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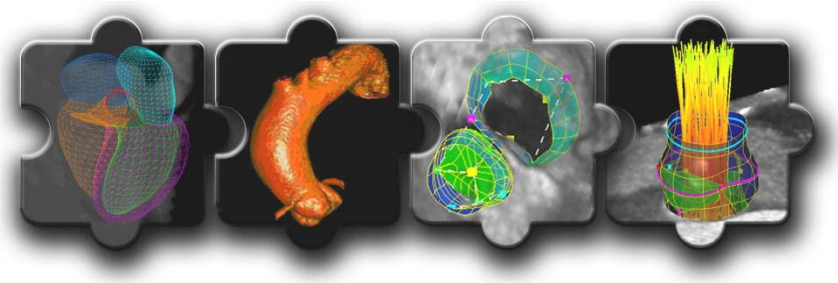

Collaboration Project

Thematic Priority: ICT

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Health-e-Child Heart Models Clinical Validation Report

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Sim-e-Child Consortium

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Table of Contents

1. Introduction

The Sim-e-Child project proposes to develop a grid-enabled platform for large-scale simulations in paediatric cardiology, providing a collaborative environment for constructing and validating multi-scale and personalized models of a growing heart and vessels. The objective of the Sim-e-Child is to strengthen the impact of the Health-e-Child project by creating an international simulation and validation environment for paediatric cardiology, supported by integrated data repositories. The project will advance the state-of-the-art by providing comprehensive and patient specific models for the dynamic and longitudinal interactions occurring in the left heart, with a focus on the congenital aortic arch disease and repair.

1.1. Purpose of the Document

The purpose of this document is to report on the clinical validation of the Health-e-Child heart models. The validation focuses on left ventricle (LV) and right ventricle (RV) models estimated from MRI images from patients affected by congenital heart disease. The results reported within this document will be submitted in form of a clinical paper to be presented at the **45th Annual Meeting of the Association of European Paediatric Cardiology, Granada, Spain 18-21 MAY, 2010.**

1.2. Scope of the Document

This document defines the objectives of the clinical validation in Section 2 and presents the applied methods in Section 3. Results are presented for the LV and RV models in Section 4. The conclusion of the clinical validation is provided in Section 5.

1.3. Abbreviations

AUTO	Fully Automated Tracing
B&A	Bland Altman
EDV	End Diastolic Volume
EF	Ejection Fraction
ESV	End Systolic Volume
HeC	Health-e-Child
LBA	Learning-Based Algorithm
LV	Left Ventricle
LVV	Left Ventricular Volume
MRI	Magnetic Resonance Imaging
MSL	Marginal Space Learning
M-TRACE	Manual Tracing
R-AUTO	Refinement of Automated Tracing
RV	Right Ventricle
RVV	Right Ventricular Volume
SeC	Sim-e-Child
TOF	Tetralogy of Fallot

2. Objectives

Quantification of right and left ventricular volume (RVV and LVV) and ejection fraction (RV EF and LV EF) in patients with complex congenital heart disease is essential and currently requires manual time consuming endocardial tracing. We compare the accuracy and post processing time of a novel automated learning-based algorithm (LBA) with current methods. Estimated models of LV and RV are illustrated in Figure 2-1.

