Original Article | **J Rehman Med Inst.**
Vol. 2, No. 1, 2016

MULTIDETECTOR CT AORTOGRAPHY IN PREOPERATIVE EVALUATION OF COARCTATION OF AORTA USING MULTIPLANAR REFORMAT AND 3D RECONSTRUCTION

Ummara Siddique,[a] Shahjehan Alam,[a] Seema Gul,[b] Syed Ghulam Ghaus[b]

ABSTRACT

Introduction: Diagnosis of Coarctation of the aorta is usually made on clinical grounds; evaluating the exact anatomy of the lesion and detecting associated abnormalities necessarily entails imaging modalities, several having been reported for thoracic aortic anomalies. CT angiography (CTA) is a promising method for the evaluation of blood vessels. The present study was undertaken to evaluate the reliability of 128-slice Multidetector Computed Tomographic (MDCT) angiography with Multi Planar Reformat (MPR) for the preoperative morphologic assessment of Coarctation of the aorta.

Materials & Methods: A descriptive cross-sectional study of 30 patients with clinical suspicion of Coarctation of the aorta investigated from January 01, 2013 to March 01, 2016 using 128-slice MDCT scanner was carried out in the Radiology Department of Rehman Medical Institute Teaching Hospital. Reconstructed 0.5mm images were viewed in axial, coronal and sagittal planes on a Vitrea 5.0 workstation. Data were processed using Microsoft Excel 2007. The sensitivity of MDCT diagnosis was assessed comparing findings of axial and MPR and overall MDCT findings with clinical findings and surgical results.

Results: The overall sensitivity of three-dimensional MDCT for the diagnosis of Coarctation of the aorta was 100%. Diagnostic sensitivities of Coarctation were 90% for axial and 100% for both MPR and 3D volume-rendered images. Moreover, MDCT was able to clearly display the location and extent of the Coarctation. Focal defects were observed in 25 cases, tubular narrowing in 2 and interruption seen in 3 cases.

Conclusion: MDCT angiography with Multiplanar and Three-Dimensional Techniques should be the method of choice for preoperative morphologic assessment of Coarctation of the aorta in pediatric as well as adult patients.

Keywords: Aortic Coarctation; Aortography; Angiography; Multidetector Computed Tomography.

Author Designation & Affiliation

a Assistant Professor, Department of Radiology, Rehman Medical Institute Teaching Hospital, Peshawar, KP, Pakistan.

b Associate Professor, Department of Radiology, Rehman Medical Institute Teaching Hospital, Peshawar, KP, Pakistan.

INTRODUCTION

A multitude of congenital anomalies may affect various portions of the aorta, one of them being Coarctation. This anomaly is found in 8% of overall cardiac congenital malformations.[1] Coarctation of the aorta is a congenital malformation and typically a disease of childhood and early adulthood.[2]

Coarctation of the aorta can occur anywhere along the course of the vessel. Coarctation is most commonly manifested as a diaphragm-like ridge in a juxtaductal location. In addition to discrete narrowing, associated hypoplasia may be present and involve a portion or all of the aortic arch.[3]

The diagnosis of Coarctation of the aorta can usually be made on clinical grounds but imaging is necessary to evaluate the exact anatomy of the lesion and to detect associated abnormalities. Several imaging modalities have been reported in the evaluation of thoracic aortic anomalies. CT angiography (CTA) is a promising method for the evaluation of blood vessels.[4] At CTA exact delineation of the location and extent of narrowing is extremely useful in pretreatment assessment and for determining whether a patient is to be treated with surgery, angioplasty, or stent placement.[3]

Knowledge of the cardiac Computed Tomography appearance of Coarctation of the aorta and associated abnormalities is critical for accurate diagnosis and management, which includes providing information to plan surgical or percutaneous therapy.[5]

During the past decade, CT angiography has become a principal examination for the evaluation of aortic anomalies. Recently Multidetector

Computed Tomography (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.[5]

