Diagnostic accuracy of dual-source multislice computed tomographic analysis for the preoperative detection of coronary artery anomalies in 100 patients with tetralogy of Fallot

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Objectives: A detailed preoperative evaluation of coronary anatomy is mandatory before surgical intervention for tetralogy of Fallot. In pediatric patients, the preoperative evaluation of coronary anatomy has relied classically on conventional angiographic analysis and, more recently, on echocardiographic analysis, which have well-known limitations and complications. Recent technological improvements allow the use of multislice computed tomographic analysis to evaluate coronary artery anatomy in very young children, even those with high heart rates. The purpose of this prospective study was to assess the accuracy of preoperative dual-source computed tomographic analysis in detecting coronary artery abnormalities by using surgical findings as the reference standard.

Methods: We prospectively evaluated 100 patients with tetralogy of Fallot before surgical intervention between November 2006 and September 2009 by using dual-source computed tomographic analysis with either retrospective, electrocardiographically gated, helical computed tomographic analysis or prospective, electrocardiographically triggered, sequential computed tomographic acquisition. The patients had a median age of 6.8 months (range, 1.2 months–6.8 years) and a median weight of 7.9 kg (range, 3–30 kg).

Results: Compared with surgical findings, dual-source computed tomographic analysis had 100% sensitivity and 100% specificity for detecting coronary artery abnormalities. Major coronary artery abnormalities were found in 7 (7%) patients. The radiation dose was low.

Conclusions: Dual-source computed tomographic analysis is an accurate and noninvasive tool for delineating coronary artery anatomy before surgical intervention in children with tetralogy of Fallot. Dual-source computed tomographic analysis might deserve to be used routinely instead of angiographic analysis and in combination with echocardiographic analysis for the preoperative assessment of patients with tetralogy of Fallot. (J Thorac Cardiovasc Surg 2011;142:120-26)

CHD

Accurate preoperative evaluation of coronary artery anatomy is essential for the successful surgical repair of tetralogy of Fallot (TOF). Approximately 5% to 12% of patients with TOF have an anomalous coronary artery crossing the right ventricular outflow tract (RVOT), a configuration that might complicate the operation.[1,2] Preoperative detection of this abnormality allows the use of an alternative surgical procedure involving the placement of an RVOT patch with either a limited right ventriculotomy or the creation of a right ventricle–pulmonary artery (RV–PA) conduit to preserve the anomalous vessel.[3,4]

Major coronary artery abnormalities are a left anterior descending coronary artery (LAD) arising from the right coronary artery (RCA) or a single coronary artery arising from either the right or left sinus with the LAD artery or the RCA, respectively, crossing the RVOT. Other coronary abnormalities can be seen, such as a small or large conal branch that does not reach the anterior interventricular septum or a dual LAD with an accessory LAD artery arising from the RCA.

Various surgical strategies are available for patients with coronary artery abnormalities. A staged approach can be used, with an aortopulmonary shunt early in life followed by the creation of an RV–PA conduit as part of the complete repair procedure. Alternatively, primary complete repair might be performed.[5]

Echocardiographic analysis is performed as part of the preoperative evaluation in patients with TOF but is rarely used as the only imaging study.[6] In many centers preoperative cardiac catheterization is performed routinely in patients with TOF to evaluate the anatomy of the heart, large vessels, and coronary arteries. The limitations and potential complications of cardiac catheterization are well known.

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Abbreviations and Acronyms

CT	= computed tomography
DLP	= dose-length product
DSCT	= dual-source multislice computed tomography
LAD	= left anterior descending coronary artery
MSCT	= multislice computed tomography
RCA	= right coronary artery
RVOT	= right ventricular outflow tract
RV–PA	= right ventricle–pulmonary artery
TOF	= tetralogy of Fallot

In recent years, technological advances, including the introduction of dual-source scanners, have considerably improved the capabilities of multislice computed tomography (MSCT). The temporal resolution of dual-source multislice computed tomography (DSCT) is now 83 ms, allowing coronary artery evaluation in everyday practice in very young infants with high heart rates.[7,8]

The purpose of this prospective study was to assess the accuracy of preoperative DSCT for detecting coronary artery abnormalities in patients with TOF. We used surgical findings as the reference standard.

MATERIALS AND METHODS

Patients

Between November 2006 and September 2009, 100 consecutive patients given diagnoses of TOF and referred to our institution for surgical treatment were included prospectively. We did not include patients who had complex TOF, which was defined as TOF with pulmonary atresia, complete atrioventricular canal, double-outlet right ventricle, absent pulmonary valve syndrome, or aortopulmonary window. Of our 100 study patients, 35 had abnormalities in addition to TOF diagnosed before surgical intervention: patent ductus arteriosus (n = 13), atrial septal defect (n = 9), anomalous systemic venous return (n = 6), anomalous aortic arches (n = 3), multiple ventricular septal defect (n = 2), or bicuspid pulmonary valve (n = 4).

