Rapid method for intraoperative assessment of aortic coarctation using three-dimensional echocardiography

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Aims The availability of three-dimensional (3D) echography with its multiplanar review analysis software on board now allows detailed examination in assessing morphological details. We evaluated the feasibility of 3D echography in assessing intraoperative morphological details of aortic coarctation (CoA) and its repair.

Methods and results Nine consecutive children scheduled for surgery of CoA were intraoperatively evaluated. Intraoperative 3D data sets were taken and analysed online before resection of the coarctation, showing the cross-sectional area (CSA) of the proximal aorta, coarctation, and the distal descending aorta. After resection of the coarctation and extended end-to-end anastomosis, a 3D data set was recorded to analyse the CSA of the anastomosis. In nine out of nine consecutive procedures, intraoperative 3D echography permitted comprehensive viewing and measuring of CoA and its repair. In three out of nine surgical procedures, intraoperative 3D echography provided additional information to support surgical decision-making.

Conclusion Intraoperative 3D echography is a feasible non-invasive imaging modality for intraoperative assessment of CoA and its repair, which provides useful additional information.

KEYWORDS
Intraoperative; 3D echography; Aortic coarctation

Introduction
Several recent studies have shown that CoA should be considered as a complex cardiovascular syndrome rather than an isolated narrowing at the aortic isthmus.1–3 In their long-term assessment of 404 patients with CoA after surgical repair, Hager et al.2 showed that repair of the CoA should not only consist of removal of the stenosis properly but also of preservation of the compliance of the aorta by end-to-end anastomosis as first choice of reconstruction4 and secondly even residual gradients of 20 mmHg or less should be treated as they significantly contribute to hypertension. The actual recommendation in the European Society of Cardiology guidelines for removal of restenosis is, however, a residual systolic blood pressure (BP) gradient at the coarctation site of >30 mmHg.5

There is controversy about the accurate assessment of the hemodynamic significance of blood flow obstruction caused by restenosis after CoA repair.6 It has been shown that after CoA repair, the arm–leg BP difference may not represent the haemodynamic significance of restenosis. At one end of the spectrum, the arm–leg BP difference may be increased by residual changes in the sympathetic regulation of BP after CoA repair.7 This may create a BP gradient in the absence of restenosis. At the other end of the spectrum, the arm–leg BP difference may be decreased by collateral circulation.5 This may eliminate a BP gradient in the presence of restenosis.6

Till today, a brachial-ankle BP difference of >20 mmHg2 or 30 mmHg5 is the only intraoperative indication for residual stenosis. No feasible intraoperative visualization of a possible residual stenosis of the aorta exits, but an exact assessment of the aortic anatomy is required for an optimal surgical repair.8

The availability of three-dimensional (3D) echography allows an intraoperative comprehensive analysis of datasets in infinite planes and detailed examination of anatomy (Figure 1).9,10 In this report, we evaluated the feasibility of 3D echography in assessing intraoperative morphological details of aorta coarctation (CoA) and its repair.

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Methods

Nine consecutive children scheduled for resection of CoA and reconstruction with extended end-to-end anastomosis were intraoperatively evaluated. Before induction of anaesthesia, all patients were monitored with right brachial non-invasive BP (NIBP) measurement. After the insertion of a peripheral venous line, general anaesthesia was induced with midazolam 0.2 mg/kg, sufentanil 2 μg/kg, and pancuronium 0.15 mg/kg. Patients were nasotracheally intubated and pressure controlled ventilated. Anaesthesia was maintained with midazolam 0.1 mg/kg/h and sufentanil 1 μg/kg/h. Invasive monitoring was applied via a 20G arterial line in the femoral artery and a Foley bladder catheter.

After performing a left thoracotomy and gently holding the lung aside, the left thorax was filled with warm saline. The x7-2 matrix-array transducer (Philips, Andover, MA, USA) was placed into a sterile Latex-free transducer probe cover and then placed into the warm saline to obtain the optimal image of the aorta isthmus. An intrathoracic 3D echography of the CoA was performed with the transducer connected to an IE33 ultrasound system (Philips).

The biplane mode ensured that our transducer position was optimal. A full-volume data set made up of seven sub-volumes was acquired during a 10 s mechanical ventilation hold to avoid motion artefacts during acquisition. Images are analysed on the online workstation Philips Qlab 3D quantification (Philips).

