Multislice computed tomography angiography is a sufficient method for detecting native aortic coarctation in children

Çok kesitli bilgisayarlı tomografik anjiyografi çocuklarda aort koarktasyonunun saptanmasında yeterli bir yöntemdir

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Background: We evaluated the feasibility and utility of low dose multislice computed tomography (MSCT) angiography as a noninvasive method in detecting anatomic structures of lesion and combined anomalies associated with coarctation of the aorta.

Methods: A total of 15 pediatric patients (9 boys, 6 girls; mean age 34 months; range 8 days to 10 years) who underwent color Doppler echocardiography (CDE) and MSCT angiography for coarctation in our clinic between February 2009 and June 2010 were included in this study. The thorax was scanned from the cupula to the top of the diaphragm by using 16-slice computed tomography.

Results: Upon axial imaging, anatomical findings related with coarctation were not apparent in two patients (86.6%; n=2). The three-dimensional images clearly showed all of the areas of coarctation (100%; n=15). The overall sensitivity of MSCT diagnosis for coarctation was 100%, which was higher than CDE (86.6%; n=13). The diagnosis for each patient was confirmed with surgery.

Conclusion: The study proved the feasibility and efficiency of low-dose MSCT angiography as a noninvasive method to detect the native aortic coarctation in children.

Key words: Children; coarctation of the aorta; multislice computed tomography.

Amaç: Düşük dozlu çok kesitli bilgisayarlı tomografik (ÇKBT) anjiyografinin aort koarktasyonu ve lezyonla ilişkili eşzamanlı anomalilerin anatomik yapısının saptanmasında non-invazif bir yöntem olarak uygulanabilirliği ve etkinliği araştırıldı.

Çalışma planı: Şubat 2009 - Haziran 2010 tarihleri arasında kliniğimizde renkli Doppler ekokardiyografi (RDE) ve ÇKBT anjiyografi uygulanan toplam 15 çocuk hasta (9 erkek, 6 kız; ort. yaş 34 ay; dağılım 8 gün ila 10 yıl) çalışmaya dahil edildi. On altı kesitli bilgisayarlı tomografide görüntüleme alanı göğüs üst bölümü ile diyafram tepe kısmı olarak seçildi.

Bulgular: Aksiyal incelemelerde koarktasyon ile ilgili bulgular iki olguda belirgin değildi (%13.3; n=2). Üç boyutlu görüntülemelerde ise tüm koarktasyon alanları net olarak gösterildi (%100; n=15). Aort koarktasyonunu saptamada ÇKBT'nin toplam duyarlılığı %100 ile RDE'ye göre daha yüksek (%86.6; n=13) idi. Tüm hastaların tanısı cerrahi olarak doğrulandı.

Sonuç: Bu çalışmada düşük dozlu ÇKBT anjiyografinin çocuklardaki aort koarktasyonunu saptamada bir non-invazif yöntem olarak uygulanabilirliği ve etkinliği kanıtlandı.

Anahtar sözcükler: Çocuklar; aort koarktasyonu; çok kesitli bilgisayarlı tomografi.

Coarctation of the aorta (CoA) is the most frequent (6-8%) congenital anomaly of the thoracic aorta, consisting of a narrowing usually located in the proximal descending aorta just distal to the left subclavian artery.[1] Isolated coarctation can remain clinically silent until adolescence or adulthood, presenting as primary hypertension with symptoms like headache, leg fatigue and leg cramps. Untreated, approximately 90% die by the age of 50 years old. The causes of death include congestive heart failure, aortic rupture and dissection, bacterial endocarditis, and intracranial hemorrhage associated with aneurysms

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of the circle of Willis. There is significant association with other cardiac lesions, such as ventricular septal defect and patent ductus arteriosus. Additionally, up to 50% of the lesions are commonly associated with a bicuspid aortic valve.[1,2] Prognosis depends on the severity of stenosis and the associated lesions. Patients with CoA should be diagnosed with imaging at a young age before complications such as hypertension and congestive heart failure develop. Imaging modalities are also vital for assessing the exact anatomy and severity of the lesion while helping to determine the surgical options.

Multislice computed tomography (MSCT) angiography has recently been introduced as a noninvasive method in the detection and quantification of coarctation. This permits high-speed scanning and adequate image quality. The increased resolution of MSCT and image processing in three-dimensional analyses provide a major improvement in the image quality.[3,4] However, as a result of technical developments which have led to increased temporal resolution through faster gantry rotation and improved spatial resolution through thinner slice collimation, MSCT is associated with an increased radiation dose.[5] 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.

The aim of this study was to evaluate the feasibility and utility of low-dose MSCT angiography as a noninvasive method for detecting anatomic structures and combined anomalies associated with CoA.

