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Original Research Article

Congenital anomalies of coronary arteries in complex congenital heart disease: Diagnosis and analysis with dual-source CT

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ABSTRACT

Background: Congenital heart diseases (CHDs) are sometimes associated with coronary artery anomalies (CAAs). Accurate preoperative evaluation of coronary artery anatomy is essential for successful surgical repair of complex CHD.

Objective: The aim of this study was to evaluate the incidence of congenital CAAs in patients with complex CHD at dual-source CT.

Methods: Four hundred seventeen consecutive patients with complex CHD underwent contrast-enhanced cardiac CT angiography. The results were retrospectively analyzed, including the types and incidences of CAAs in various forms of complex CHD. Each patient was analyzed independently by 2 experienced cardiovascular radiologists. Image quality of coronary arteries was assessed on a 5-point scale with 2 or less being nondiagnostic.

Results: Thirty-five of 417 studies were nondiagnostic (8.39%). Sixty-three cases of CAA (15.11%) were detected by anomalous ostia and coronary arteries. CAA was involved in 6 of 108 patients with tetralogy of Fallot (5.56%), 18 of 84 patients with double outlet right ventricle (21.43%), 11 of 97 patients with pulmonary artery atresia (11.34%), 7 of 36 patients with transposition of the great arteries (22.22%), 15 of 41 patients with single ventricle (36.59%), 4 of 12 patients with truncus arteriosus/aortopulmonary window (33.33%), and 2 of 39 patients with interruption of the aortic arch/coarctation of the aorta (5.13%). Twenty of these were accompanied with an anomalous coronary course (31.74%).

Conclusion: Patients with complex CHD have a higher prevalence of CAAs, which should be considered before surgery. Dual-source CT is an effective technique to visualize and evaluate complex CHD.

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1. Introduction

Congenital heart diseases (CHDs) are often associated with coronary artery anomalies (CAAs). The prevalence of congenital CAAs in the general population has been found in 0.3% to 2.2% of autopsies with structurally normal hearts.[1] Accurate preoperative evaluation of coronary artery anatomy is essential for successful surgical repair of CHD.[2–5] Traditionally, evaluation of neonates and children with complex CHD has included echocardiography and cardiac catheterization. However, detection of coronary arteries by echocardiography is limited by the acoustic window and spatial resolution.[6] Cardiac catheterization is an invasive procedure with a potential procedure-related death rate of approximately 0.1% to 1% for neonates.[7] Furthermore, cardiac catheterization is a 2-dimensional technique and cannot provide sufficient spatial information about the coronary artery course, myocardium, and great vessels in patients with complex abnormal anatomy.

CT has undergone rapid technical improvement in the past 10 years. Modern CT systems have substantially enhanced speed of image acquisition with higher temporal and spatial resolutions. When synchronized with the patient's electrocardiogram (ECG), CT is able to delineate rapidly moving cardiac structures without motion artifact. These advancements allow for comprehensive assessment of the anatomic relationship of the coronary arteries to the adjacent anatomy.[8] The aim of this study was to evaluate the incidence of congenital CAAs in patients with complex CHD at dual-source CT (DSCT).

2. Methods

2.1. Patients

The hospital's ethics committee approved this retrospective study. We reviewed 417 consecutive patients with complex CHD who underwent CT angiography (CTA) from August 2009 to February 2012. None of the patients had prior surgery. All patients had an echocardiogram, and some also received invasive catheter angiography before CTA as reference. Before surgery, patients with complex CHD were clinically referred for CTA to visualize relevant anatomy (eg, pulmonary arteries and veins, aortic arch, aorta-pulmonary collateral vessels, and constriction of the trachea and bronchus), which are difficult to evaluate with transthoracic echocardiography. Some of the patients with complex CHD underwent surgery for primary repair after CTA. Because no precise definition exists, complex CHD in this study was defined as CHD with more than 1 separate cardiovascular anomaly.

2.2. DSCT data acquisition

All CT examinations were performed on a DSCT scanner (SOMATOM Definition; Siemens Healthcare, Forchheim, Germany). Patients were scanned in a craniocaudal direction. Short-term sedation was performed with intravenous injection of ketamine (1 mg/kg) to pediatric patients if necessary. All of the older patients (>6 years) were able to comply with breathhold commands during the acquisition. The injection protocol consisted of a single phase Iodixanol injection (320 mgI/mL; Visipaque; GE Healthcare) through a single-head power injector (Stellant Dual Flow; Medrad) delivered via the antecubital vein. Contrast volume was adjusted to the body weight of infants and children or young adults and older patients, 1.5 to 2.0 mL/kg at a flow rate of 0.8 to 1.2 mL/s and 0.6 to 1.0 mL/kg at a flow rate of 3.0 to 5.0 mL/s, respectively, depending on the structure to be visualized. Bolus tracking was used in a region of interest in the descending aorta. When an attenuation threshold within the region of interest exceeded 80 HU, scan acquisition automatically commenced after a delay of 6 to 8 seconds. Most acquisitions used a prospective ECG-triggering protocol. The start phase of the CT data acquisition was at 70% of the R–R interval with baseline heart rate $\leq$ 70 beats/min or 40% of the R–R interval with baseline heart rate $>$ 70 beats/min. The acquisition window was 380 milliseconds with the use of ECG padding, which allows approximately ±10% R–R interval flexibility for image reconstruction. Acquisitions in 2009 used a retrospectively ECG-gated protocol. ECG-dependent tube current modulation was used with full dose during 35% to 75% of the R–R interval. A radiologist and a pediatrician were present to monitor vital signs, including ECG and blood oxygen saturation, during the examination of pediatric patients.

The following acquisition parameters were used: detector collimation, 32 mm × 0.6 mm × 2 mm; gantry rotation time, 0.33 second; slice thickness, 0.6 mm; and field of view, 200 mm × 200 mm. Tube voltage and tube current were set to 80 kV and 100 mAs, respectively, in patients <10 years of age; tube voltage of 100 kV or 120 kV, and tube current of 200 to 400 mAs were used and adjusted by body mass index (calculated as weight divided by height squared; kg/m^2) in patients >10 years of age.

2.3. Image reconstruction and analysis

All images were transferred to an offline workstation (MMWP; Siemens) for data analysis. Images were reconstructed with a section thickness of 0.75 mm and a medium smooth-tissue convolution kernel (B26f). The reconstruction interval was 0.5 mm. Curved planar reformatting, maximum intensity projection, multiplanar reformation, and volume rendering were used to visualize cardiac abnormalities, depending on target structure and purpose. Image evaluation was performed with a standardized window level of 100 HU and window width of 700 HU.

Each subject was analyzed independently by 2 experienced cardiovascular radiologists who were aware of echocardiogram findings. However, the echocardiographic findings did not include information on coronary artery anatomy. Because secondary branches of the main coronary arteries, such as diagonal and marginal branches, are usually not identified in neonates, the left main, proximal left anterior descending, proximal circumflex, and proximal right coronary arteries (RCA) were analyzed. Two radiologists assessed the coronary

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