In the present study, role of MDCT Angiography was assessed in the diagnoses of aortic Coarctation and sensitivity of Three Dimensional (3D) and post processing techniques of Multiplanar Reconstruction (MPR) were assessed. MDCT angiography with Multiplanar and 3D 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.[6,7] Low dose prospectively gated axial CT angiography is a valuable tool in the routine clinical evaluation of infants with congenital heart and vascular disease providing a comprehensive three dimensional evaluation.[7,8]

MATERIALS & METHODS

This was a descriptive cross-sectional study conducted on thirty outdoor and indoor patients with clinical suspicion of Coarctation of the aorta who underwent MDCT angiography after referral to Radiology Department of Rehman Medical Institute Teaching Hospital Peshawar from January 2013 to March 2016. Nature and duration of the procedure, benefits and involved documented risks of the intravenous contrast were narrated in an easy /native language to the patients. MDCT aortography was performed on a 128 slice Toshiba scanner.

MDCT scanning technique

MDCT angiography examinations were performed with a 128 slice Toshiba MDCT scanner. Patients were examined while supine, and images extending from base of the neck to the diaphragm were acquired during a single breath-hold. Imaging parameters were as follows: tube voltage of 100 to 120kV; tube current of 140–330mA (both tube current and voltage varied according to body size); collimation of 16 × 1.25mm; slice thickness of 1.25mm; increment of 0.6mm; table feed of 27.5mm/s; and rotation time of 0.5s. In children younger than 8 years old, tube voltage was reduced to 100kvp. Helical CT data acquisition was performed in one breath-hold. In children younger than 5 years old, helical CT data acquisition was carried out in deep sedation without intubation (Midazolam/ Dormicum, 0.1-0.2mg/kg body weight). The imaging data were acquired during an intravenous injection of 90–120mL iodinated contrast agent (Iopamiro/Iopamidol, 370mgI/mL) at a rate of 4mL/s. The scanning delay was determined with a bolus tracking technique. The examination was initiated 4 seconds after attenuation of the region of interest (positioned in the aortic arch) reached 180HU. For three-dimensional image reconstruction, the volumetric CT data sets were processed on a separate workstation (Advanced Workstation 5.0 Vitrea) with Multiplanar reformatting, curved planar reformatting, maximum intensity projection, and volume rendering. At least two qualified radiologists evaluated the axial source images and the two- and three-dimensional datasets for each of the 30 cases by consensus. Maximum Intensity Projection (MIP) reconstructions were rendered and displayed at a center window level of 250 and a window width of 1000. In addition to the CT axial slices, 3D reconstructions such as volume rendering and Multiplanar reformation were used to diagnose Coarctation and associated cardiac abnormalities.

Pre-procedure patient preparation

The patient was on fast for about 2–3 h before appointment due to the administration of contrast media in this examination. Hydration was recommended 4 h prior to the examination.

All MDCT images were evaluated for the site, degree and length of the Coarctation; the presence of additional cardiac defects, such as patent ductus arteriosus and atrial or ventricular septal defect; and associated vascular anomalies such as an aberrant subclavian artery. The presence of an associated aneurysm and dissection of the thoracic aorta was assessed. The origin, visibility, and course of collateral vessels were also evaluated. Coarctation of the aorta was defined as greater than 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 or focal 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 findings were compared with both Doppler echocardiography and surgical results.

