Journal of Cardiovascular Magnetic Resonance

Poster presentation

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Assesment of cardiac volumes in children with congenital heart disease using a 3D dual cardiac phase technique and a new segmentation tool

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from 13th Annual SCMR Scientific Sessions
Phoenix, AZ, USA. 21-24 January 2010

Published: 21 January 2010

Journal of Cardiovascular Magnetic Resonance 2010, **12**(Suppl 1):P2 doi:10.1186/1532-429X-12-S1-P2

This abstract is available from: http://jcmr-online.com/content/12/S1/P2

Introduction

For children with complex congenital heart disease (CHD), the decision regarding univentricular or biventricular surgical repair may depend on accurate ventricular volume assessment. We have previously shown that three-dimensional (3d) whole-heart imaging acquired during end-systole and end-diastole (dual-phase) during one free-breathing MRI examination, when combined with semi-automatic analysis, may be more reproducible in calculating ventricular volumes than standard techniques (Uribe et al, 2008). We describe here, for the first time, use of 3d dual-phase imaging in children with complex CHD.

Purpose

To show 3d dual-phase imaging is feasible in children with complex CHD despite high heart rates.

Methods

The dual-phase sequence was used alongside standard 2d multi-slice cine in ten children with complex CHD (table 1). Analysis required a new semi-automatic segmentation tool which incorporates multiplanar reformatting and volume rendering to identify ventricular boundaries (ViewForum, Philips Healthcare, Figure 1). Two observers independently assessed end-diastolic and end-systolic ventricular volumes using both standard 2d cine with manual segmentation and new 3d dual-phase with semi-automatic segmentation. If applicable, stroke volumes obtained were compared to phase contrast results. Bland-Altman was used to assess agreement and Pearson's coefficient for correlation.

Results

The mean age was 3 yrs (range 3 months-9 yrs) and heart rate range was 58-139 bpm. Volumetric analysis was feasible in all cases. Inter- and Intra-observer variability was similar for both methods. For 2d cine, acquired resolution was 1.8 mm × 1.8 mm; slice thickness 5 to 6 mm & temporal resolution 30 ms (20-40 phases). For 3d dual-phase, acquired resolution was 1.3 mm isotropic & temporal resolution 60 ms (2 phases). Bland-Altman (Figure 2A (systole), 2B (diastole)) showed excellent agreement between standard 2d cine and 3d dual-phase analyses (also, correlation 0.96(systole) and 0.93(diastole)). Similarly, Bland Altman for phase contrast stroke volume showed slightly better agreement with 3d dual-phase (Figure 2C) than with standard 2d cine (Figure 2D) (correlation 0.90 and 0.88 respectively).

Table 1: Patient diagnoses

Diagnosis	Which Ventricle Segmented	Number of Patients with given diagnosis
Repaired Pulmonary Atresia, VSD, Major Aorto-Pulmonary Collaterals with severely dilated RV	RV	2
Hypoplastic Left Heart Syndrome; Status Post Glenn Procedure	RV	1
Hypoplastic Left Heart Syndrome; Status Post Norwood Procedure	RV	1
Left Atrial Isomerism, Univentricular AV connection, Solitary RV, Aortic Atresia, Dextrocardia, Azygous continuation. Status Post Norwood	RV	1
Transposition of Great Arteries, VSD, Pulmonary Stenosis, Dextrocardia, Status Post Rastelli Procedure	RV	1
Situs Solitus, AV concordance, VA disconcordance, Dextrocardia, Unbalanced AVSD with Rudimentary Left Ventricle, Status Post Glenn	RV	1
Situs Solitus, AV concordance, Pulmonary Atresia with Aorta from RV, Unbalanced AVSD with Rudimentary Left Ventricle, Status Post Modified Blalock-Thomas-Taussig shunt	RV	1
Unrepaired Tetralogy of Fallot, with Major Aorto-Pulmonary Collaterals.	RV	1
Double Inlet Left Ventricle, Pulmonary Atresia, Status Post Glenn Procedure	LV	1

