Validity of MSCT angiography in guiding selection of the appropriate treatment modality in patients with coarctation of the thoracic aorta

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Received 23 February 2015; accepted 6 April 2015
Available online 18 April 2015

Abstract  Aim: To detect the value of MDCT for selection of the appropriate treatment modality in patients with native coarctation (CoA).
Methods: Between January 2013 and December 2014, 25 patients (15 males and 10 females) with a mean age of 15 years (1 month–45 years) were referred for management of echocardiographically documented isolated native CoA. MDCT scans of the heart and aorta were obtained in all patients using a 16-row CT scanner. The choice of definitive management strategy, whether catheter-based or surgical, was decided based on aortic anatomy and CoA morphology depicted in the MDCT images.
Results: Four of the 25 patients included in the study were deemed unsuitable for catheter-based intervention based on the MDCT images. Of the four patients, one had dense annular calcification of the proximal descending aorta, two had aneurysms of the ascending or descending aorta related to the CoA site and the fourth had a hypoplastic aortic arch. Findings were confirmed at surgery. Surgeries were successful and uncomplicated. Balloon angioplasty with/without stent placement was performed in the remaining 21 patients. In this group, the peak systolic gradient decreased from a mean of 77 mmHg to a mean of 7 mmHg and the CoA site diameter increased from a mean of 2.4 mm to a mean of 13 mm. There were no complications.
Conclusion: MDCT readily delineates aortic and CoA site anatomic and morphologic features that may negate catheter-based intervention in favor of surgical repair. This may help avoid complications and enhance successful and safe management of patients with native CoA.

KEYWORDS
CT; Coarctation; Angiography; Aorta; Treatment

1. Introduction

Coarctation of the aorta (CoA) refers to narrowing of a segment of the aorta, most commonly juxta-ductal, with consequent obstruction to blood flow. It accounts for approximately 5–8% of all congenital heart diseases and entails significant
Treatment modalities of CoA include either catheter-based balloon dilation with/without stent placement (angioplasty) or surgical correction (2). The choice of treatment crucially relies on certain anatomical and hemodynamic parameters related to the coarctation, the presence or absence of associated cardiac defects as well as factors related to the patient such as age and weight. Of particular importance are the morphology of the coarctation segment and the anatomy of the ascending, arch and descending aorta. Generally, patients with long segment coarctation, those with hypoplastic aortic arch and those with diseased aortic walls are not suitable for catheter-based intervention and are thus referred for surgical repair (3–9). Conversely, patients with discrete coarctation and good size of the proximal aorta are amenable to catheter-based dilatation and stenting. Delineation of the anatomy and hemodynamics is thus of utmost importance in deciding the optimal modality of treatment in patients with CoA (7).

Although cardiac catheterization and angiography remain the gold standard in the evaluation of CoA and can provide almost all the necessary information required for planning definitive treatment, it carries the drawback of being an invasive procedure as well as the incapability to provide information on aortic wall calcification (10). For this reason imaging modalities such as echocardiography, magnetic resonance angiography (MRA) and multislice computed tomography (MDCT) are increasingly employed as non-invasive alternatives. However, two-dimensional (2D) transthoracic echocardiography (TTE) is frequently limited in adults and occasionally in children by unfavorable acoustic windows. Although transesophageal echocardiography (TEE) can visualize the ascending and descending aorta and can adequately visualize the arch, it can overestimate the coarctation diameter and is not technically easy in infants (11). Furthermore, the sensitivity of both TTE and TEE in the detection of aortic wall disease including calcification and dissection hampered by inability to visualize the entire aortic wall owing to acoustic window limitations encountered with either technique (11). MRA is theoretically an ideal tool for the assessment of CoA as it can provide high quality images of the entire thoracic aorta as well as flow velocities and hence pressure gradients across the CoA segment (11). However, the relatively limited availability and expertise in this imaging modality in congenital heart disease practically restrict its use to a few centers worldwide (12). MSCT imaging offers an alternative to MRA with comparable or even better image resolution, faster image acquisition and greater availability (12). Drawbacks of this imaging modality are exposure to ionizing radiation, requirement of contrast agent injection and inability to provide hemodynamic information such as velocities and gradients across the narrowed aortic segment. Nonetheless, because of aforementioned advantages MDCT is now an established imaging modality for the diagnosis and follow-up of CoA, no studies have utilized this technique for selection of the optimal treatment modality in patients with CoA.

