Role of multidetector computed tomography (MDCT) angiography in preoperative assessment of coarctation of the aorta in pediatric patients and young adults

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Coarctation of aorta (COA); Patent ductus arteriosus (PDA); Ventricular septal defect (VSD); Atrial septal defect (ASD); Aortic aneurysm (AA); Right subclavian artery (RtSCA)

Abstract
Introduction: Aim of this work is to assess the reliability of 64-slice multidetector computed tomographic (MDCT) angiography for the preoperative assessment of coarctation of the aorta in pediatric patients and young adults.

Material and methods: Twenty eight patients with clinical suspicion of coarctation of the aorta who underwent both Doppler echocardiography and MDCT angiography were included in the study. MDCT angiography findings were compared with both Doppler echocardiography and surgical results.

Results: The overall sensitivity of three-dimensional MDCT angiography for diagnosis of the coarctation of the aorta was (100%) which was higher than that of Doppler echocardiography (91%). The overall sensitivity of MDCT angiography for the assessment of cardiac defects was (88%) which was lower than that of Doppler echocardiography (100%).

Conclusion: We concluded that MDCT angiography with multiplanar and three dimensional techniques can be considered the modality of choice for preoperative assessment of coarctation of the aorta in pediatric patients and young adults.

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1. Introduction

Coarctation of the aorta is a congenital malformation and typically a disease of childhood and early adulthood (1). Hypertensive vascular complications, cerebrovascular hemorrhages, aortic valve destruction, premature coronary artery disease and aortic aneurysms are seen in patients with un repaired coarctation of the aorta. In addition, dissection or rupture of the aorta is a life threatening complication of coarctation of the aorta (2).
Although the diagnosis of coarctation of the aorta can usually be made on clinical grounds, imaging is necessary to evaluate the exact anatomy of the lesion and to detect associated abnormalities.

Recently, multidetector computed tomographic (MDCT) angiography has become a principal imaging modality for the evaluation of thoracic vascular anomalies because of its short acquisition time and high spatial resolution (3).

MDCT angiography with multiplanar and three dimensional techniques is the non invasive method of choice for assessing the morphology of coarctation of the aorta particularly to characterize the location, degree and length of the narrowing, presence of collateral circulation, relationship to the left subclavian artery and associated cardiovascular abnormalities.

It is important to have accurate information about each of these parameters to devise surgical or interventional repair (4,5).

The aim of this work is to assess the reliability of 64-slice multidetector computed tomographic (MDCT) angiography for the preoperative assessment of coarctation of the aorta in pediatric patients and young adults.

2. Material and methods

Twenty eight patients (15 males and 13 females) were included in the study. Age range (5–20 years), mean age (13 years). They are presented with clinical suspicion of coarctation of the aorta. Symptoms include dyspnea (n = 16), chest pain (n = 5), congestive heart failure (n = 3), palpitation (n = 4). Signs were blood pressure gradient in the extremities, weak femoral pulses and murmur. They all underwent Doppler echocardiography. These patients fulfilled the inclusion criteria of our study and composed our study sample.

They were referred to the Radiology department for preoperative assessment of coarctation of aorta by multidetector computed tomography (MDCT) angiography. The radiologist was blind to results of the Doppler echocardiography.

All MDCT images were evaluated for the site, length and degree of coarctation of the aorta. The presence of additional cardiac anomalies including cardiac defects such as atrial septal defect, ventricular septal defect or patent ductus arteriosus was recorded.

The presence of associated vascular anomalies such as an aberrant subclavian artery is also recorded. The presence of associated aneurysm and dissection of thoracic aorta was also assessed. The visibility, origin and course of collateral vessels were also evaluated.

Coarctation of the aorta was defined as greater than a 25% decrease in vessel diameter. The degree of stenosis was considered severe if the ratio of the coarctation diameter to the distal descending aortic diameter was less than 50%.

The length of the coarctation was considered short if the length of the narrowed aortic segment was less than 5 mm and long if the length of the narrowed aortic segment was more than 5 mm.

MDCT angiography examinations were performed using (Siemens Somatom Definition) 64-slices spiral CT scanner. Patients were examined in a supine position, images extended from base of neck to the diaphragm during a single breath hold. Imaging parameters were as follows: 100 kVp, 100-200 mA. (varied automatically according to the body size), collimation 16 × 1.25 mm, slice thickness 1.25 mm, increment 0.6 mm and rotation time 0.5S. Oral administration of chlorhydrate (50 mg/kg body weight) was given to sedate young patients before MDCT examination.

Contrast medium administration:

Non ionic contrast medium was injected into an arm vein at a flow rate of 4 ml/s (omnipaque 300; GE Health care, USA) with the aid of an injection pump (Medrad; Medical Systems, USA) to ensure satisfactory vessel opacification in the entire volume examined. Dose of contrast material injected was 2 ml/kmg.