Image Analysis

The volume data sets were reconstructed on a computer Vitrea workstation version 5.0. Aortic diameters were measured at the following six intrathoracic levels: aortic valve sinus; ascending aorta at the level of the right pulmonary artery; proximal to the innominate artery; proximal transverse aortic arch; distal transverse aortic arch; and the aortic isthmus at its narrowest point (Figure 1). The slices for the measurements were manually adjusted separately for each aortic level to get an oblique plane that was strictly perpendicular to the course of the aorta. The internal vessel diameters were measured in three different directions by an electronic caliper. Those three estimates were made, and the arithmetic mean was used for performing further calculations. All reformations and measurements were performed by the same person (i.e., one of the authors). To describe morphologic aortic wall irregularities and other anatomic details, additional oblique planes were reconstructed from the CT scan data with the axial, frontal, and double-oblique planes. Furthermore, three-dimensional reconstruction with surface rendering was performed from the volume data sets. Some complications associated with long term Coarctation were observed and documented. These were: Collaterals, Left ventricular hypertrophy, Atherosclerosis, Patent ductus arteriosus, coronary artery variants, early coronary artery disease, pre stenotic aortic ectasia or aortic aneurysm, Bicuspid aortic valve and PDA aneurysm.

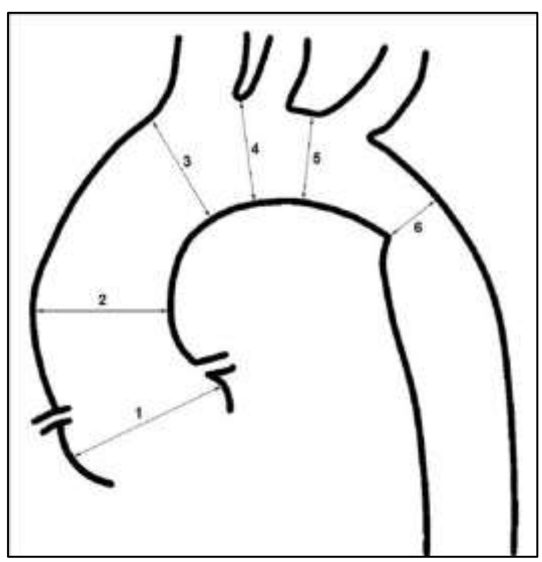


Figure 1: The aortic diameters were measured at different levels as follows:[8]

1. Aortic valve sinus
2. Ascending aorta at the level of the right pulmonary artery
3. Proximal to the innominate artery
4. Proximal transverse aortic arch
5. Distal transverse aortic arch
6. Aortic isthmus

RESULTS

CT Aortography of thirty patients (median age of 31 years; range, 1–53 years) was performed. Diagnostic sensitivities of Coarctation were 90% for axial and 100% for both Multi Planar and 3D volume-rendered images. Moreover, MDCT was able to clearly display the location and extent of the Coarctation. Focal defects were observed in 25 cases, tubular narrowing in 2 and interruption seen in 3 cases (Figure 2).

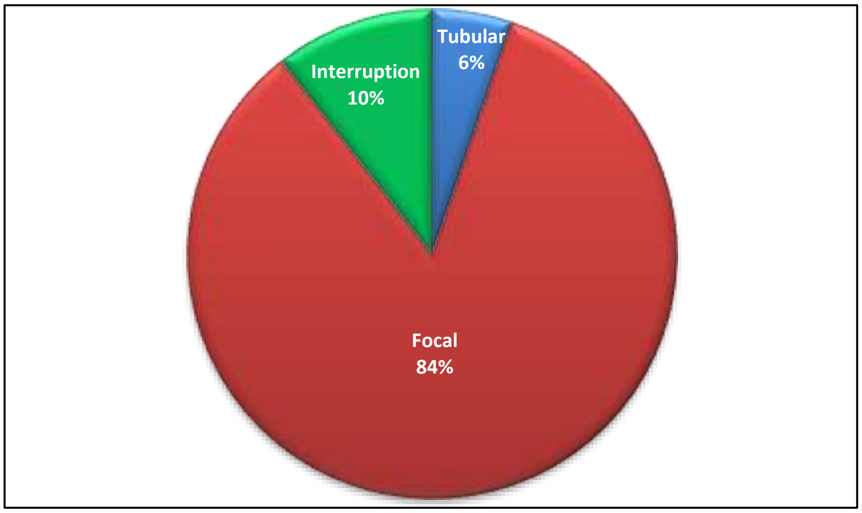


Figure 2: Figure showing distribution of Focal Coarctation, tubular hypoplasia and aortic interruption (n=30).