All DSCT evaluations were done as part of the standard care provided at our institution. Our institutional review board approved the study, and informed consent was obtained from all parents before study inclusion. The information supplied to parents included explanations about possible adverse effects of contrast medium injection and radiation exposure.

Preoperative Evaluation

In addition to DSCT, all patients underwent echocardiographic analysis. Preoperative echocardiographic analysis caused us to suspect an anomalous coronary artery in 4 patients: 3 left anterior arteries arising from the RCA and a single RCA with the LAD crossing the RVOT. All 4 cases were confirmed at DSCT, with total correlation with surgical findings. The radiologists interpreting the computed tomographic (CT) examination results were not aware of the suspected anomaly at the time of examination.

Diagnostic cardiac catheterization was performed in a single patient, early in the study to confirm DSCT findings, suggesting a large conal branch. Therapeutic cardiac catheterization was performed in 8 patients, either for percutaneous pulmonary valve dilatation before complete surgical repair or for systemic–pulmonary shunt thrombosis.

DSCT Protocol

Short-term sedation, if needed, was achieved by using oral hydroxyzine dichlorhydrate at 1 mg/kg, with rectal midazolam hydrochloride at 0.3 mg/kg. Neonates were given only saccharose syrup. None of the patients received β-blocker therapy to decrease the heart rate.

A Somatom Definition DSCT scanner (Siemens AG, Forchheim, Germany) was used in all patients. Technological improvements that occurred over the 3-year study period, together with the experience accumulated by the study radiologists, led to a switch from retrospective (helical) electrocardiographically gated acquisition early in the study to prospective (sequential) electrocardiographically gated acquisition after December 2008. The helical protocol involved 2 acquisitions, namely a nongated helical thoracic acquisition followed by a retrospective, electrocardiographically gated, helical cardiac acquisition. The nongated helical acquisition from the upper thoracic inlet to the diaphragm was obtained by using a collimation of 64 × 0.6 mm, pitch of 1.4, rotation time of 330 ms, and a 1-mm slice thickness with a 0.75-mm reconstruction interval by using a medium convolution filter (B30 kernel) for soft tissue. Immediately afterward, a retrospective, electrocardiographically gated, helical cardiac acquisition was obtained. This acquisition was limited to the level of the coronary arteries to minimize radiation exposure. Parameters were a collimation of 64 × 0.6 mm, pitch of 0.2 to 0.4 depending on heart rate, rotation time of 330 ms, and a 1-mm reconstruction slice thickness with a 0.75-mm reconstruction interval and soft convolution filter (B20 kernel). Eight data sets were reconstructed at 10% R-R interval increments, from 20% to 90% of the R-R interval, with a 1-mm slice thickness. A low-dose protocol involving an 80-kV tube voltage and weight-based adjustment of tube current was used in all patients. Tube current for the nongated helical acquisition was 30 mA in patients weighing up to 3 kg and 30 mA plus 5 mA per additional kilogram in patients weighing more than 3 kg; for the retrospective, electrocardiographically gated, helical cardiac acquisition, tube current was 150% of the value used for the nongated acquisition.

The sequential protocol used after December 2008 consisted of a single prospective, electrocardiographically triggered, sequential thoracic acquisition. This protocol allowed a 1-step evaluation of cardiac and other thoracic structures with less radiation exposure. The settings were a collimation of 64 × 0.6 mm, rotation time of 330 ms, and reconstruction of a 1-mm slice thickness with a 0.75-mm interval and a soft convolution filter (B20 kernel). Experience acquired during the first part of the study, before December 2008, indicated that the optimal reconstruction time point was usually end-systole. Therefore reconstructions in the prospective protocol were set at the end-systolic phase, starting at the T-wave peak (at 40% to 50% of the R-R interval) without padding. Acquisition length was adjusted between 2 and 4 table moves to encompass the heart and great vessels. All patients received the same low-dose protocol involving 80-kV tube voltage and weight-based adjustment of tube current with 10 mA/kg up to 3 kg and then 30 mA plus 5 mA/kg at greater than 3 kg.

The helical protocol was used in 42 patients, and the sequential protocol was used in 58 patients. Of the 58 patients examined by using the sequential protocol, 5 required a second acquisition because of agitation during the first acquisition. In these patients only the data from the second acquisition were recorded. After December 2008, despite the availability of sequential acquisition, the helical protocol was used in 5 patients who had mild agitation, suggesting a risk of poor image quality with sequential acquisition.

Intravenous Contrast Medium Injection

In all patients an iodinated contrast medium (iopromide, 300 mg/mL; Ultravist 300; Bayer Schering Pharma, Berlin, Germany) was injected with a single-head power injector (Stellant; Medrad, Indianola, Pa) to ensure a continuous and regular flow rate. The dose was 2 mL/kg for both acquisition protocols, and the injection rate ranged from 0.4 to 3 mL/s