PATIENTS AND METHODS

Patients

A total of 15 pediatric patients (9 boys, 6 girls; median age 34 months; range 8 days to 10 years) who underwent color Doppler echocardiography (CDE) and MSCT angiography for CoA between February 2009 and June 2010 were included in this study. Coarctation was considered because of high upper extremity blood pressure (n=7), murmur (n=5), and dyspnea with tachycardia (n=3). All patients underwent routine CDE by pediatric cardiologists and were then referred for an MSCT examination. X-ray angiography was not performed on any of the patients prior to MSCT. After diagnosis of CoA, all patients underwent surgical intervention. The local ethics committee approved the study protocol, and a written informed consent was obtained from the parents of all patients.

Multislice computed tomography angiography technique

The thorax was scanned from the cupula to the top of the diaphragm using 16-slice computed tomography (Siemens Medical Systems, Erlangen, Germany). Children with the ability to hold their breath were told to take a deep breath before the scanning commenced. Small children were allowed to rest or fall asleep. When required, sedation was achieved by an oral dose of chloral hydrate (40-60 mg/kg) prior to the exam. A non-ionic iodinated contrast material (1.5 ml/kg) was injected by a power injector with a rate of 1 ml/sec via antecubital vein. The bolus tracking method was used.

Scan parameters (collimation 16x0.75 mm, pitch 1, gantry rotation time 0.5 sec, 100 kV) led to an estimated radiation exposure of between 2.5 and 5.2 mSv. This examination was systematically obtained by adjusting the mAs setting according to the patient’s size and anatomic shape. According to this setting, the value of mAs ranged between 30 and 75. The scanning duration was 5-8 s (mean 6.6 s).

Multislice computed tomography data analysis

Acquired axial slices were evaluated, and non-vascular thoracic organ abnormalities were noted. The image data of the CT angiography was transferred to a computer workstation (Wizard, Siemens, Germany). Then axial slices were reconstructed using Maximum Intensity Projection (MIP) and Volume Rendering Technique (VRT). Images were reconstructed with a 0.75 mm slice thickness and 0.4 mm reconstruction intervals. These reconstructed axial images were processed and evaluated with the consensus of two experienced pediatric radiologists. On the three-dimensional page, the reconstructed images were evaluated in the axial, sagittal, and coronal planes. The course, morphology, and sizes, especially of the aorta and its main branches, were examined. In patients with CoA, the region of the stenotic segment, length, collaterals, and accompanying anomalies were noted.

RESULTS

Multislice computed tomography was performed successfully in all 15 patients. There was complete agreement among the observers regarding the findings of the MSCT images. Motion artifacts did not limit the diagnostic accuracy of the images. In CDE examination, because of the young age and a large ventricular septal defect, CoA was not diagnosed in two patients (86.6%; 13/15). With axial imaging, anatomical information related to CoA was not apparent in two patients (86.6%; 13/15). The three-dimensional images clearly showed all of the areas of CoA (100%; 15/15). There was excellent agreement between the three-dimensional images and surgery. All of them were juxtaductal resulting in a luminal narrowing of greater than 50%. Focal lesions were observed in 15 patients ranging in length from 4 mm to 2 cm. The sensitivities of MSCT diagnosis for CoA were 86.6% for axial and 100% for three-dimensional images, which was higher than for CDE (86.6%). The associated congenital malformations, such as ventricular septal defect (n=4), patent ductus arteriosus (n=2; Figure 1), arcus hypoplasia (n=2; Figure 2), and collaterals (n=2; Figure 3), were detected. The diagnosis for each patient was confirmed with surgery, and all patients underwent end-to-end anastomosis without any complications. The diagnostic findings of echocardiography, three-dimensional images, and surgery in patients with coarctation are shown in table 1.

DISCUSSION

Since the computed tomography represents technological advantages, MSCT angiography has given spectacular knowledge about vascular structures, especially with great vessels. It was hard to show and evaluate the complex structures of the vessels using axial slices in the past because there was a high risk of false results. With the assistance of high resolution image quality, decrease in slice thickness, and utilization of workstations which reconstruct three-dimensional images, MSCT has gained successful results in the evaluation of aortic anomalies in the pediatric population.[3,4,6] Also, MSCT, in combination with a three-dimensional reconstruction of the aortic arch, appears to be an adequate examination in cases with CoA before surgery. For preoperative planning, the localization, shape, and length of the stenosis as well as the course of collateral vessels can be clearly assessed using MSCT. It also has proven to be a noninvasive follow-up tool in children after angioplasty or end-to-end anastomosis of the aorta.[7]

Multislice 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 old 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 (5-7 sec). The short scanning time reduces motion artifacts, and image quality is not affected at all. Because

Figure 1. Volume rendering technique posterolateral projection shows patent ductus arteriosus (black arrow) and coarctation of aorta distal to the origin of the left subclavian artery (white arrow) in a 2-year-old boy.