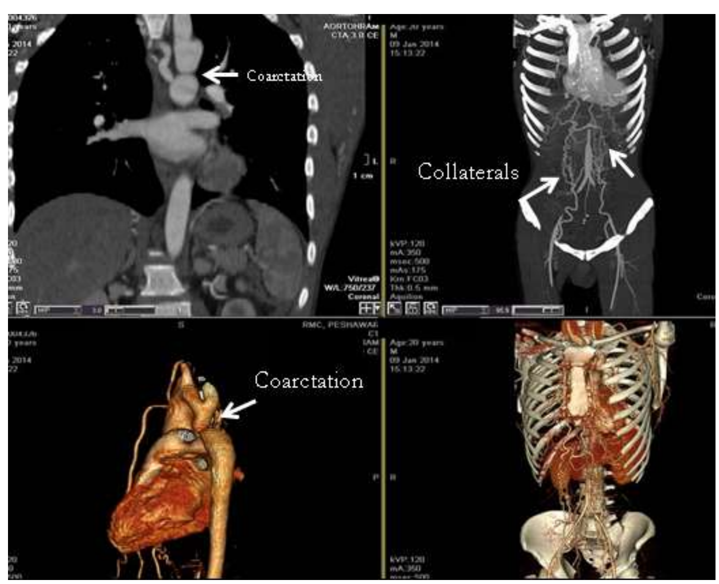
The sensitivity of MDCT diagnosis for Coarctation of the aorta was 100%. Pre-stenotic dilatation was seen in 1, post-stenotic in 2, ascending aortic dilatation was seen in 7 and aortic arch was tortuous in 1. Atrial septal defect (ASD) was diagnosed in 1 case. In addition, 4 patients had patent ductus arteriosus (PDA), 1 patient had a small PDA diverticulum whereas 1 patient had a large saccular aneurysm of PDA. One patient had bicuspid aortic valve. 20 patients in this study had collateral vessel formation.

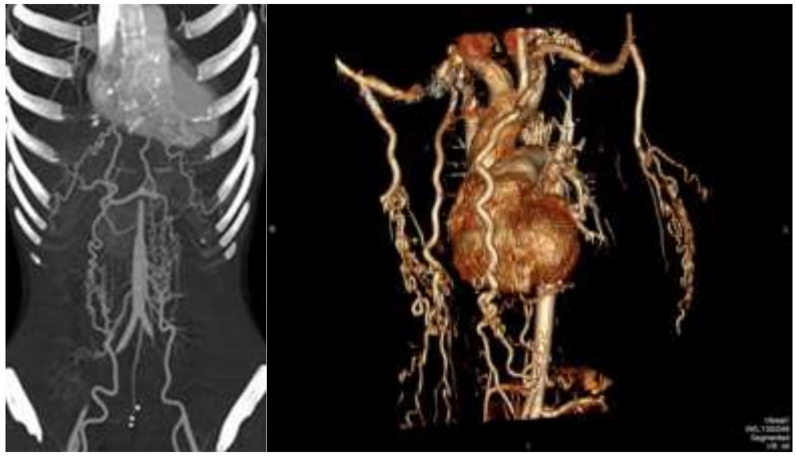
Three-dimensional reconstructions created excellent images of the aortic anatomy and are particularly useful for providing the spatial relation of complex vascular arrangements. Figures 3 to 8 depict the imaging results.

Figure 3: Severe Aortic Coarctation

MDCT angiography images of a 20 year old male. Coronal MPR, Coronal MIP and 3D-volume rendered images showing severe Coarctation of proximal descending aorta.

Multiple collaterals seen on curved reformatted coronal and 3D images.





(a) (b)

Figure 4: Collateral vessels seen with aortic Coarctation

(a) Coronal maximum intensity projection of a 20 year old male with Coarctation of aorta showing collateral vessels.

