated. Cramer's V is an extension of the chi-square test and is intended for use with the binary variables such as those contained in our dataset. This method is more appropriate than regression when there is no clear dependent variable, for example, when testing for a relationship between demographics and coronary morphology. One advantage of Cramer's V is that it avoids scaling distortions when the data are not normally distributed; while Pearson's correlation coefficient can only reach $+1$ (perfect positive correlation) or -1 (perfect negative correlation) when the data are normally distributed, Cramer's V is standardized and always has limits of -1 to $+1$. Therefore, the magnitude of the correlation is more accurately estimated for binary data when Cramer's V is calculated. *P* values were also calculated to quantify the significance of correlations between variables. The association of demographics, symptoms, and coronary morphology with management was explored by univariable and multivariable logistic regression. A *P* value of .05 was deemed significant. All statistical calculations were performed using SAS 9.3 (SAS Institute, Cary, North Carolina).

Results

The CHSS member institutions participating in the registry (Table 1) enrolled 198 patients as of June 2012, 97 of which were enrolled retrospectively. Median age at diagnosis was 10.2 years (range 0-29.3 years), with nearly all patients diagnosed before reaching 20 years of age. Summarized demographics are presented in Table 2 (age, gender, presenting symptom, or indication for diagnostic test).

Imaging reports from 196 patients described AAORCA in 144 (73%) patients, AAOLCA in 51 (26%) patients, and AAORCA/AAOLCA in 1 (1%) patient. Surgery (n = 104) or autopsy without prior surgery (n = 2) was performed in 106 patients (71 AAORCA [67%]; 31 AAOLCA [29%]; and 4 AAORCA/AAOLCA [4%]) at a median age of 12.6 years. Overall, 52% of the patients with AAORCA and 67% with AAOLCA had surgery. Most surgical operative reports described an intramural segment of the coronary artery with anomalous origin (60 of 71 AAORCA; 24 of 31 AAOLCA). The AAOCA was diagnosed at autopsy in two patients who presented with sudden death (one with AAOLCA; one with a single ostium above a commissure giving rise to both left and right coronary arteries). Atomized features of morphology