1.1. Aim of the work

The specific question addressed in this study is whether MSCT can be used as a non-invasive imaging modality to guide selection of the appropriate treatment modality in patients with native CoA.

2. Material and methods

2.1. Study population

Between January 2013 and December 2014, 25 consecutive patients with isolated native CoA confirmed by 2D and Doppler echocardiography were included in this study. Fifteen patients were males and ten were females. Their mean age was 15 years (1 month–45 years). Initial diagnosis of CoA was clinical based on the finding of weak femoral pulses and radio-femoral delay in patients with systemic arterial hypertension or congestive heart failure.

2.2. MDCT imaging

Consent for imaging was obtained from all patients or their legal guardians. Children who were not able to hold their breath for the duration of the MDCT examination were sedated with 50–75 mg/kg chloral hydrate administered orally or rectally before the scan.

All examinations were performed using a 16-row CT scanner (Sensation CT scanner, Siemens Medical Systems, Germany). Data were obtained using a weight-based low-dose CT protocol (120 kVp, 30–80 mA) with a rotation time of 0.5 s and a table speed of 13.5 mm and 16 × 0.75 mm collimation. Scanning was performed from the thoracic inlet level to the L1–2 level proceeding in the caudocranial direction to decrease contrast agent–related artifacts and to achieve homogeneous contrast enhancement. Nonionic contrast agent (2 ml/kg with a maximum of 100 ml of Ultravist 300, Schering, Germany) injected by automatic pump (Mallinckrodt, optivantage DH, USA) into peripheral veins in the hand. The injection rate was adjusted to achieve adequate vessel opacification throughout the scan period and ranged from 2 to 4 ml/s. The scan delay was determined on a patient-to-patient basis after test injections of small amount of contrast media using an automatic bolus tracking system after placing a single region of interest in the root of the ascending aorta and a threshold level of 70HU was set for starting the scan. Electrocardiography- and respiration-gated techniques were not used.

Following acquisition of axial slices, various reformatting techniques including curved planar, maximum intensity projection and volume rendering were employed for image reconstruction performed on a workstation (Syngo software, Siemens, Germany). Reconstruction was done using a slice thickness of 1 mm and reconstruction increment of 0.7 mm. Planes of the reconstructed images were adjusted to correspond to the long axis of the descending aorta. Thin-section multiplanar reformatting was used to accurately measure the diameter or area of the structure in question. Data derived from the MDCT scans included length of the coarctation segment, its narrowest diameter, relation of the stenosed segment to the origin of the left subclavian artery, the size of the transverse arch of the aorta and the presence or absence of aortic wall abnormalities such as dissection and calcification.

2.3. Angioplasty

The femoral approach was employed in all procedures and was combined with the radial approach in two cases due to inability to cross the area of aortic narrowing retrograde. Pre-
post-procedure systolic gradients were recorded by catheter pull-back down the arch and descending aorta. Contrast injections in the aortic arch before and after the procedure were performed to facilitate measurement of the CoA segment diameters.

3. Results

3.1. Imaging

MDCT imaging was performed in all patients prior to definitive treatment to confirm the diagnosis and to delineate the aortic anatomy and the morphologic features of the coarctation segment. The MDCT-derived mean length of the CoA segment was 21 mm (10–40 mm) and the mean narrowest diameter was 2.6 mm (1–4 mm). The mean aortic arch diameter was 12.9 mm (11–15 mm). Dense annular calcification involving the distal part of the aortic arch proximal to the CoA segment was identified in one patient (Fig. 1A and B) and aneurysmal dilatation of parts of segments of the aorta was present in two other patients (involving the ascending aorta and proximal arch in one patient (Fig. 1C and D) and the descending aorta just distal to the CoA site in another patient (Fig. 1E). Hypoplastic aortic arch was detected in one patient (Fig. 1F).

3.2. Angioplasty

Catheter-based intervention was deemed the appropriate procedure for the treatment of the CoA in 21 of the 25 patients included in the study. The decision was based on the anatomic and morphologic features of the aorta depicted by MSCT imaging. Relief of the aortic obstruction was achievable by balloon dilation only in four patients, all of whom were younger than one year. In the remaining 17 patients stent placement was performed without predilatation. All procedures were uncomplicated. Theystolicic diameter across the CoA segment was reduced from a mean of 77 mmHg pre-procedure to a mean of 7 mmHg post-procedure. The narrowest aortic diameter at the site of the CoA as measured during the angioplasty procedure was increased from a mean of 2.4 mm (0.8–4.3 mm) to a mean of 13 mm (9–17 mm). One patient underwent stent re-dilatation 12 months after the initial procedure due to residual mild hypertension.