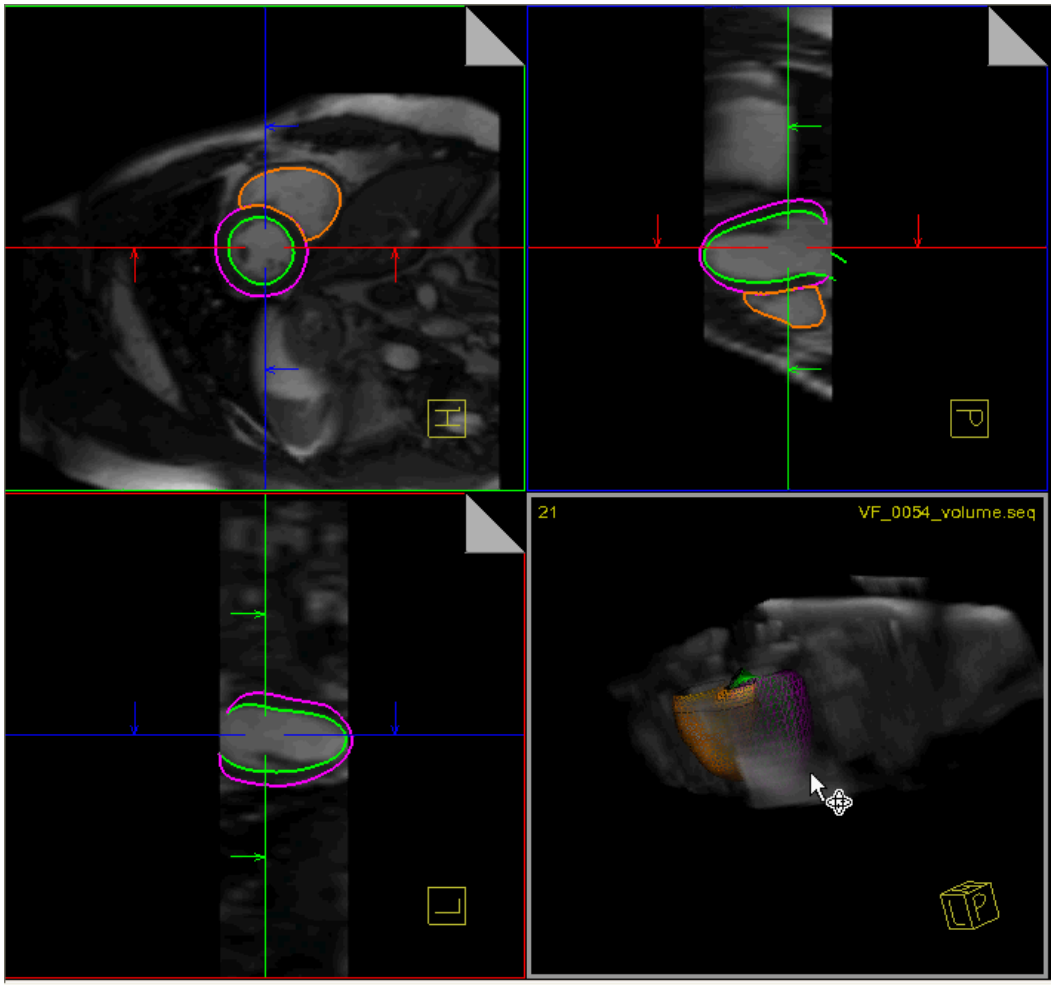

Figure 2-1. LV - RV models automatically estimated from MRI images

3. Methods

LBA relies on robust machine learning methods to captures complex statistics of the left and right ventricle shape and appearance in cinesteady-state free precession or gradient images. Within the Health-e-Child project, the LBA was trained on 114 patients with Tetralogy of Fallot (TOF) and is applied to automatically estimate the three-dimensional RV and LV boundary from MRI images of unseen patients.

The Health-e-Child model estimation from MRI images relies on robust parameter estimation techniques developed by SCR [Zheng et al. 2007, Zheng et al. 2008, Ionasec et al. 2008, Ionasec et al. 2009]. The Marginal Space Learning (MSL) framework is applied to efficiently estimate the high-dimensional models by operating on spaces with increasing complexity.

To validate the LBA method we examined 15 additional patients with TOF and compared three methods blindly in measuring RVV, LVV, LV EF and RV EF: current standard manual tracing (M-TRACE), fully automated LBA (AUTO), and LBA with manual boundary refinement of fully automated tracings (R-AUTO). Using linear regression and Bland Altman plots, left and right ventricular systolic (LV ESV and RV ESV) and diastolic volumes (LV EDV and RV EDV) and LV EF, RV EF were compared between manual and automated methods. Average processing time per patient was compared between techniques.