The scanning delay was determined with a bolus tracking technique. The examination initiated 4 s after attenuation of the region of interest positioned in the ascending aorta reached 150 HU.

For three dimensional images, the volumetric CT data sets were processed on a separate work station (Syngo Multimodality Workplace) with multiplanar reformattting, maximum intensity projection and volume rendering. Axial source images, the two and three dimensional data sets were evaluated for each of the 28 patients.

On the basis of Doppler echocardiography and 3-dimensional MDCT angiography findings, surgery was performed in all 28 patients. MDCT findings were compared with both Doppler echocardiography and surgical results.

3. Results

All coarctations were classified as postdural type. The degree of stenosis was considered severe in 24 cases. The length of the coarctation was short in 23 cases and long in five cases. The coarctation was located distal to the origin of the left subclavian artery in all cases.

Whereas all coarctations were diagnosed correctly by multiplanar and three dimensional images with 100% sensitivity, two short (< 5 mm) coarctations were missed by axial images resulting in 93% sensitivity.

The site, degree and the length of the coarctation were reliably evaluated by multiplanar and three dimensional MDCT angiography images.

MDCT findings were compared with both Doppler echocardiography and surgical results.

Overall sensitivity of MDCT angiography for diagnosis of the coarctation of the aorta (Figs. 1–6) was 100% which was higher than that of Doppler echocardiography (91%). Coarctation of the aorta was associated with additional cardiac defects in 12 cases. Two cases had atrial septal defect, 4 cases had ventricular septal defect and 6 cases had patent ductus arteriosus. The diameter of patent ductus arteriosus ranged from 2 to 3 mm. All cases of patent ductus arteriosus were correctly diagnosed by both MDCT angiography and Doppler echocardiography with 100% sensitivity.

One case with a small VSD was missed by MDCT but diagnosed by Doppler echocardiography. All cases of atrial septal defect were diagnosed correctly with MDCT and Doppler echocardiography. The overall sensitivity of MDCT for the assessment of cardiac defects was (88%) which was lower than that of Doppler echocardiography (100%).

In our study, coarctation of the aorta was accompanied by an ascending aorta aneurysm, in one of these cases aneurysm...
Figure 1  Axial (A), volume rendering (B) and multiplanar images (C) showing short segment of stenosis in the aorta distal to the origin of left subclavian artery (arrows).

Figure 2  (A, B) showing short segment of severe stenosis in the aorta just distal to the origin of left subclavian artery (thick and curved arrows). Incidental finding of double superior vena cava, image (C) shows left sided superior vena cava (thin arrow).

Figure 3  Axial images (A) and volume rendering (B) showing localized narrowing at the aorta distal to the origin of left subclavian artery (arrows). Incidental finding is small sized aortic arch.
of the descending aorta was also noted (Fig. 4). No dissection was noted in all cases.

MDCT showed associated cardiac and vascular anomalies such as aberrant right subclavian artery in 3 cases. It originated from the aorta proximal to the coarctation site in 2 cases, and distal to the coarctation site in 1 case. Double superior vena cava (Fig. 2) was noted in one case and a small sized aortic arch was noted in one case (Fig. 3).

Collateral vessel formation was noted in 16 cases. The origin and course of collateral vessels were clearly seen on three dimensional MDCT (Fig. 4). Hypertrophied internal mammary artery was also noted.

Beyond the cardiovascular system, MDCT found extracardiovascular lesion in 3 patients; 2 patients had pneumonia and one patient had atelectasis.

The estimated radiation exposure was between 2.5 and 5.2 mSv.

4. Discussion

Several imaging modalities have been reported in the evaluation of coarctation of the aorta. Because of its ability to provide both anatomic and hemodynamic information, conventional angiography remains the gold standard for pretherapeutic workup of patients with aortic coarctation. It allows pressure gradient measurement across the coarctation, visualization of the collaterals and assessment of associated cardiac malformations, however, this technique is invasive and enhances the risk for complications imposed by the coarctation (6).
Multidetector computed tomography has several advantages versus conventional angiography, especially for children. Commonly, there is no need for sedation and general anesthesia. It has been successfully applied to children four years of age and above because they can easily adjust to the instructions. Low doses of sedatives can be used for smaller or agitated children. In uncooperative cases, scanning is performed during a few seconds of calm. The short scanning time reduces motion artifacts, and image quality is not affected at all. Because of the fast scanning, MDCT is preferable when there is a severe illness or life-threatening situation. Also, it presents minimal invasive mortality and morbidity risks (7,8). Contrary to conventional angiography, potential interventional complications (dissection, occlusion, bleeding, etc.) are absent. It is easily applied in the case of bleeding diathesis. Conventional angiography has the disadvantage of taking a long time, being invasive and requiring anesthesia in the pediatric population. However, unlike angiography, additional information, such as pressure curves and oxygen saturation data, cannot be derived from an MDCT examination.