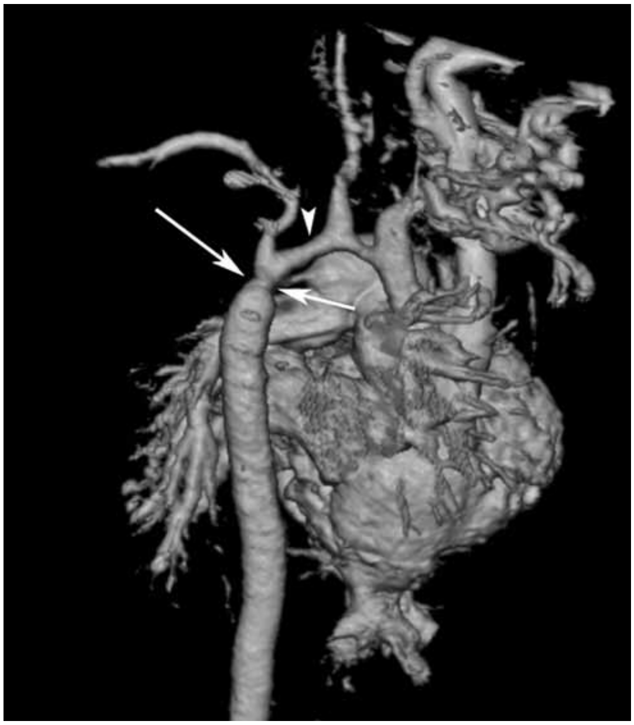

Figure 2. Volume rendering technique shows marked hypoplasia of arcus aorta (arrowhead) and coarctation of aorta (arrows) distal to the origin of the left subclavian artery in a 3-year-old girl.

Figure 3. Maximum intensity projection shows coarctation of aorta distal to the origin of the left subclavian artery (arrowhead) and collateral of the internal mammarian artery (arrow) in a 10-year-old boy.

of the fast scanning, MSCT is preferable when there is a severe illness or life-threatening situation. Also, it presents minimal invasive mortality and morbidity risks.[8,9] 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 MSCT examination.

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-dimensional, volume-rendered images.[3] In another study, the results were consistent with the former study.[4] Previous and present studies demonstrate that MSCT angiography is a noninvasive, feasible technique for assessing CoA.

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 MSCT is radiation exposure. Computed tomography protocols are associated with a known increase in the risk of future malignancy.[9,10] 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.[11-13] As with all pediatric CT, mAs must be adjusted for patient size. For gated evaluation, in general, three-four different tube current categories may be more practical, ranging from about

Table 1. The findings of echocardiography, 3D images and surgery in patients with coarctation

Age (months)	Wight (kg)	Echocardiography	3D images	Surgery findings
0.3	2.9	VSD	CoA, VSD	CoA, VSD
1	3.1	VSD	CoA, VSD	CoA, VSD
10	8.0	CoA, arcus hypoplasia	CoA, arcus hypoplasia	CoA, arcus hypoplasia
12	7.4	CoA	CoA	CoA
15	8.5	CoA, VSD	CoA, VSD	CoA, VSD
24	10.7	CoA, PDA	CoA, PDA	CoA, PDA
32	11.0	CoA	CoA	CoA
34	11.4	CoA, VSD	CoA, VSD	CoA, VSD
36	12.0	CoA, arcus hypoplasia	CoA, arcus hypoplasia	CoA, arcus hypoplasia
42	13.8	CoA, PDA	CoA, PDA	CoA, PDA
56	13.1	CoA	CoA	CoA
60	15.0	CoA	CoA, collateral artery	CoA
72	15.0	CoA	CoA	CoA
96	23.5	CoA	CoA	CoA
120	23.0	CoA	CoA, collateral artery	CoA

3D: Three-dimensional; CoA: Coarctation of aorta; PDA: Patent ductus arteriosus; VSD: Ventricular septal defect.

one-third of the adult mAs for the smallest child to the adult mAs for adult-sized children.[4,14] In this current study, we used the lowest parameter of 30 mAs and 100 kVp to provide optimal quality images without any significant loss of diagnostic data.

The small number of patients and lack of X-ray angiography and magnetic resonance imaging (MRI) to assess the accuracy of the MSCT data are the major limitations of the present study; however, increasing the sample size in the future is being planned. Because of the radiation burden, we were not able to compare this technique with conventional angiography. MRI provides not only the advantage of imaging without radiation, but functional assessment as well. In particular, flow measurements are of interest to identify relevant collateral circulation.[15] However, in this technique, the scanning time is longer than in MSCT which may require prolonged sedation and may be difficult to perform in seriously ill children.

In conclusion, this study proved the feasibility and efficiency of low dose MSCT angiography as a noninvasive method in detecting anatomic structures of CoA and combined anomalies without any significant loss of diagnostic data. MSCT with three-dimensional reconstruction displayed the vascular structures clearly; therefore, it can be used in place of conventional angiography in the diagnosis and follow-up of patients with CoA.

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