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Preoperative evaluation of coronary artery fistula using dual-source computed tomography

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ABSTRACT

Objectives: To evaluate the efficacy of dual-source computed tomography (DSCT) in assessing the morphological features, quantitative features, and associated coronary artery lesions among patients with coronary artery fistula (CAF) before surgery.
Methods: We enrolled 34 patients with CAF that were morphologically and quantitatively analyzed by DSCT and compared the analyses with surgical results (reference standard). The associated coronary artery lesions were also assessed.
Results: By DSCT, we identified 15 patients (44.1%) with left-sided CAF, 9 (26.5%) with right-sided CAF, and 10 (29.4%) with bilateral CAF; the left anterior descending coronary artery (50.0%) was most frequently involved. Drainage was most commonly in the main pulmonary artery (41.2%), and those with right-sided CAF had larger feeding coronary arteries and drainage sites than those with left-sided or bilateral CAF ($p < 0.05$). All the morphological features presented by DSCT were confirmed at surgery. In the quantitative analysis of CAF, DSCT was as accurate as surgery ($r = 0.95–0.98$, $p < 0.001$), and it was able to evaluate associated lesions accurately, including arteriosclerotic plaques, coronary artery aneurysms, and myocardial bridges. The evaluation could be completed in a single scan, without requiring an increased radiation dose (mean ED $= 2.27 \pm 1.92$ mSv).
Conclusions: DSCT is an alternative noninvasive imaging method that enables accurate assessment of morphological features, quantitative features, and associated coronary artery lesions in patients with CAF. It can be used to provide comprehensive information for determining surgical strategies.

1. Introduction

Coronary artery fistula (CAF) is a rare anomaly with an estimated prevalence of 0.2%–0.4% among congenital heart diseases [1]. First described by Krause in 1865, a CAF is defined as any coronary artery anomaly that terminates into a cardiac chamber or other adjacent vascular structure [2,3]. Typically, patients with CAF have clinically silent disease in early life, with cardiovascular symptoms and complications only developing as they become older [4]. Currently, the American College of Cardiology/American Heart Association (ACC/AHA) recommend that surgical repair of this disorder is preferable, before serious complications develop [5]. Hence, detailed knowledge of the underlying anatomy of CAF is essential to determining effective surgical strategies.

Traditionally, invasive cardiac catheterization has been regarded as the gold standard imaging modality for CAF. However, in addition to the high radiation dose that is required, this procedure is associated with catheter- and anesthesia-related risks [6]. Therefore, an imaging modality is needed that is less invasive and produces lower radiation exposure. In recent years, dual-source computed tomography (DSCT), with its short examining time, low radiation dose, and excellent image quality, has been widely applied in clinical practice [7,8]. To the best of our knowledge, few studies with this technique have focused on the morphological features of CAF [9–11]. Further study has been missing regarding the quantitative accuracy of DSCT before surgical intervention, together with its ability to demonstrate the morphological characteristics and lesions associated with CAF. Therefore, in this study, we investigated the efficacy of DSCT for the preoperative assessment of CAF.

2. Materials and methods

2.1. Study population

A total of 41 patients with CAF, referred to our hospital between January 2010 and December 2015, were initially enrolled. Diagnosis was made by DSCT on the basis of the ACC/AHA 2008 guideline [5]. The exclusion criteria were nonsurgical patients, incomplete clinical history, and unstable clinical conditions ($n = 7$). Finally, 34 patients were included (15 males and 19 females; average age 51.1 ± 18.3 years, range 6–78 years). The

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institutional review board of our hospital approved this study (No. 14-163), and we obtained written informed consent from all patients, including for radiation exposure and adverse reactions to the iodinated contrast agent. All patient-sensitive information was treated with full confidentiality and used solely for the purposes of this study.

2.2. Dual-source computed tomography

Scanning was performed using a DSCT scanner (Somatom Definition; Siemens Medical Solutions, Forchheim, Germany). Patients were asked to hold their breath during scans, and no sedation was used. A retrospective electrocardiography (ECG)-gated protocol was also used. The scanning parameters were set as follows: tube voltage of 100–120 kV (adapted to body mass index), tube current of 220 mAs, gantry rotation time of 0.33 s, and pitch of 0.2–0.5 (adapted to heart rate). Patients received a nonionic contrast agent (iopamidol, 370 mg/ml, Bracco, Italy) at a flow rate of 5 ml/s via an antecubital vein, followed by 20 ml of saline solution at the same flow rate. Acquired data were then processed on a workstation (Syngo; Siemens Medical System, Forchheim, Germany), and the images were reconstructed with a slice thickness of 0.75 mm and an increment of 0.7 mm.

2.3. Image analysis

Two experienced radiologists, who were blind to the DSCT results, described the morphological characteristics of CAF, including the feeding coronary artery and the drainage site. CAF were classified into three groups: left-sided, right-sided, and bilateral. Left-sided CAF referred to anomalies of the left main artery, left anterior descending coronary artery, or left circumflex coronary artery. Right-sided CAF referred to anomalies of the right coronary artery. Bilateral CAF then referred to anomalies of both the left and right. Consensus was reached when there was a difference in option. The size of the feeding coronary artery and the drainage site was measured by computer caliper at the maximum site during the same reconstructed cardiac phase. Surgical results were used as the reference standard to determine the quantitative accuracy of DSCT. To determine the intraobserver variability of DSCT measurements, the measurements of one radiologist were repeated by that radiologist a month later. To determine the interobserver variability, the other radiologist, who was unaware of these results, also reanalyzed the data.