(b) 3D surface rendered image of another patient showing extensive collaterals in thorax and abdomen.

Figure 5: Complete Interruption of Aorta

CT Aortogram multiplanar images showing complete interruption of aorta (arrows). Numerous chest wall and mediastinal collateral vessels appreciated on axial images.

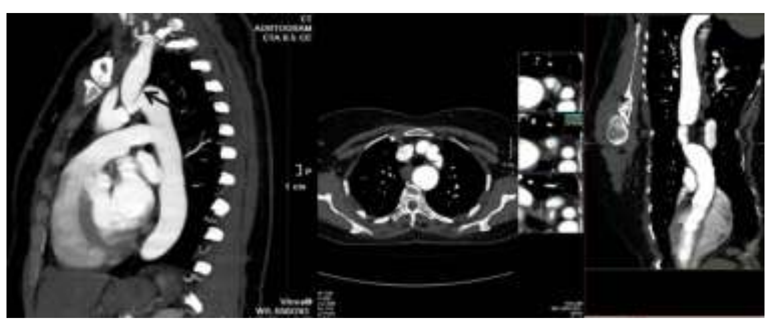


Figure 6: Tubular narrowing of aortic arch

Tubular narrowing of aortic arch in a 50 years old female. Sagittal MIP image showing narrowed aortic arch, involving the origin of left subclavian artery. Left subclavian artery is dilated, post-stenotic dilatation (arrow). Calcified focus seen in involved aortic segment as Coarctation segment has a predisposition for atherosclerosis. Axial and curved MPR images show tubular hypoplasia of aortic arch. By the use of curved multiplanar reformatting, the exact length of involved aorta can be assessed, which is not possible on axial image.

Figure 7: Pre-stenotic focal dilatation

3D-Surface rendered image of a 2 year old boy with Coarctation of aorta. Arrow shows prestenotic focal dilatation.

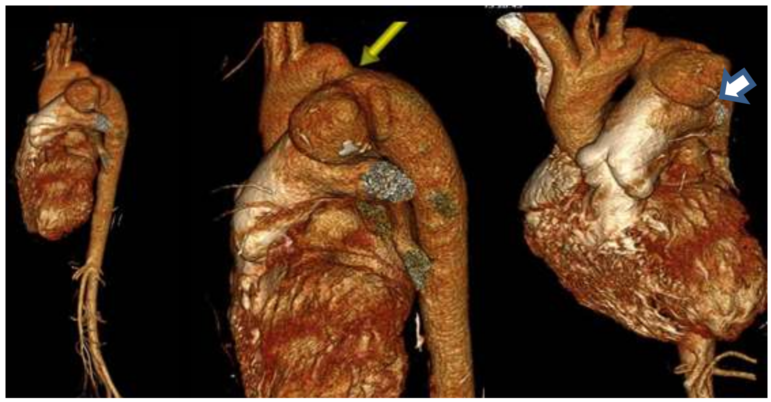


Figure 8: Patent ductus arteriosus (PDA) aneurysm in patient with Coarctation of Aorta.

Coarctation of aorta in 26 years old patient; big arrow shows focal Coarctation. There is patent ductus arteriosus (PDA) with a saccular aneurysm (small arrow).

DISCUSSION

Coarctation of the aorta is a relatively common abnormality that occurs in about 40 to 50 of every 100,000 live births, with a 2:1 ratio in males versus females.[9] About 98% of aortic Coarctations occur immediately beneath the origin of the left subclavian artery at the site of attachment of the ductus arteriosus (juxtaductal Coarctation).[10] During the past decade, CT angiography has become a principal examination for the evaluation of aortic anomalies.[11] CT can be used for accurate measurement of aortic diameter facilitating the diagnosis of abnormal dilatation and narrowing.[3]