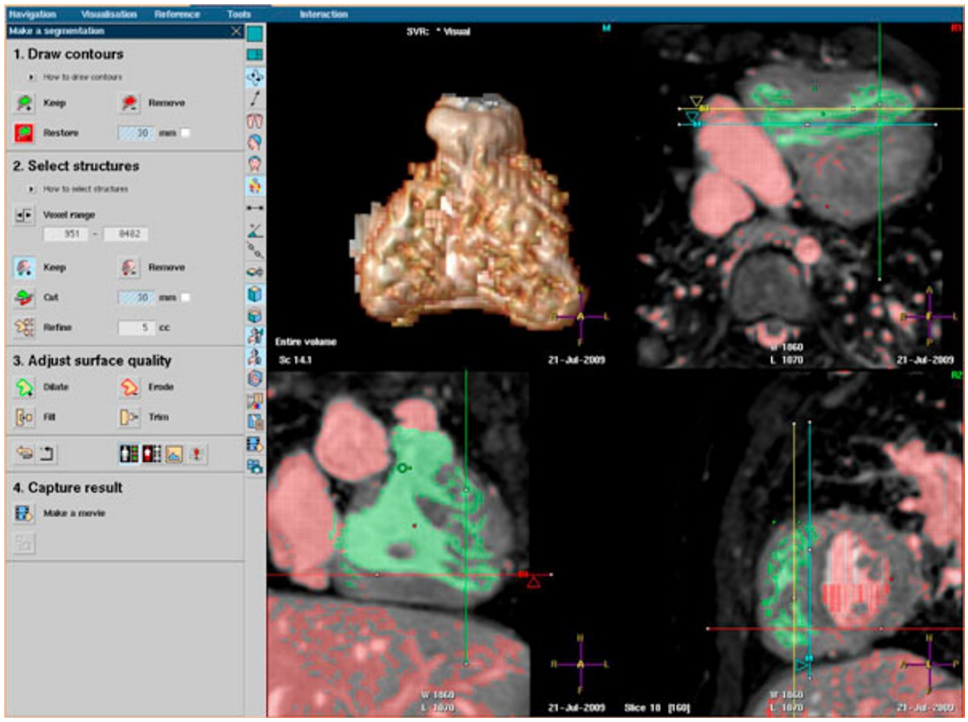

Figure 1

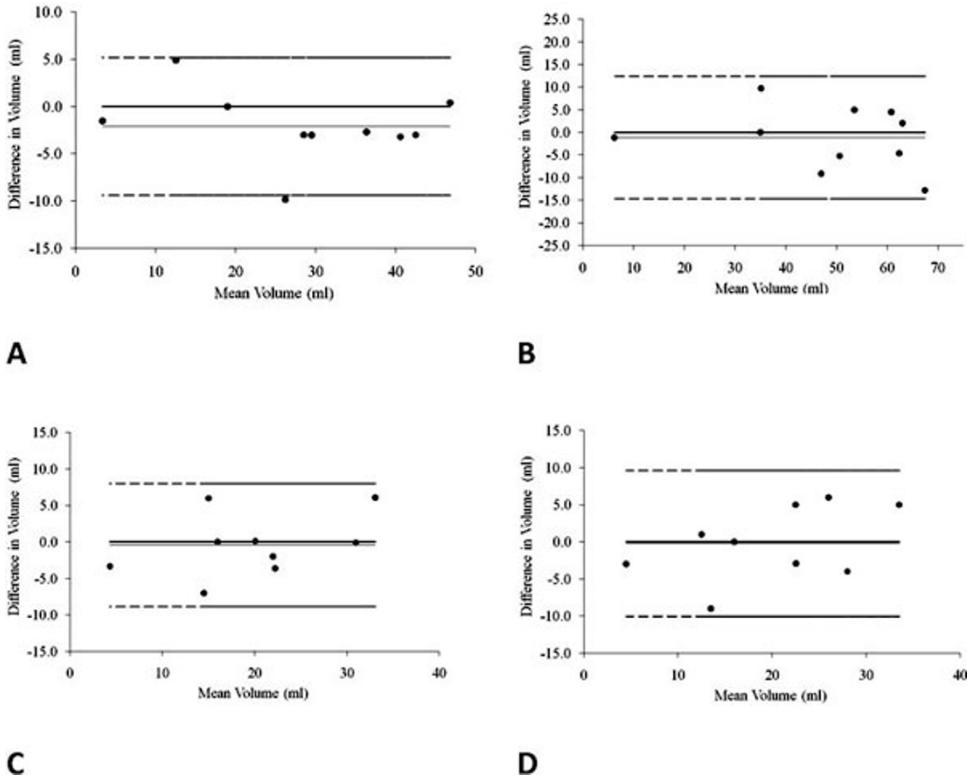

Figure 2

Conclusion

Standard ventricular analysis involves manual segmentation of cross-sectional cine images acquired over several breath-holds. This can have problems with slice misalignment. Furthermore, lack of isotropic resolution (by using thick slices which move during the cardiac cycle) makes definition of atrio-ventricular & ventriculo-arterial boundaries difficult. Therefore, acquisition and segmentation relies on operator experience. We believe that 3d dual-phase imaging with semi-automatic analysis overcomes these issues. This study demonstrates that 3d dual-phase imaging can successfully be performed even in very young children with complex CHD. Reliable and valid volumetric analysis was possible using the new semi-automatic segmentation technique.