POSTER PRESENTATION

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A systematic evaluation of left ventricular (LV) models for estimating LV volumes in children using cardiac cine (MRI)

Jiming Zhang^{1*}, Carlo Uribe², Jason Liu³, Benjamin Cheong^{2,4}, Amol Pednekar⁴, Paolo Angelini², Raja Muthupillai^{2,4}

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Background

Assumptions about LV shape are often used to estimate LV volumes in ultrasound and x-ray angiography, which are not necessary for CMRI.

Purpose

Using CMRI as the gold standard, we sought to systematically evaluate the performance of commonly used models, and a linear combination of the models, to estimate LV volumes of children.

Methods

Subjects

198 children (137 male, age: 12.4 ± 1.2 years, range 11~15 years) who provided written informed consent, in the context of a screening study for causes of sudden cardiac death, were enrolled in this IRB approved study.

MRI Acquisition

Breath held CMRI cine images were acquired in standard orientations (4-chamber (4Ch), Left-Ventricular Outflow Tract (LVOT), and Short Axis (Sax)) were acquired using a vendor provided stock SSFP sequence at 1.5 T (Philips Healthcare) with an in-plane resolution $< 2 \times 2 \text{ mm}^2$, and an acquired temporal resolution $< 50 \text{ ms}$ for all subjects.

Data Analysis

An expert observer drew contours in end-diastole (ED) and in end-systole (ES) to estimate LV volumes on CMR images acquired in all orientations (Sax, LVOT, and 4Ch). In 4Ch and LVOT views, longitudinal length (distance from mitral valve annulus to apical endocardium),

and the transverse width (at mitral valve annulus) of the LV were recorded.

Models

The performance of six geometric models (described in Figure 1), and 15 weighted models generated (LVV_w) using a linear combination of any two of the six geometric models ($LVV_w = \alpha_i LVV_i + \beta_j LVV_j$, where α_i , β_j were the coefficients estimated in 100 subjects via minimizing the least-square's error compared to volumes estimated from Sax) were evaluated.

Data Analysis

Using Sax volumes as the reference, percentage-error of EDV, ESV, and ejection fraction (EF) of all 21 models were calculated.

Results

Commonly used biplane[1] and triplane[1] ellipsoid models have significant mean percentage error (at least 9%) for EDV/ESV/EF (Table 1), and triplane model was more reproducible than bi-plane model. A linear-weighted model of biplane and parabola substantially diminishes percentage error for EDV, ESV and EF to $0.3 \pm 6.0\%$, $0.5 \pm 10.7\%$ and $0.0 \pm 6.4\%$ ($\alpha_{EDV} = 0.4$, $\beta_{EDV} = 0.7$; $\alpha_{ESV} = 0.9$, $\beta_{ESV} = 0.2$) respectively.

Conclusions

In this group of young children, our results show that the estimation of LV volumes of conventional bi-plane and triplane models can be significantly improved by using a linear weighted model of bi-plane and parabolic models. These findings have to be confirmed in a larger study.

¹Physcs and Texas Center for Superconductivity, University of Houston, Houston, TX, USA

Full list of author information is available at the end of the article

$LVV = \frac{8A_1 \times A_2}{3\pi L}$	$LVV = \frac{4}{3} \sqrt{\frac{A_1 A_2 A_p}{\pi}} \times 0.752$	$LVV = 8\pi L_1^2 L$

$LVV = \frac{\pi}{3} AL_2$	$LVV = \frac{\pi}{3} (r_1^2 h_1 + r_2^2 L + r_1 r_2 h_1)$	$LVV = \frac{\pi}{12} (r_1^2 + r_1^2 + r_1 r_2) h_1 + 32\pi r_2^2 h_2$

Figure 1 Geometric models considered in the current study. A, L₁ and r₂: area, diameter and radius from short-axis slice at papillary muscle level; L: longer length from apex to base in 4CH and LVOT views; r₁: bigger half width at mitral valve annulus in 4CH and LVOT views; h₁: length from base to papillary muscle level; h₂ = L-h₁

Table 1 Estimation result of EDV, ESV and EF by weighted models

	[%]	Biplane	Triplane	Parabola	Cone	Cutcone+Parabola	Cutcone+Cone
Biplane	EDV	10.4±9.8	0.3±6.0	0.3±6.0	0.3±6.0	-0.7±7.0	-1.0±7.4
	ESV	-10.8±16.0	0.5±11.0	0.5±10.7	0.5±10.7	-0.7±7.0	-1.3±11.8
	EF	13.3±8.6	0.0±6.5	0.0±6.4	0.0±6.4	0.1±6.7	0.2±7.3
Triplane	EDV	X	-16.1±5.1	0.3±6.0	0.3±6.0	0.0±6.1	-0.1±6.1
	ESV	X	-27.2±8.7	0.5±10.7	0.5±10.7	-0.4±10.4	-0.6±10.8
	EF	X	9.2±6.4	0.0±6.5	0.0±6.5	0.4±6.6	0.5±6.7
Parabola	EDV	X	X	-14.0±6.6	0.7±7.7	0.2±7.6	0.2±7.6
	ESV	X	X	-19.5±9.1	0.3±11.4	-0.4±10.6	-0.5±10.8
	EF	X	X	4.4±7.1	0.3±7.4	0.5±7.0	0.5±7.2
Cone	EDV	X	X	X	-43.4±4.3	0.2±7.6	0.2±7.6
	ESV	X	X	X	-47.0±6.0	-0.4±10.6	-0.5±10.8
	EF	X	X	X	4.4±7.1	0.5±7.0	0.0±8.8
Cutcone+Parabola	EDV	X	X	X	X	14.0±11.2	0.0±8.8
	ESV	X	X	X	X	15.3±13.4	-0.1±10.3
	EF	X	X	X	X	0.9±7.9	0.1±6.9
Cutcone+Cone	EDV	X	X	X	X	X	-1.6±11.1
	ESV	X	X	X	X	X	0.3±13.5
	EF	X	X	X	X	X	-1.6±9.3

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Author details

¹Physcs and Texas Center for Superconductivity, University of Houston, Houston, TX, USA. ²Center for coronary artery anomalies, Texas Heart Institute, Houston, TX, USA. ³Glenda Dawson High School, Pearland, TX, USA. ⁴Diagnostic and Interventional Radiology, St. Luke's Episcopal Hospital, Houston, TX, USA.

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