When multiplanar and three dimensional post-processing techniques became available, the role of CT in the assessment of thoracic vascular anomalies changed. Recently 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.[11] CT angiography is a preferable modality of diagnosis for arterial disease as an alternative to conventional angiography.[12] MDCT has changed not only the imaging evaluation approach to thoracic aortic anomalies but also challenged the role of conventional angiography.[13] In addition to displaying vascular anatomy, thoracic CT angiograms provide information about both airway and lung parenchyma, which is important in patients who have thoracic vascular anomalies. Three dimensional images allow excellent display of vascular anomalies that can be used as vascular road map by surgeon.[12]

Preoperative CTA can accurately depict the location and degree of stenosis, extent of collateral vessel formation and severity of post-stenotic dilatation (Figures 3 & 4). The degree of aortic Coarctation can be extremely variable, ranging from minimal narrowing to essentially complete interruption (Figure 5).

Advantages of CT include near universal availability, the ability to image the entire aorta, including lumen, wall, and peri-aortic regions; to identify anatomic variants and branch vessel involvement.[9] Measurements of aortic diameter should be taken at reproducible anatomic landmarks, perpendicular to the axis of blood flow, and reported in a clear and consistent format, as provided by the 2010 guidelines of American Cardiology Foundation and Fellows.[9]

Unlike echocardiography, CT cannot be used to assess the hemodynamic significance of an area of aortic narrowing, and web like stenosis can be missed.[3] But, unfortunately in adults with CoA both transthoracic and transesophageal echocardiography (TEE) have a limited acoustic window, especially in their view of the aortic arch. Therefore, CT and MRI are the current preferred noninvasive methods for imaging the whole thoracic aorta in adults.[14]

MDCT has also gained increasing acceptance as an alternative to MRI in the screening of vascular anomalies. Compared with MR angiography, CT angiography has the advantage of the ability to acquire high spatial resolution in a shorter acquisition time that means a reduced need for sedation in infants and less intensive anesthetic management.[15] Cardiac CT angiography has showed an excellent spatial resolution and a good capability for finding associated anomalies. After correction of Coarctation of the aorta, serial cardiac magnetic resonance imaging can commonly be performed to avoid repeated radiation exposure.[16]

Coarctation of aorta is associated with other abnormalities like bicuspid aortic valve and berry aneurysms of cerebral circulation.[17] It is commonly associated with congenital and acquired cardiac lesions that may require surgical intervention.[18] It is important to recognize cardiac and vascular anomalies early for proper treatment and follow-up, and also to prevent morbidities and mortalities.[15] In our study, cardiac defects were seen in 10% cases.

Diagnostic sensitivities of Coarctation were 90% for axial and 100% for both Multiplanar and 3D volume-rendered images. Moreover, MDCT was able to clearly display the location and extent of the Coarctation. Focal defects were observed in 84% (n=25) cases, tubular narrowing in 6% (n=2) and complete interruption was seen in 10% (n=3) cases; 53% were females and 47% were males. Interrupted aorta was seen more in females (2 out of 3).

In this current study, the overall sensitivity of MDCT for the assessment of cardiac defects was lower than that of Doppler echocardiography. These results are in agreement with Hu et al.[5] in their study done in 2008 for assessment of Coarctation of the aorta in young children and also with Turkvatan et al[14] in their study done in 2009 for assessment of Coarctation of the aorta.

