

# Flow-Derived Measurement of Left Ventricular Stroke Volume in Children: Agreement Between Segmented 2D Cine Phase Contrast MRI and Real-Time 3D Angle-Independent Doppler Echocardiography

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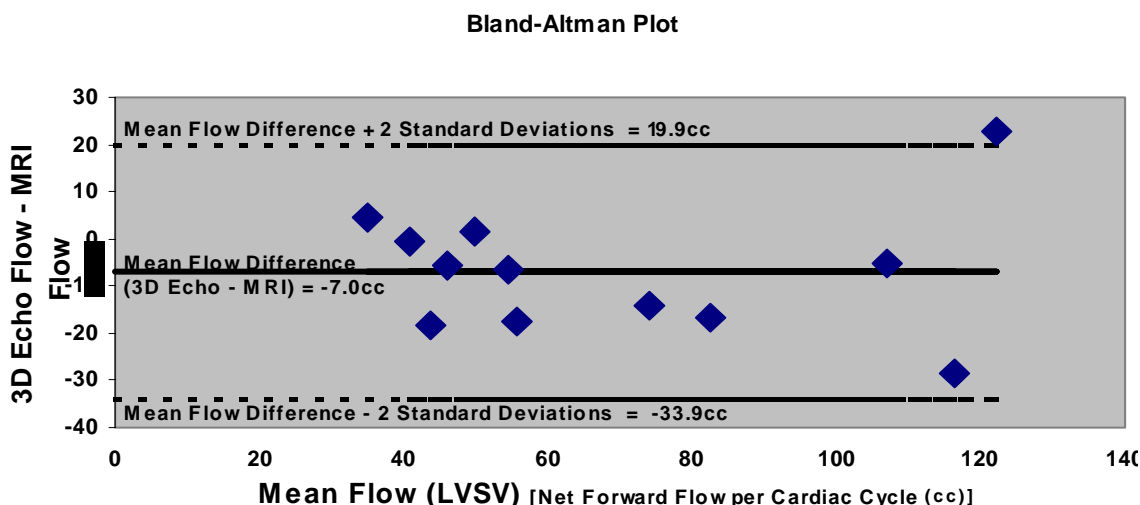
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**Objectives:** This study was designed to assess the agreement of *flow*-based measurements of left ventricular stroke volume (LVSV) in children by two noninvasive techniques: 2D phase contrast magnetic resonance imaging (PCMRI) and real time 3D Doppler echocardiography (RT3DE), a new technique that measures flow in an angle-independent manner by projecting the raw Doppler velocity information onto a curved surface [1].

**Background:** Cardiac flow and chamber size are important in the evaluation of heart disease. RT3DE is a new modality that provides portable, real-time grey scale and Doppler images, but requires an adequate acoustic window. Both cardiac MRI and RT3DE provide superior accuracy in comparison to 2D echocardiography in the measurement of left ventricular volumes [2]. 2D echocardiography relies on geometric assumptions and is susceptible to errors in positioning the image plane. RT3DE and cardiac MRI have no such limitations. Mannaerts et al. have reported that RT3DE and MRI provide comparable measurements of cardiac chamber volumes [3]. PCMRI has evolved into a clinical tool that allows quantification of blood flow in the normal and diseased cardiovascular system [4]. Recently, a real-time 3D digital Doppler system was developed by Philips. We and others have developed an algorithm to quantify flow from the real time 3D digital Doppler velocity profile. This approach minimizes the importance of the Doppler intercept angle. In this study, we sought to compare *flow*-based measurements of LVSV in normal children by PCMRI and RT3DE, as this comparison has not been previously described.

**Methods:** 12 normal children (age range: 6-13 yrs) were studied. MRI was performed on a GE CV/i 1.5T scanner with a torso coil. 2D cine phase contrast images were acquired in a plane perpendicular to the long axis of the ascending aorta (VENC=150cm/s, 256x160 matrix, 20° flip angle, 32 kHz bandwidth, 6 views/segment, 20 cardiac phases). As an internal control, LVSV was also measured volumetrically from short axis 2D Fiesta images by summing the areas enclosed by the LV endocardial border on contiguous slices in end-systole and end-diastole. MR data were transferred to an off-line workstation (GE Advantage Windows) and analyzed using vendor-provided software. Parameters for 2D Fiesta were 8mm slice thickness, 224x160 matrix, 40° flip angle, 125 kHz bandwidth, 12-16 views/segment and 20 cardiac phases. Net forward flow per cardiac cycle was quantified from PCMRI phase images by manually tracing the boundary of the ascending aorta and main pulmonary artery on magnitude images. On the same day, RT3DE was performed with a Philips SONOS 7500 X4 matrix array transducer. Real time 3-D Doppler flow was measured with the following parameters: 80x80x208 voxels, and 11-20 frames per cardiac cycle. Diastolic mitral inflow Doppler vectors across a spherical surface, manually positioned at the tips of the mitral valve leaflets, were summated to yield the LVSV using the equation: Flow Rate(t) = ∫S velocity(x,y,z,t) dS, where S is the ROI area on Gaussian control surface; and Flow Volume = ∫ flowrate(t) dt. The Nyquist limit was set to minimize aliasing.

Subject	RT3DE LVSV	PCMRI LVSV
1	102	130.7
2	40.6	40.99
3	105	109.6
4	74.2	91.05
5	50.7	49.2
6	67.1	81.16
7	34.7	52.9
8	134	110.7
9	51.2	57.64
10	46.9	64.35
11	43.2	48.92
12	37.1	32.7



**Results:** RT3DE and PCMRI data are shown in the table. RT3DE Doppler flow-derived LVSV measurements correlated well with PCMRI ( $r=0.91$ ,  $y=0.92x - 1.28$ ) and short axis-derived 2D Fiesta ( $r=0.94$ ,  $y=0.95x + 1.52$ ) LVSV measurements. A Bland-Altman plot (shown above) revealed good agreement between RT3DE and PCMRI flow measurements. LVSV measurements by PCMRI and 2D Fiesta were also highly correlated ( $r=0.95$ ,  $y=0.96x - 1.69$ ), thereby providing an internal control

**Conclusion:** RT3DE and PCMRI flow-based measurements of LVSV show good agreement and correlate well with volumetric MRI methods in normal children. PCMRI has already been validated in children with cardiovascular disease. Although there is limited experience with RT3DE, this technique offers great promise for assessing children with congenital heart disease.

## References:

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