4. Results

4.1. LV Validation

Correlation of R-AUTO and AUTO with M-Trace demonstrated good agreement for both LV EDV (0.93 and 0.86, respectively) and LV ESV (0.87 and 0.93, respectively). Results for LV EDV are illustrated in Figure 4-1. EF measurements showed also a good correlation between R-AUTO and M-Trace (0.89), however less consistent for AUTO and M-Trace (0.66). LBA volume inaccuracy was most commonly due to incorrect identification of the aortic and mitral annuli.

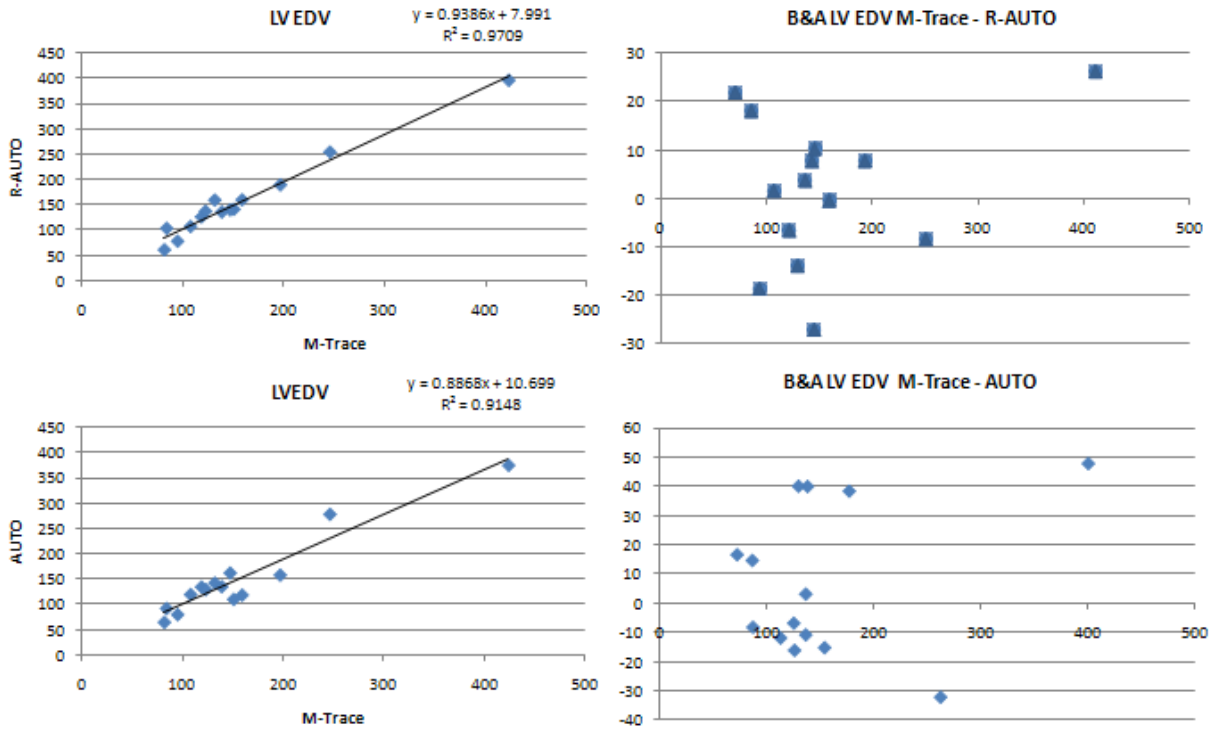

Figure 4-1. LV Validation; Left: Correlation plots, Right: Bland Altman Plots.

4.2. RV Validation

Mean processing time (minutes) per patient was significantly reduced using the fully automated method but not when adding the overhead of manual correction: M-Trace, 5.7±0.9; AUTO, 0.7 ($p<0.001$); and R-AUTO, 16.2±2.0 ($p< 0.002$). Correlation with results from manual tracing demonstrated poor correlation with diastolic volumes (RVEDV AUTO 0.595; R-AUTO, 0.930); good correlation with systolic volumes (RVESV AUTO, 0.874; R-AUTO, 0.918), and superior EF measures (AUTO, 0.854; R-AUTO, 0.633). LBA volume inaccuracy was most commonly due to incorrect identification of the tricuspid and pulmonary annuli (see Figure 4-2).