In axial CT slices, the course of complex vascular malformation such as Coarctation is not clearly displayed. MPR and reformatted and 3D volume-rendered images are useful in the evaluation of this condition because areas of Coarctation may be only a few millimeters long and difficult to appreciate on axial images owing to partial volume-averaging artifact.[3] On axial images, the appearances of aortic Coarctation are sometimes misleading ranging from a slice of non-visualization of descending aorta, beaking of a part of aorta to just narrowing of aortic segment, which can be under-diagnosed or missed. MPR clearly demarcates the exact site of aortic involvement. Previous studies have described the role of axial and three dimensional volume rendering in the diagnosis of mediastinal vascular anomalies.[11] Previous studies have also shown that three-dimensional (3D) reconstructions were useful in patients with suspected aortic Coarctation.[19] Becker et al have shown in their study that three-dimensional (3D) reconstructions were useful in patients with suspected aortic Coarctation.[19] This technique is also very useful for noninvasive postoperative follow up after surgical repair of Coarctation.[20] This current study compared the accuracy of axial CT, multiplanar reformats and 3D volume rendered images in the evaluation of Coarctation of the aorta in pediatric patients. The results of this study show that in the evaluation of Coarctation, Multiplanar and 3D volume rendered images performed slightly better than axial images (Figure 6). For the diagnosis of Coarctation, sensitivities were 90% for axial, 100% for Multiplanar and 100% for volume rendered images. Recently, a study concerning CT angiography and three-dimensional reconstruction in young children with CoA showed the diagnostic sensitivities of CoA were 87.5% for axial and 100% for multiplanar and three dimensional volume-rendered images.[5] In another study, the results were consistent with this former study,[4] which are almost similar to our results. Previous and these current studies reported that the MDCT angiography is a non-invasive, feasible technique for assessing aortic Coarctation.

The main disadvantage of MDCT is radiation exposure. Computed tomography protocols are associated with a known increase in the risk of future malignancy. Radiation exposure is important in the pediatric population because children are considered to be more sensitive to ionizing radiation than adults, and they have longer life expectancy. Although CT is performed with ionizing radiation, a variety of imaging parameters can be adjusted to minimize radiation exposure of children and maintain image quality.[3] 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 time, 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.[21-23]

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.

Nie et al. concluded that prospective ECG-gated Dual Source CT (DSCT) with a low radiation dose is a valuable technique in the diagnosis of Coarctation of the aorta in infants and children.[12] Gao et al. stated that prospective ECG-triggering DSCT angiography was associated with a significant lower effective radiation dose than retrospective protocol while maintaining image quality for diagnosis. Prospective ECG-triggering CT angiography can be used as a very important diagnostic tool in infants with complex congenital heart disease.[13]

Coarctation of the aorta is one of the more common congenital lesions that may be recognized for the first time in adulthood. Recurrent Coarctation of the aorta first treated in childhood is also commonly encountered in the adult age-group.[24] MDCT angiography is and should be the method of choice for preoperative assessment of Coarctation of the aorta in pediatric patients and young adults. It can easily identify the precise location and the degree of the Coarctation and its relationship with the branch vessels (Figures 6 & 7). The presence of associated aneurysm or dissection and origin and course of collateral vessels can also be depicted with MDCT (Figure 8). Because axial images may be insufficient for evaluation of short Coarctation, multi-planar and three dimensional images are needed in the assessment of Coarctation of the aorta (Figure 6).

CONCLUSIONS

CT Aortography with Multi-Planar Reformat and 3D Reconstruction represents a reliable noninvasive technique for the assessment of

Coarctation of the aorta. It serves as an essential informative noninvasive diagnostic tool before intervention and surgical treatment.

Acknowledgements

We would like to thank Mr. Arshad Ali and Mr. Junaid Gul for their typing skills and technical help in data compilation.

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Corresponding Author

Dr Ummara Siddique Umer, Assistant Professor, Department of Radiology, Rehman Medical Institute Teaching Hospital, Peshawar, Khyber Pakhtunkhwa, Pakistan.

Email: ummara_81@hotmail.com

Submitted for Publication: March 10, 2016.

The authors have no conflict of interest. All authors contributed substantially to the planning of research, questionnaire design, data collection, data analysis and write-up of the article. The authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

This article may be cited as:

Umer US, Alam S, Gul S, Ghaus SG. Multidetector CT Aortography in preoperative evaluation of Coarctation of aorta using Multiplanar Reformat and 3d Reconstruction. J Rehman Med Inst. 2016 Jan-Mar;2(1):5-14.