In addition, we evaluated the associated coronary artery lesions, including arteriosclerotic lesions, for each patient. Plaques were categorized into calcified plaques (i.e., those with higher CT attenuation than a contrast-enhanced lumen), noncalcified plaques (i.e., those with lower CT attenuation than a contrast-enhanced lumen, without any calcification), and mixed plaques (plaques with both noncalcified and calcified elements) [12,13]. Image analysis was by multiplanar reformation, maximum intensity projection, and volume rendering.

2.4. Radiation dose estimation

The volume CT dose index ($CTDI_{vol}$) and dose-length product were automatically displayed on the CT console and recorded. The effective dose (ED) was calculated by multiplying the conversion coefficients according to the 2007 recommendations of the International Commission on Radiological Protection [14,15].

2.5. Statistical analysis

Statistical analysis was performed using SPSS software (version 17.0 for windows, SPSS, Chicago, IL, USA) and MedCalc software (version 9.3.0.0, MedCalc software, Mariakerke, Belgium). Continuous variables were expressed as mean ± standard deviations, and categorical variables were expressed as numbers and percentages. Linear regression analysis was used to assess the correlation between DSCT and surgery; Pearson's correlation coefficient with 95% confidence intervals was calculated. Bland–Altman analysis was performed to assess the agreement between DSCT and surgery further, by calculating the bias (mean difference) and the 95% limits of agreement (1.96 standards deviations around the difference). Intraclass correlation coefficients (ICCs) were calculated to assess the intra- and interobserver variability. One-way analysis of variance was used to compare the differences in the size of feeding vessel and in the drainage site among left-sided, right-sided, and bilateral CAF, as measured by DSCT. A two-tailed P value of <0.05 was considered statistically significant in all analyses.

3. Results

3.1. Baseline characteristics

The baseline characteristics of patients with CAF are presented in Table 1. Patients had a median age of 51.1 ± 18.3 years, and there were 19 females and 15 males. Among these 34 patients, 31 (91.1%) complained of cardiovascular-related symptoms when referred to our hospital, of which 11 (32.4%) presented with chest pain, 3 (8.8%) presented with dyspnea, 9 (26.5%) presented with palpitation, 6 (17.6%) presented with cardiac murmurs, 1 (12.9%) presented with syncope, and 1 (2.9%) presented with fatigue. Furthermore, 20 patients (58.8%) had comorbidities, of which 9 (26.5%) had coronary artery disease, 7 (20.6%) had hypertension, 1 (2.9%) had diabetes, and 3 (8.8%) had arrhythmias.

3.2. Morphological analysis of CAF

The morphological characteristics of CAF are summarized in Table 2. There were 15 patients (44.1%) with left-sided CAF, 9 patients (26.5%) with right-sided CAF, and 10 patients (29.4%) with bilateral CAF (Figs. 1–3). The left anterior descending coronary artery was most frequently involved (50.0%) in our study, followed by the right coronary artery (43.1%) and left circumflex coronary artery (6.9%). Drainage most commonly occurred in the main pulmonary artery (41.2%), followed by the right ventricle (26.5%), right atrium (14.7%), left ventricle (11.8%), left atrium (2.9%), and superior vena cava (2.9%). Most patients (85.3%) had a single fistula, but 5 patients (14.7%) had multiple fistulas (Fig. 1). All findings were confirmed by surgery.

3.3. Quantitative analysis of CAF

The size of feeding coronary artery and drainage sites for the left-sided, right-sided, and bilateral CAF, as measured by DSCT and surgery, are presented in Table 3. There was excellent correlation between DSCT and surgery in the quantitative analysis of CAF ($r = 0.95$–0.98, all $p < 0.001$; Fig. 4, Table 3). The diameters of feeding coronary arteries and drainage sites were larger for right-sided CAF than for left-sided or bilateral CAF (Table 3). Bland–Altman analysis demonstrated good agreement between DSCT and surgery results (Fig. 5).

3.4. Associated coronary artery lesions

Overall, only 4 left-sided CAF were associated with arteriosclerotic plaques, of which 1 was calcified, 1 was noncalcified, and 2 were mixed. All 3 right-sided CAF associated with arteriosclerosis had calcified plaques. Among the 7 bilateral CAF associated with arteriosclerotic plaques, 4 were calcified, 1 was noncalcified, and 2 were mixed. We identified 7 patients with associated coronary artery aneurysms, of whom 2 had left-sided CAF (Fig. 1), 1 had a right-sided CAF, and 4 had bilateral CAF. Finally, 3 patients with left-sided CAF had associated myocardial bridges, and 1 patient with a right-sided CAF had an aortic sinus aneurysm (Fig. 3).

Table 1
Baseline characteristics ($n = 34$).

Variables	
Age, years	51.1 ± 18.3
Male, n (%)	15 (44.1%)
Body mass index (kg/m^2)	21.5 ± 2.9
Heart rate (bpm)	84.1 ± 12.3
Systolic blood pressure (mmHg)	118.6 ± 11.8
Diastolic blood pressure (mmHg)	75.8 ± 9.1
Symptoms, n (%)	
Chest pain	11 (32.4%)
Dyspnea	3 (8.8%)
Palpitation	9 (26.5%)
Cardiac murmurs	6 (17.6%)
Syncope	1 (2.9%)
Fatigue	1 (2.9%)
Medical history, n (%)	
Coronary artery disease	9 (26.5%)
Hypertension	7 (20.6%)
Diabetes	1 (2.9%)
Arrhythmia	3 (8.8%)

Values are presented as mean ± SD or percentages.