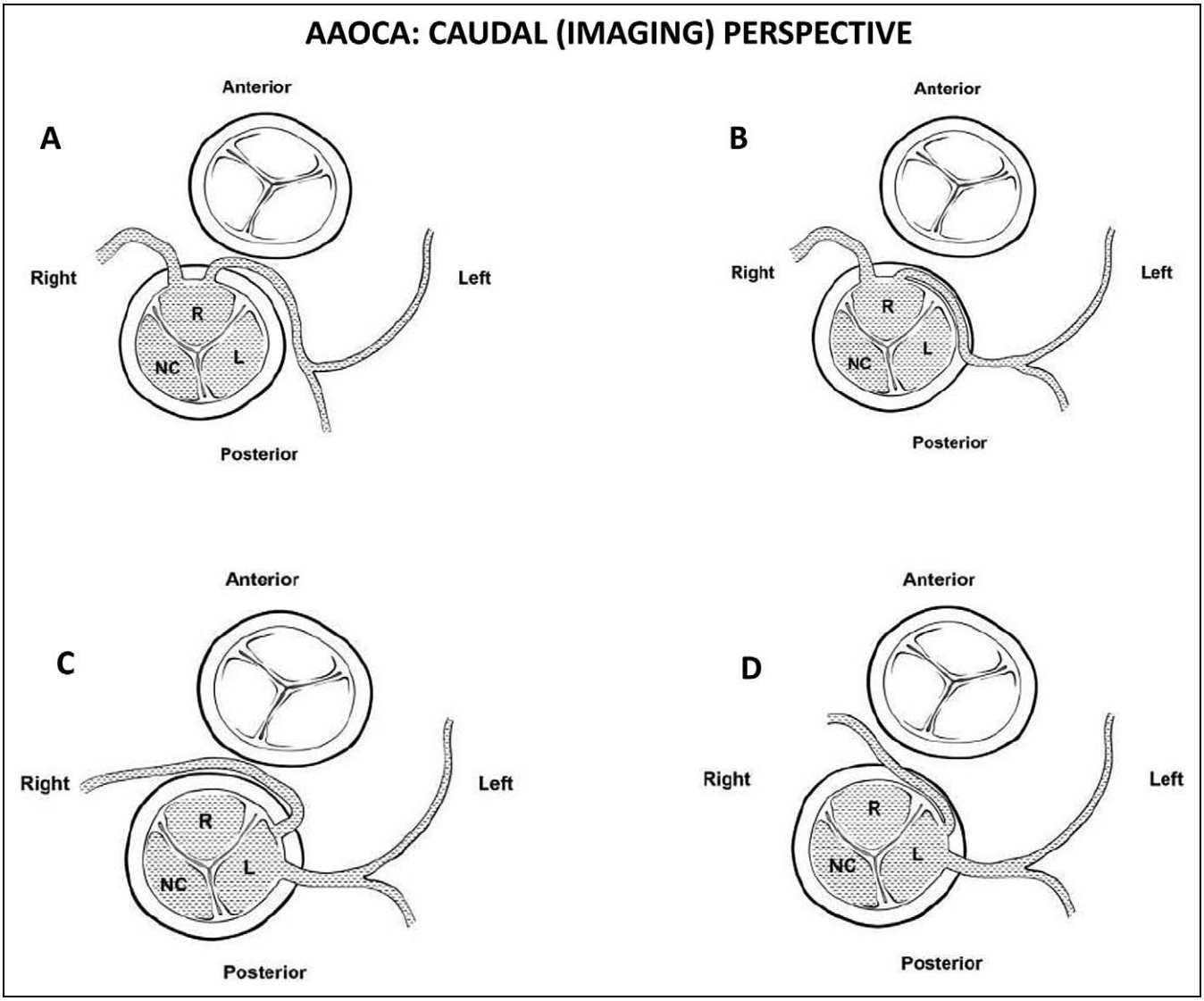

Figure 1. Anomalous aortic origin of a coronary artery (AAOCA): Imaging view types, viewed from the caudal perspective. This is the perspective from which the coronary anatomy is visualized and described in studies including echocardiography, CT scan and cardiac magnetic resonance imaging (MRI). The variations of AAOCA illustrated here were commonly observed within the cohort (see Table 3 for complete list of variants of coronary artery anatomy). A, Anomalous aortic origin of the left coronary artery from right coronary sinus, with inter-arterial course. B, Anomalous aortic origin of the left coronary artery from right coronary sinus, with inter-arterial course and intramural segment. C, Anomalous aortic origin of the right coronary artery from left coronary sinus, with inter-arterial course. D, Anomalous aortic origin of the right coronary artery from left coronary sinus, with inter-arterial course and intramural segment.

from imaging studies and from surgical and autopsy reports are summarized in Table 3.

Coronary morphology was associated with reason for presentation, initial symptoms, and other atomized features of coronary morphology (Table 4). As indicated by values of Cramer's V of +0.1 to +0.3, a small to moderate positive association between syncope with exercise and AAOLCA by imaging was observed; a similar association was also identified for patients with AAOLCA with intramural segment at surgery. The AAORCA by imaging, however, was negatively associated with syncope with exercise; AAORCA with intramural segment at surgery was positively associated with chest pain with exercise but negatively associated with syncope with exercise. Initial presentation as screening for murmur was associated with AAORCA on subsequent imaging. No murmur was attributable to hemodynamically significant structural heart disease.

Surgical referral was associated with symptoms or reason for presentation, coronary morphology, and older age at diagnosis (Table 5). The AAOLCA with intramural segment and chest pain with exercise were by far the most influential predictors of subsequent surgery. In those patients who underwent surgical intervention, the majority (91 patients, 87%) underwent a procedure that included unroofing of an intramural segment. The remainder had coronary ostioplasty, coronary artery bypass grafting, coronary reimplantation, or pulmonary artery translocation.