Intraoperative 3D data sets before resection of the CoA were analysed with regard to the cross-sectional area (CSA) of the distal transverse aortic arch, CoA, and the descending aorta. After reconstruction of the aorta, an analysis was made of the CSA of the end-to-end anastomosis.

Statistical analysis

Descriptive statistics were performed with Graphpad 4.0 software package (Graphpad software Inc., San Diego, USA).

Results

Nine consecutive infants scheduled for surgical CoA repair were evaluated. Patient’s characteristics are reported in Table 1. In all patients, 3D echographic data sets were taken and analysed intraoperatively before and after surgical repair. None of the patients were excluded. In three out of the nine surgical procedures, 3D echography provided additional information to support decision-making.

In one patient with a coarctation CSA of 0.1 cm² (Figure 2) and a brachial-ankle BP difference of 35 mmHg, a post-correction anastomosis CSA of 0.05 cm² and the brachial-ankle BP difference of only 30 mmHg were found in relation to a thrombus in the descending aorta. After thrombectomy and additional resection of 1.5 mm, both proximally and distally the anastomosis CSA was 0.16 cm² and brachial-ankle BP difference was 19 mmHg.

In a second patient, the brachial-ankle systolic BP difference was 60 mmHg after end-to-end anastomosis, which was confirmed by a 3D echo-CSA measurement of the anastomosis of 0.07 cm². After re-anastomosis, the CSA was 0.18 cm² and brachial-ankle pressure gradient (PG) was 15 mmHg.

In a third patient with a pre-operative brachial-ankle systolic PG of 70 mmHg, an invasive arterial line was placed in the right femoral artery (no pulsations, good oxygenated blood aspiration) after induction of general anaesthesia. Indeed, the brachial NIBP was 92/45 mmHg and invasive femoral artery systolic BP was 20 mmHg. Because of easy aspiration of oxygenated blood, we assumed a correct positioning of the femoral artery line. After resection of the coarctation (CSA 0.05 cm²) and extended end-to-end anastomosis, femoral arterial BP was still pulse less and 20 mmHg, but 3D echography showed an adequate anastomosis with a CSA of 0.44 cm². Relying on the 3D echographic measurements, surgery was completed. After surgery, the femoral artery pulsations were good (right leg NIBP = 96/48 mmHg) and the femoral artery line was removed.

Descriptive statistics of CSA of CoA, proximal aorta, anastomosis, and the distal aorta are shown in Figure 3.

Discussion

Multiplanar review (MPR) analysis of 3D data sets is a sensitive and accurate mode for delineation of morphological details, providing additional information to 2D echography. The MPR mode allows the operator to view the moving 3D data set in three orthogonal planes simultaneously and to review the image in infinite planes by moving each of the three planes through the data set. Each plane is referenced in each of the other two planes being simultaneously viewed, allowing anatomical structures to be examined in their entirety in 3D. This has an advantage over 2D echocardiography, in that the anatomical structure is not examined in fixed single planes, with detail missing between the planes viewed, but can be examined completely by moving each plane gradually throughout the data set. Acquiring and analysing a 3D data set in the MPR mode took no more than 2 min. Position and CSA of CoA and its repair were clearly visualized and measured by MPR in all nine patients.

Till today, the difference in systolic pressure between arm and ankle has been widely used clinically to predict the central aortic pressure difference, with an intraoperative brachial-ankle BP difference >20² or 30 mmHg² giving an
indication of residual stenosis. However, realizing that the pressure difference across a constriction is related to flow accuracy of this test has been debated, because aortic blood flow depends on cardiac output. Evaluations of CoA repair should preferably contain not only hemodynamic but also anatomical information to achieve the highest possible diagnostic accuracy, given a re-intervention rate of up to 16.6%. In our series, in nine out of nine surgical procedures, intraoperative 3D echography permitted comprehensive viewing and measuring of CoA and its repair, and in three out of nine surgical procedures, intraoperative 3D echography provided additional information to support intraoperative decision-making.

**Conclusion**

Intraoperative 3D echography permitted comprehensive 3D viewing and measuring of CoA, aorta arch, anastomosis, and descending aorta, revealing their exact CSA. In our opinion, 3D echography is a feasible and non-invasive imaging modality for intraoperative assessment of coarctation repair, providing useful additional information to support intraoperative decision-making. Further investigation for defining the exact clinical value of 3D echography during CoA repair is mandatory.

**Conflict of interest:** none declared.

**References**

