Improved cardiovascular planning strategies in patients with congenital heart disease

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Purpose:

Planning of cardiovascular magnetic resonance imaging (MRI) exams in patients with congenital heart disease (CHD) is complex and time consuming due to small cardiac and vascular structures in atypical locations. Therefore we propose a new planning tool for accurate and time efficient planning in this group of patients.

Methods and Materials:
In 14 children with complex CHD (Table 1) MRI was performed on a 1.5T scanner (Philips Healthcare, Best, The Netherlands). Patients were anesthetized according to our institutional protocol. Double oblique long axis cuts of selected anatomic regions (Table 2) were performed using two methods. In method 1, 2D axial (fig. 1 A) and coronal (fig. 1 B) planes were acquired with single slice black blood (BB) sequences to plan the final double oblique plane (e.g. the left pulmonary artery, fig. 1 C). Method 2 used a 3D contrast enhanced angiography dataset and a newly developed planning tool to produce similar multiplanar reformatted images (MPR) compared to method 1. This was done offline on a separate workstation (ViewForum, Philips Healthcare). This tool (Fig. 2) consists of three viewports for interactive reformatting to determine certain scan planes. The orientation of the active viewport is shown as cross section lines in the other viewports. Once a certain scan-plane has been determined (e.g. pulmonary artery) this orientation was used for subsequent planning. The reformatted images were sent to the scanner, and their spatial orientation parameters were used to acquire the final single slice black blood (BB) image (fig. 2). Planning results were compared by showing the distances and angles between the planes of the final BB images obtained with method 1 and 2.

Table 1. Baseline patient and surgical characteristics. (Median±STD and ranges)

Age (years)	2.6±2.8 (0.2±7.6)	
Weight (kg)	11.8 ± 6.6 (4.9±23.6)	
Height (cm)	88±22 (56±121)	
Patients (n=14)	Diagnosis	Previous intervention
2	Coarctation of the aorta	Balloon angioplasty
1	Double aortic arch	Surgical division anterior patch
1	TOF	RVOT patch
2	PA, VSD	BT shunt
1	PA with IVS	PDA stent
1	DORV	BTS
1	TA, ccTGA	BTS
1	HLHS	Central shunt
1	HLHS	Norwood-I
2	HLHS	Norwood-II
1	HLHS	Norwood-III

BTS, Blalock-Taussig shunt; ccTGA, congenitally corrected transposition of the great arteries; DORV, double outlet right ventricle; IVS, intact ventricular septum; PA, pulmonary atresia; PDA, persistent ductus arteriosus; RV, right ventricle; TA, tricuspid atresia; VSD, ventricular septal defect.

Table 2.

Planes (n=31)	Total
Left Pulmonary Artery	11
Right Pulmonary Artery	12
Aortic Arch	3
Left Ventricular Outflow Tract	4
Four chamber view	1
Differences between planning tools	Median±STD
Distance of planes (mm)	1.8±2.0
Differences in angulations (degrees)	
Axial	1.3±6.3
Coronal	-2.6±7.9
Sagittal	0.7±6.5

Results:
The results show that similar spatial positions were found for the planes produced using the two methods (Table 2). In addition both sets of images were visually examined by two experienced cardiologists, and were determined to be of similar quality and fulfilled the clinical requirements. The mean time for reformatting the pulmonary arteries was 72±21 seconds (inter observer variability using a t-test r=0.98) using method 2 and 240 seconds for method 1. Additional scanner time was saved by method 2 as reformatting was carried out offline, enabling planning of other sequences on the scanner console.

Conclusion: The method presented here for planning MRI for visualization of small vascular structures in children with CHD allows accurate planning in a much shorter time than conventional planning (method 1). In the future one high resolution 3D dataset (3D steady-state-free precession and/ or 3D contrast enhanced angiography) may be acquired by a technician and relevant double oblique 2D images of BB, cine and flow imaging can be planned off-line by an experienced pediatric cardiologist/ radiologist who does not need to be in the scanner room. In addition several studies could be run in parallel and 2D cuts for imaging of complex cardiovascular structures in patients with complex CHD could be planned by teleradiology.

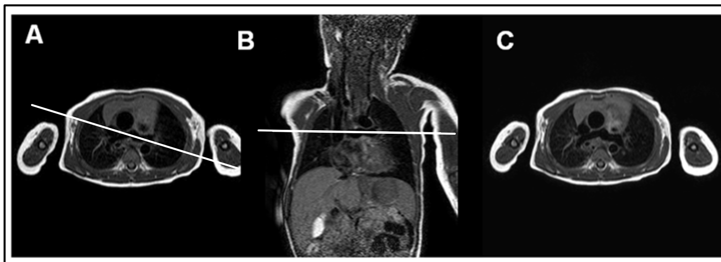

Fig 1: Conventional planning: Method 1. Planes A and B acquired using traditional black blood imaging are used to construct long axis vessel plane C.

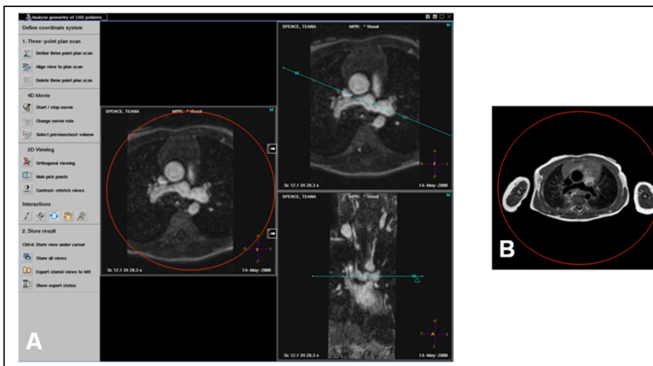

Fig 2: Proposed planning: Method 2 is based on 3D contrast enhanced angiography. Reformatted planes are constructed offline using a new planning tool (A) on a separate workstation (View Forum, Philips Healthcare) and used to construct long axis vessel plane B.