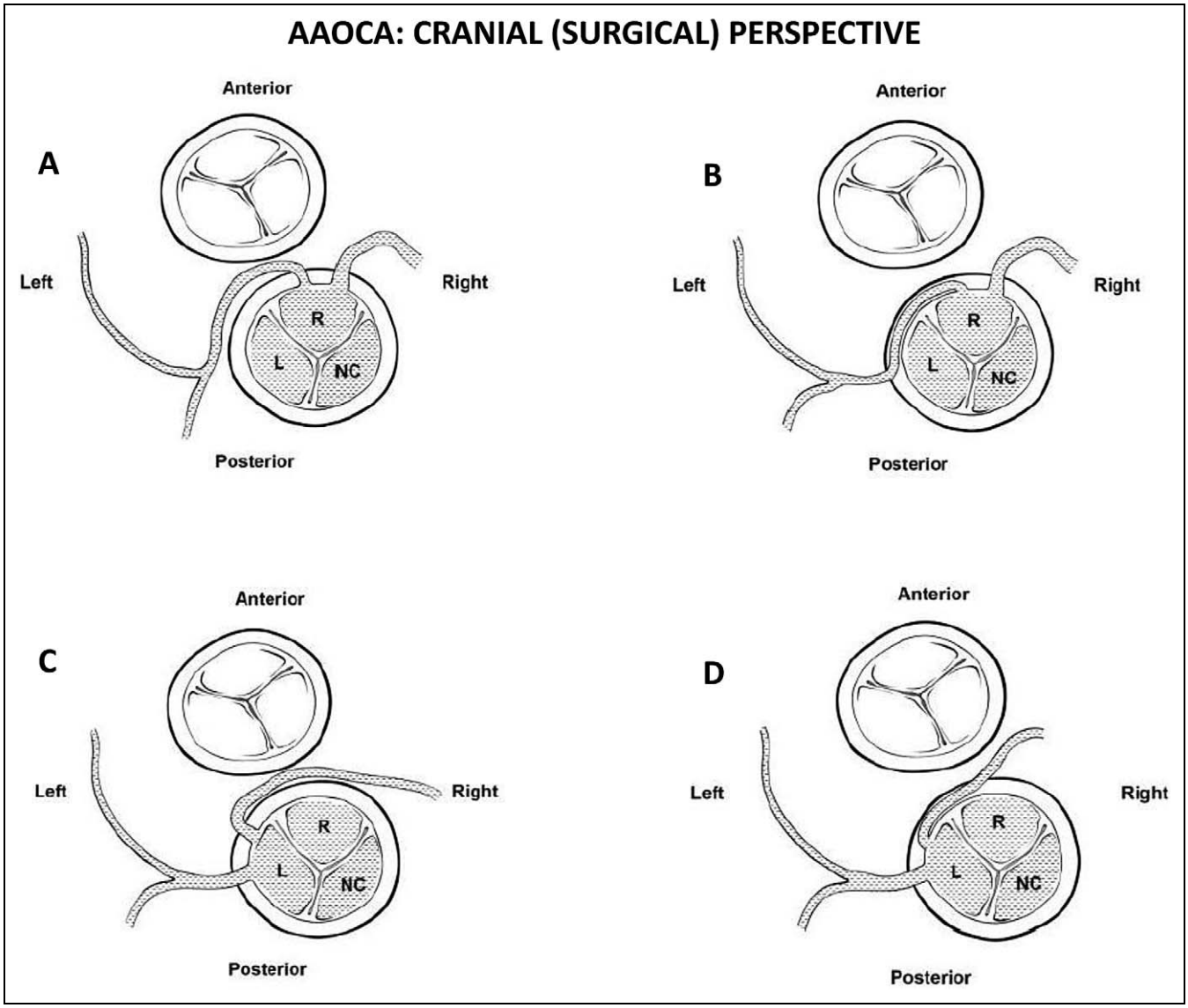

Figure 2. Anomalous aortic origin of a coronary artery (AAOCA): Surgical view types, as viewed from the cranial perspective. This is the perspective from which the coronary anatomy is visualized and described by surgeons. This system was also used to represent coronary anatomy as described in autopsy reports. The variations of AAOCA illustrated here were commonly observed within the cohort (see Table 3 for complete list of variants of coronary artery anatomy). The imaging view diagrams and surgical view diagrams depict the same morphology—only the perspective of the viewer is different. A, Anomalous aortic origin of the left coronary artery from right coronary sinus, with inter-arterial course. B, Anomalous aortic origin of the left coronary artery from right coronary sinus, with inter-arterial course and intramural segment. C, Anomalous aortic origin of the right coronary artery from left coronary sinus, with inter-arterial course. D, Anomalous aortic origin of the right coronary artery from left coronary sinus, with inter-arterial course and intramural segment.

Discussion

Current understanding of the natural history of AAOCA is limited and even less is known about the "unnatural" history of AAOCA following surgical intervention. Our previous survey[6] revealed a great deal of variability in attitudes and practices among pediatric cardiologists and congenital heart surgeons regarding management of young patients with AAOCA. The AAOCA has been difficult to study because of the wide spectrum of variation in coronary morphology, making it challenging to draw inferences based on relatively small numbers of patients with any given variant. This multi-institutional cohort of patients with AAOCA is the largest to date. The associations described in this report should be understood in the context of the analytic methodology. Analysis of correlations is a means of testing for relationships, which does not assume or infer any independent–dependent relationship between variables. As such, the observed correlations between morphology and symptoms should not be interpreted as evidence of causality. To do so could be misleading in important ways. For example, both heart murmurs and chest pain in young individuals frequently lead to evaluations that include echocardiography. Given the higher frequency of an echocardiographic

Table 1. Participating Institutions (Alphabetical Order).