Doppler echocardiography is currently the first imaging modality used, identifying the location and the severity of the coarctation and has the advantage of a non invasive estimation of the pressure gradient across the narrowing. But it is sometimes difficult to obtain good visualization of the site of coarctation because of a poor acoustic window and the long distance between the transducer and the isthmic region (9). In our study, two coarctations were missed by Doppler echocardiography yielding a sensitivity of 91%.

Before the introduction of MDCT technology, magnetic resonance imaging (MRI) was frequently used for the assessment of congenital thoracic vascular anomalies because of its multiplanar capability. Contrast enhanced MR angiography is, for the most part, sufficient for evaluation of the aorta and its branches, whereas cine MRI and phase contrast MRI allow assessment of the hemodynamic significance of the coarctation as well as cardiac and valvular function (9,10).

When multiplanar and three dimensional postprocessing techniques became available, the role of CT in the assessment of thoracic vascular anomalies changed. MDCT has changed not only the imaging evaluation approach to thoracic aortic anomalies but also challenged the role of conventional angiography (11-14).

Compared with MR angiography, MDCT angiography has the advantage of the ability to acquire high spatial resolution in a shorter acquisition time. In addition volume rendered and multiplanar reconstructions are better for MDCT angiography data display than MRI (15).

MDCT with multiplanar and three dimensional techniques provides morphologic images of coarctation of the aorta and its relationship to the arch vessels as well as demonstrating collateral circulatory pathways (4,5). But it is not useful for visualizing the aortic gradient or small cardiac malformations (4). In the present study, overall sensitivity of MDCT for the assessment of cardiac defects was 88% which was lower than that of Doppler echocardiography (100%). These results are in agreement with Hu et al. (4) in their study done on 2008 for assessment of coarctation of the aorta in young children and also with Turkvatan et al. (16) in their study done on 2009 for assessment of coarctation of the aorta in adults.

A number of image reconstruction options are available for postprocessing of volumetric data sets. We currently use the reconstruction displays to highlight areas of interest (multiplanar reformations and 3D volume renderings). Our study compared the accuracy of axial CT, multiplanar and 3D volume rendered images in the evaluation of coarctation of the aorta in pediatric patients and young adults. The results of our study show that in the evaluation of coarctation, multiplanar and 3D volume rendered images performed slightly better than axial images. For the diagnosis of coarctation, sensitivities were 88% for axial, 100% for multiplanar and 100% for volume rendered images.

Previous studies have described the role of axial and three-dimensional renderings in the diagnosis of mediastinal vascular anomalies (3,4). Recently, a study associated with CT angiography and three-dimensional reconstruction in young children with CoA showed the diagnostic sensitivities of CoA as being 87.5% for axial and 100% for three-dimen-
sional, volume-rendered images (4). In another study, the results were consistent with the former study (3). Previous and present studies demonstrate that MDCT angiography is a non-invasive, feasible technique for assessing CoA.

MDCT is an excellent means for identifying aortic aneurysm and dissection, the most serious complication of coarctation. Although the development of aneurysms proximal to the site of coarctation is expected, aneurysms may occur distal to the coarctation site secondary to turbulent flow (17). In our study there were two cases with aneurysm of the ascending aorta, in one of these cases aneurysm of the descending aorta was noted.

Radiation exposure is important in the pediatric population because children are considered to be more sensitive to ionizing radiation than adults, and they have a longer life expectancy. The main disadvantage of MDCT is radiation exposure. Computed tomography protocols are associated with a known increase in the risk of future malignancy (18). According to these findings, dose-saving algorithms are very important in reducing radiation exposure and should be used in every imaging modality, especially during childhood. These algorithms include shorter scan volumes, lower tube currents, increased table speed or pitch, and increased speed of gantry rotation. As with all pediatric CT, mAs must be adjusted for patient size (19,20). In this current study, we used the parameters of 100 kVp and 100–200 mAs (varied automatically according to body size) to provide optimal quality images without any significant loss of diagnostic data (Table 1).

Table 1 Features of the 28 patients with coarctation of the aorta.

<table>
<thead>
<tr>
<th>No.</th>
<th>Degree of COA</th>
<th>Length of COA</th>
<th>Collateral vessels</th>
<th>PDA</th>
<th>VSD</th>
<th>ASD</th>
<th>AA</th>
<th>AA</th>
<th>Vascular anomalies</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 cases</td>
<td>Severe in 26, moderate in 2</td>
<td>Short in 23, long in 5</td>
<td>16 Cases</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3 Abberant RtSCA</td>
</tr>
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References