Measurement of right and left ventricular stroke volumes in children: comparison of 2D cine true steady state free precession gradient echo and 2D cine phase contrast MRI

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Introduction: Cine gradient echo MRI is a well-established anatomic technique for measuring ventricular stroke volume and assessing cardiac function. 2D cine phase contrast (2D cine PC) provides information about flow velocity profiles and volumetric flow rates that are not available from anatomic imaging alone.[1,2] 2D cine PC also provides an alternative method to measure ventricular stroke volume. Graves et al. compared segmented 2D cine gradient echo and 2D cine PC for measuring stroke volumes in adults and showed good agreement between the two techniques.[3] The purpose of our study was to assess the agreement between anatomic and velocity mapping MR techniques for measuring stroke volumes in children.

Methods: Twenty normal volunteer children participated in the study, but one volunteer was excluded due to an incidentally discovered atrial septal defect. The 19 study subjects (10M, 9F) ranged in age from 6-16 years. Imaging was performed on a GE CV/i 1.5T scanner equipped with a torso coil. Spiral real-time imaging was used to prescribe the cardiac long and short axis planes. Anatomic imaging was performed with a segmented 2D cine true steady-state free precession gradient echo sequence (2D Fiesta) with the following parameters: TR 3-4 ms, TE 1-1.5 ms, 40° flip angle, 8mm slice thickness, 224x160 matrix, 125 kHz bandwidth, 20 cardiac phases, 12-16 views/segment (depending on heart rate). 2D cine PC images were acquired in planes perpendicular to the long axis of the ascending aorta and main pulmonary artery. The parameters were 20° flip angle, 4 mm slice thickness, VENC=150cm/s, 256x160 matrix, 32 kHz bandwidth, 20 cardiac phases, and 6 views/segment. 2D Fiesta and 2D cine PC images were acquired during suspended respiration (7-13 sec) at end-expiration. MR images were transferred to an off-line workstation (GE Advantage Windows) and analyzed using vendor-supplied software. Manual tracings of the right and left ventricular endocardial borders in end-systole and end-diastole on short axis 2D Fiesta images were used to calculate ventricular stroke volumes. The position of the mitral and tricuspid annulae in systole and diastole were carefully defined on cross-referenced horizontal long axis images. Volumetric flow data for the ascending aorta and main pulmonary artery were obtained from 2D cine PC phase images. The vascular borders were manually traced from the corresponding magnitude images, and net forward flow per cardiac cycle was calculated. Blocked design ANOVA and Bland-Altman analysis were used to assess agreement between right and left ventricular stroke volumes (RVSV and LVSV, respectively) and net forward flow per cardiac cycle in the ascending aorta (Ao) and main pulmonary artery (PA).

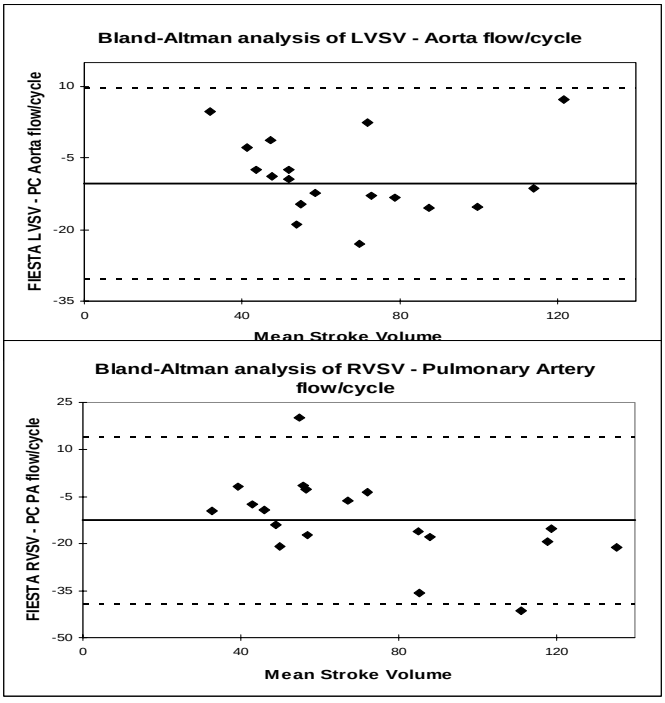

Fig. 1. Bland-Altman analysis of ventricular stroke volume measured against flow per cycle. Hatched lines represent two standard deviations above and below the mean difference of stroke volume from 2D FIESTA – flow per cycle from 2D cine PC, in the right and left heart respectively.

Results: A mean difference of –12.6 ml was observed for RVSV and PA (95%CI: -19.6 to -6.0 ml, p=0.001); the corresponding value for LVSV and Ao was –10.3 ml (95%CI -15.2 to -5.5, p<0.001). The correlation between the RVSV and PA data and between the LVSV and Ao data was high (r=0.93 and 0.94, respectively). Bland-Altman analysis showed good agreement between the volumetric and flow-based measurements of ventricular stroke volume (Fig. 1).

Discussion: The use of two different MRI techniques to measure ventricular stroke volume provides internal validation of this key gauge of cardiac function. We found good agreement between volumetric measurements of RVSV and LVSV by 2D Fiesta and (separately) between flow-based measurements in the Ao and PA by 2D cine PC. However, stroke volumes obtained from flow data were consistently greater that those obtained from volumetric data. Despite these differences, both measurements of stroke volume were highly correlated. The border pixel effect could account for over-estimation of stroke volume by 2D cine PC. The clinical utility of quantitative cardiac MR techniques depends on both accuracy and reproducibility. Consequently, we are currently evaluating the reproducibility of 2D Fiesta and 2D cine PC measurements and the possible benefits of automated and semi-automated measurement software.

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