Arnold Palmer Hospital for Children, Orlando, FL
Cardinal Glennon Children's Hospital, St Louis, MO
Cincinnati Children's Hospital, Cincinnati, OH
Children's Heart Clinic of Minnesota, Minneapolis, MN
Children's Hospital of Michigan, Detroit, MI
Children's Hospital of Philadelphia, Philadelphia, PA
Children's Hospital of Wisconsin, Milwaukee, WI
Cleveland Clinic, Cleveland, OH
Congenital Heart Institute of Florida, St Petersburg, FL
Emory University/Children's Healthcare of Atlanta, Atlanta, GA
Inova Fairfax Hospital, Falls Church, VA
Lurie Children's Hospital, Chicago, IL
Mayo Clinic, Rochester, MN
Medical University of South Carolina, Charleston, SC
Montefiore Medical Center, New York, NY
Mott Children's Hospital, Ann Arbor, MI
Mt. Sinai Hospital, New York, NY
Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE
Seattle Children's Hospital, Seattle, WA
St Louis Medical Center, St Louis, MO
Stanford University, Palo Alto, CA
The Hospital for Sick Children, Toronto, ON, Canada
University of Minnesota, Minneapolis, MN

Table 2. Characteristics of 198 AAOCA Registry Patients.

	Median	Range
Age at diagnosis, years	10.2	0–29.3
Age as of June 2012, years	14.3	0.7–32.8
	Number	Percent
Male sex	127	64
Patient presentation		
Symptomatic	106	54
Chest pain at rest	30	15
Chest pain during exercise	48	24
Presyncope at rest	4	2
Presyncope during exercise	7	4
Syncope at rest	3	2
Syncope during exercise	16	8
Palpitations	5	3
Arrhythmia	8	4
Gastrointestinal symptoms	3	2
Aborted sudden cardiac death	2	1
Myocardial infarction	1	1
Sudden cardiac death	2	1
Screening of asymptomatic patient	79	40
Murmur	44	22
Family history of congenital heart disease	10	5
Family history of sudden cardiac death	8	4
Family history of coronary anomaly	7	4
Unknown	13	7

Abbreviation: AAOCA, anomalous aortic origin of a coronary artery.

diagnosis of AAORCA than of AAOLCA, possible associations between murmur or chest pain and AAORCA would come as no surprise. As the registry matures and the data set grows, it is expected that it will eventually become appropriate to explore causal associations further using independent variables of demographics and coronary morphology and each symptom or outcome as a dependent variable in risk-adjusted regression and/or parametric hazard models. At this early stage in the life of the registry, it does appear that surgical referral is related to patient symptoms, age at diagnosis, and coronary morphology.

The registry continues to grow with ongoing enrollment and the addition of more participating centers. Eighteen additional CHSS member institutions have obtained institutional review board approval to participate in the registry and nine of these centers are actively enrolling patients. The establishment of an Imaging Core Lab enables us to take advantage of a highly specialized group of imaging experts to assess the details of ostial anatomy, origin, and course of the coronary arteries in all enrolled patients using defined criteria. Atomization of the morphologic data, as detailed earlier, should enable us to systematically compare the anatomy as described by imaging studies with direct surgical observations in those patients who undergo surgery. Based on the long-term follow-up of this relatively large cohort, we hope to characterize associations between morphologic subtypes and clinical course, among those managed either with or without surgery. Our ultimate goals are to describe the natural and unnatural history of various subtypes of AAOCA, characterize outcomes after interventions for AAOCA, and develop models to identify patients in whom the risk of observation is greater than the risk of intervention and, conversely, patients in whom the risk of intervention is greater than the risk of observation. The descriptive analysis presented here is a preliminary step in that process.