3.3. Surgery

Four patients were referred for surgical repair of the CoA. Indications for referral were circumferential calcification of the descending aorta proximal to the CoA (one patient), aneurysmal dilatation of the aorta (two patients) and hypoplastic arch of the aorta (one patient). All four patients had successful repair of the CoA with no residual gradient across the repair site as estimated by echocardiography postoperatively. Intra-operative direct visualization of the affected aortic segments confirmed the pre-operative findings in the MSCT images in all four patients. There were no peri-operative complications.

4. Discussion

Balloon angioplasty with or without stenting for native CoA generally carries low procedural risk and good early and intermediate-term results (13,14). However, the presence of certain features such as extensive calcification, long CoA segment, aortic hypoplasia, aneurysm or dissection is associated with high failure rates and/or suboptimal long term results (15). It is therefore important to identify patients with any of these features in whom surgical repair is considered as the better treatment modality.

In this study we evaluate the utilization of MSCT imaging in therapeutic decision-making for native CoA. Using MSCT imaging, patients with native CoA were screened for angioplasty high-risk features that warrant surgical rather than catheter-based repair. Four patients with such features were correctly identified among the 25 patients included in the study. These patients were referred to and underwent successful and uncomplicated surgical repair. In the remaining 21 patients, successful angioplasty was achieved using balloon dilation with or without stent placement. The decision of therapeutic angioplasty was based on the favorable aortic anatomy and lesion morphology evident in MSCT images. The consistent high quality images and short scan times using a 16-slice MSCT machine indicate the applicability of this imaging modality even in infants who inherently have rapid heart and respiratory rates. The lack of procedure-related complications emphasizes the validity of this imaging technique as a selection tool for the appropriate management strategy in patients with native CoA. This is further corroborated by the successful and complication-free surgical repair of the CoA in patients deemed unsuitable for angioplasty based on unfavorable aortic anatomy and/or CoA morphology depicted by MSCT imaging.

Although previous reports have highlighted the usefulness of MSCT in the setting of CoA, emphasis has always been on diagnosis per se or on post-intervention and post-operative follow-up (12,16–19). Based on our results, we propose an additional role for MSCT in the workup of native CoA wherein this imaging modality serves as a guide for the selection of the optimal treatment strategy.

In our study we utilized various MSCT post-processing reconstruction techniques to analyze the coarctation of the aorta. The axial images were limited in detailed assessment of tortuosity and abnormal kinking of the curved vascular structures however the multiplanar and 3D volume rendering techniques were more valuable and visually appealing on this manner. This was in agreement with the study performed by Ahmed and Moussa in 2011 (20), which stated that in the evaluation of coarctation, multiplanar and 3D volume rendered images performed slightly better than axial images.

Finally, the employment MSCT in the evaluation of native CoA maybe particularly worthwhile in patients planned to undergo stenting of the CoA segment. This is rationalized by the recommendation by Hager et al. that the imaging modality employed pre- and post-intervention should be the same in order to avoid erroneous gain or loss of aortic diameter related to the use of different techniques (18). In the presence of stents, MSCT, unlike MRI, yields artifact-free images of the stented aortic segment and is therefore ideally suited for follow-up of these patients (19).

5. Conclusion

Our results show that MSCT imaging is a valuable and reliable tool for selection of the appropriate treatment modality in patients with native CoA. Procedural complications can be
avoided and hence outcome can be improved by proper selection of patients based on anatomic and morphologic assessment of the aorta and CoA segment using MSCT imaging.

Conflict of interest

The authors declare that there are no conflict of interests.

Fig. 1  Multidetector computed tomography (MDCT) scans of four of the patients with native coarctation of the aorta (CoA) and high-risk angioplasty features. (A and B) Transaxial and sagittal reformatted images demonstrating circumferential calcification (red arrowheads) of the distal segment of the aortic arch. (C and D) Transaxial and sagittal reformatted images of another patient showing marked dilatation of the ascending aorta and proximal part of the aortic arch (green arrows) above the CoA site (red arrowhead). (E) Sagittal reformatted image of a patient with aneurismal dilation of the descending aorta (green arrow) immediately distal to the CoA site (red arrowhead). (F) Three dimensional volume rendering reconstruction of MDCT images showing hypoplasia of the aortic arch (green arrow) proximal to the CoA segment (red arrowhead).
References