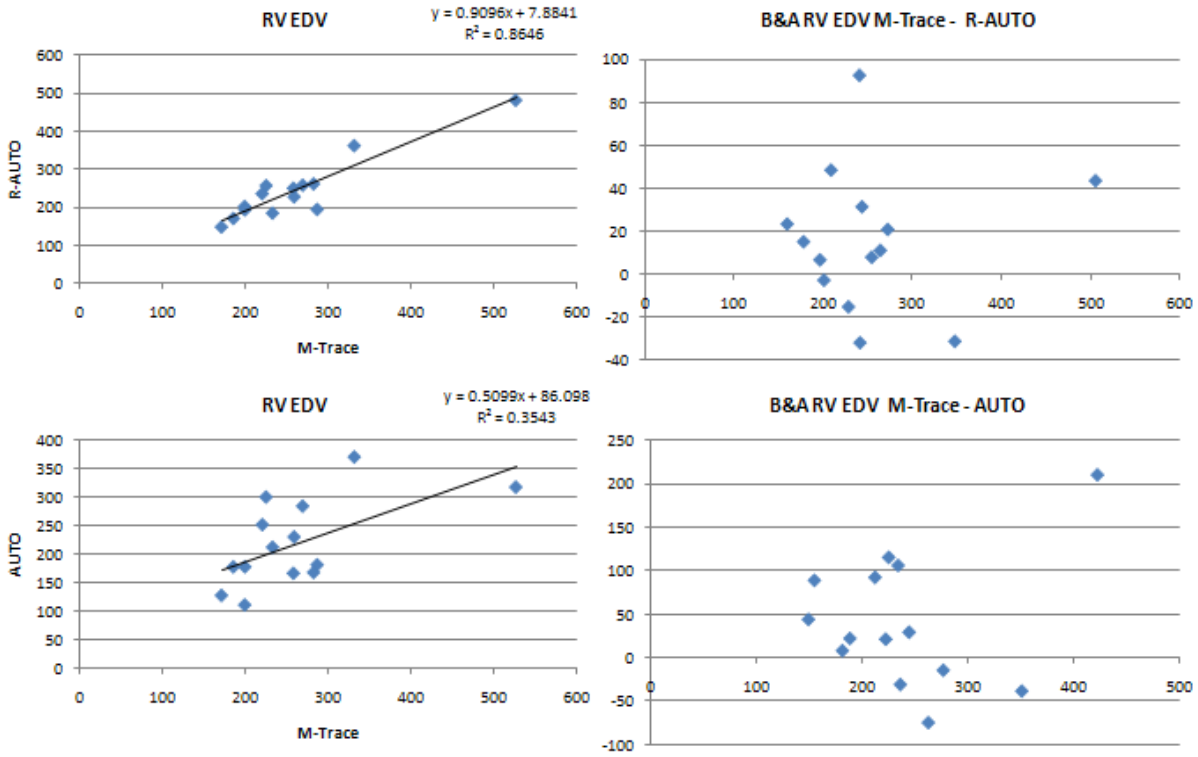

Figure 4-2. RV Validation; Left: Correlation plots, Right: Bland Altman Plots.

5. Conclusion

Our fully automated LBA method markedly reduces the time necessary to complete volumetric assessment of left and right ventricular function. Left ventricular values are consistent when compared to manual measurements however, due to failure to delineate accurately the tricuspid and pulmonary valve annuli, LBA underestimates predominately diastolic right ventricular volume. With additional case training, LBDA offers the opportunity to develop fully automatic volumetric measures to overcome the complexity of left and right ventricular function assessment of congenital heart disease and thereby reduce operator variability.

6. References

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