We acknowledge several limitations of this study. First, patients more than 30 years of age at the time of diagnosis were excluded from the study. This upper limit for age at the time of diagnosis was chosen to avoid consideration of the potential effects of superimposed acquired heart disease in individuals who otherwise had ostensibly remained free of symptoms for the first three decades of life. Also, myocardial ischemia leading to sudden death due to the coronary anomaly almost always occurs before age 30[12]; therefore, this cohort should represent those patients at highest risk of an ischemic event. In the future, it would be interesting to examine a cohort of older adult patients with these coronary anomalies to compare and contrast their coronary anatomy with that of patients in our cohort. Such a comparison may reveal clues as to which specific morphologic features are associated with increased risk of adverse events in young individuals. Similarly, we excluded patients with other structural congenital cardiac anomalies that were felt to present a significant risk of hemodynamic alterations that could confound our understanding of the natural history of isolated AAOCA. We recognize that AAOCA is commonly diagnosed in conjunction with other congenital cardiac anomalies, approaching 25% of cases of AAOCA in one study.[9] Certainly, further studies of patients with AAOCA coincident with other congenital heart disease are warranted. Registries of all types also engender certain inherent risks, including that the registry itself may not collect all pertinent data. The authors and the CHSS Data Center staff are acutely aware of this risk and have discussed each data field in great detail in group sessions to minimize it. As with all CHSS studies, there is no way to ascertain with certainty that every

Table 3. Features of Coronary Anatomy.

	Total	Acute Angulation		Ostial Take-off Above Sinutubular Junction		Slit-Like Orifice	
	n	n	%	n	%	n	%
Imaging atomization (n = 196)							
AAOLCA	51	17	33	0	0	7	14
AAOLCA w/origin from right sinus							
Interarterial but nonintramural course	9	2	22	0	0	0	0
Interarterial and intramural course	12	12	100	0	0	4	33
Interarterial course, NOS[a]	20	1	5	0	0	2	10
w/anterior (prepulmonary) looping course	2	0	0	0	0	0	0
AAOLCA w/origin from noncoronary sinus	1	0	0	0	0	0	0
Other AAOLCA	7	2	29	0	0	1	14
AAORCA	144	62	43	4	3	29	20
AAORCA w/origin from the left sinus							
Interarterial but nonintramural course	22	4	18	0	0	4	18
Interarterial and intramural course	55	51	93	0	0	17	31
Interarterial course, NOS[a]	56	3	5	1	2	6	11
Other AAORCA	11	4	36	3	27	2	18
AAOLCA/AAORCA							
Anomalous left and right coronary arteries	1	0	0	1	100	1	100
Surgical (n = 104) and autopsy without surgery (n = 2) atomization							
AAOLCA	31	25	81	1	3	12	39
AAOLCA w/origin from right sinus							
Interarterial but nonintramural course	3	0	0	0	0	0	0
Interarterial and intramural course	24	24	100	0	0	11	46
Other AAOLCA	4	1	25	1	25	1	25
AAORCA	71	67	94	6	8	36	51
AAORCA w/origin from the left sinus							
Interarterial but nonintramural course	3	0	0	0	0	0	0
Interarterial and intramural course	60	60	100	0	0	30	50
Other AAORCA	8	7	88	6	75	6	75
AAOLCA/AAORCA							
Anomalous left and right coronary arteries	4	2	50	4	100	2	50

Abbreviations: AAOLCA, anomalous aortic origin of the left coronary artery; AAORCA, anomalous aortic origin of the right coronary artery; NOS, not otherwise specified on the basis of imaging.
[a]Possibility of intramural segment not specified in imaging report.

Table 4. Associations Between Coronary Morphology and Clinical History.

Variable for Comparison	Correlated Variable	Cramer's V	Direction of Association	*df*	Effective Sample Size	χ^2	*P*
AAOLCA by imaging	Syncope with exercise	0.26	↑	1	185	12.58	<.001
	Screening for murmur	−0.15	↓	1	185	4.31	<.05
	Interarterial course by imaging	−0.14	↓	1	185	4.09	<.05
AAORCA by imaging	Screening for murmur	0.15	↑	1	185	4.02	<.05
	Syncope with exercise	−0.24	↓	1	185	10.58	<.001
	Intramural course by imaging	0.14	↑	1	198	4.00	<.05
	Interarterial course by imaging	0.22	↑	1	198	9.90	<.01
	Sudden cardiac death as initial presentation	−0.17	↓	1	185	5.27	<.05
Intramural AAOLCA at surgery	Chest pain with exercise	−0.28	↓	1	106	8.16	<.01
	Syncope with exercise	0.35	↑	1	106	12.56	<.001
Intramural AAORCA at surgery	Chest pain with exercise	0.23	↑	1	106	5.74	<.05
	Syncope with exercise	−0.31	↓	1	106	10.16	<.01

Abbreviations: AAOLCA, anomalous aortic origin of the left coronary artery; AAORCA, anomalous aortic origin of the right coronary artery; df, degrees of freedom; χ^2, chi-square.

Table 5. Associations With Surgery by Univariable Logistic Regression.[a]

Variable	Odds Ratio	Lower 95% CL	Upper 95% CL	*P*
Older age at diagnosis, years	1.12	1.06	1.18	<.001
Asymptomatic	0.40	0.22	0.73	.003
Murmur	0.36	0.18	0.73	.004
Chest pain w/exertion	3.27	1.54	6.93	.002
AAOLCA IM	13.17	1.68	103.15	.02
AAOLCA IA	2.2	1.09	4.51	.03

Abbreviations: AAOLCA IM, anomalous aortic origin of the left coronary artery with intramural segment; AAOLCA IA, anomalous aortic origin of the left coronary artery with interarterial course, without intramural segment; CL, confidence limit.
[a]No predictor variables were identified on multivariable regression.

patient with AAOCA seen at a CHSS participating institution was offered the opportunity for enrollment in the registry. As well, not every patient diagnosed with AAOCA will be seen at a CHSS participating institution. We have tried to capture as many patients into the registry as possible by allowing enrollment if the patient has had their records reviewed by one of the physicians at a CHSS participating institution. However, we acknowledge that there will still be patients that we are missing. Finally, with regard to the evaluation of correlations between patient demographics, symptoms, and coronary morphology, and potential associations with referral for surgery, we have not attempted to estimate the extent to which these observations may be driven by patterns of referral and practices at the centers which have enrolled the largest numbers of patients in the registry.

Ongoing AAOCA Registry Studies

At the time of this report, the following studies were underway:

- Imaging review: Core Lab review of all available echocardiograms, CT, and MRI studies. These data are being analyzed to examine (1) correlations between initial clinical interpretation of imaging studies and Core Lab expert panel interpretation of imaging studies, (2) correlations between AAOCA subtypes (AAOLCA vs AAORCA) and details of origin, ostial morphology, and proximal course (including intramural segment), (3) correlations between preoperative imaging diagnostic details and operative findings, and (4) best practices in imaging, with the objective of developing guidelines for a standardized approach to echocardiographic diagnosis of AAOCA.
- Surgical techniques review: all available operative reports have been reviewed to ascertain the details of morphology (using atomization scheme) and details of operative procedures.
- Review of demographic data, imaging data, and surgical data exploring associations between anatomy and patient factors, including age at diagnosis and clinical presentation.

It is important to point out that all the data analyzed in the present study come from reports submitted by participating centers. Future analyses will include data which represent the result of expert review by the Core Lab.

Conclusion

The CHSS has established a North American Registry of young patients with AAOCA. As of June 2012, 198 patients were enrolled. A preliminary descriptive analysis suggests that management decisions including surgical referral appear to be related, at least in part, to patient symptoms and coronary morphology. Future analysis of this expanding cohort will include correlation of imaging studies with clinical events including outcomes achieved with surgical and nonsurgical management. Information derived from annual follow-up of all enrolled patients, including the occurrence of late deaths, ischemia, arrhythmias, and other clinical events in surgical and nonsurgical patients, should enable us to develop evidence-based protocols to manage the spectrum of risk in this heterogeneous population of young patients.

Declaration of Conflicting Interests

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Appendix A

The Congenital Heart Surgeons Society AAOCA Working Group

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Robert Jaquiss	Duke University Medical Center
Constantine Mavroudis	Florida Hospital
Rene Herlong	Levine Children's Hospital
Jeffrey Poynter	Indiana University, Department of Surgery
Samuel Weinstein	Montefiore Medical Center
Sara K. Pasquali	Mott Children's Hospital, Ann Arbor
Christian Pizarro	Nemours Cardiac Center
Mike McCulloch	Nemours Cardiac Center
Peter Gruber	Primary Children's Medical Center
Karl Welke	Children's Hospital of Illinois
Pirooz Eghtesady	St Louis Children's Hospital
Richard Mainwaring	Stanford University
Jeff Heinle	Texas Children's Hospital
Carlos Mery	Texas Children's Hospital
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Stephen Paridon	The Children's Hospital of Philadelphia
Julie Brothers	The Children's Hospital of Philadelphia
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