Comparison of Left and Right Ventricle Functional Measurements Using Steady State Free Precession-Short Axis versus Four Chamber Analysis

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Introduction

Measurement of ventricular function is an important component of the comprehensive evaluation of the heart. Cardiovascular Magnetic Resonance Imaging (CMR), unlike echocardiography is not limited by acoustic windows, and therefore contiguous sections of the entire heart can be acquired in any imaging plane. Although, short axis (SA) CMR functional evaluation of the left ventricle (LV) has become standard of practice, similar application to the right ventricle (RV) is problematic with significant measurable differences found between the ventricles in normal controls [1]. The four-chamber (FC) view although frequently used as a single slice evaluation of the septum and atrioventricular valves has not been fully explored as a plane to directly measure cardiac function. Utilization of the FC view for a dual application could help reduce overall imaging times in studies where both RV and LV functional assessment is required, as well as providing a more thorough evaluation of the septum and cardiac valves. The goal of this study was to determine if ventricular measurements of stroke volume (SV), end-diastolic volume (EDV) and end-systolic volume (ESV) were correlated between imaging orientations and to identify possible causes for any measured differences between the two techniques.

Methods

15 sequential cardiac patients (10 males, 5 females; age range 17-79, ave. = 52 yrs.) without CMR or EC evidence of significant valvular disease or intra-cardiac shunts were collected over a 12-week period. The study was performed at 1.5 Tesla utilizing breath-hold vectorcardiographic triggered CINE steady state free precession pulse sequence (TR = 3.4-3.7 msec, TE = 1.7-1.9 msec, FA = 70 degrees; 8-10mm thick sections with no gap) in both SA and FC planes. Two radiologists using cardiac analysis software (VMR Workstation, Philips Medical System, Best, Netherlands) independently traced the endocardial margin of each ventricle in both end-systole and end-diastole for SA and FC views, carefully avoiding the pulmonary artery and atria. In the SA and FC views, the papillary muscles were excluded. EDV, ESV and SV were calculated for each ventricle and imaging plane. The results of the two radiologists were averaged and a t-test comparing the imaging planes was calculated in addition to inter-observer variability. In the FC view at the mid septal level, the length of each ventricle from the mid valvular plane to the epicardial surface of the cardiac apex was measured (arrows) (fig. 1). The diameter of the left ventricle at mid cardiac level was measured in end-systole (ES) and end-diastole (ED) from epicardial to epicardial surface (arrow) (fig. 2). A t-test was calculated for ventricular shortening comparing ED and ES values.

Results

The averaged results of SA and FC measurements for SV, EDV and ESV for LV and RV with associated probability values are shown (fig. Ventricular Function). The LV and RV SA measurements of SV show a difference of 24 cc (37%)(P=0.007) whereas the FC measurements have only a 3 cc (4%)(P=0.46) difference. The RV SV was consistently lower than the LV in the SA view with an inter-observer variability of P=0.92.The differences between SA and FC measurements for LV-EDV, RV-EDV and LV-ESV are 6% or less (P> 0.05) whereas RV-ESV show a difference of 34% (P<0.001). Analysis of length and diameter changes in the ventricles is shown (fig. Ventricular Shortening). The diameter the left ventricle shows the least variability with average change of 5.8% where as the length of LV changed 12.6 %. The greatest change in length occurred with the right ventricle averaging 26.7%. T-test results show significant differences (P < 0.001) in shortening values between ED and ES.

Figure 1

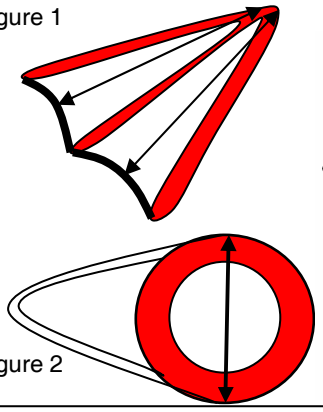


Figure 2

Figure Ventricular Function

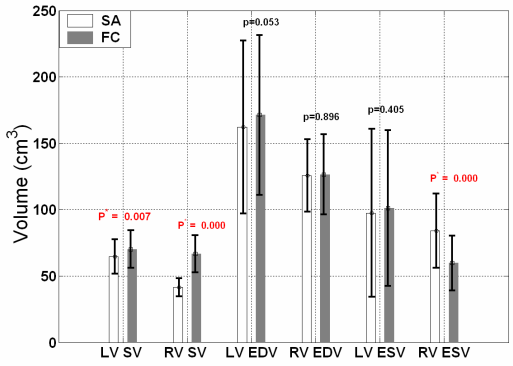
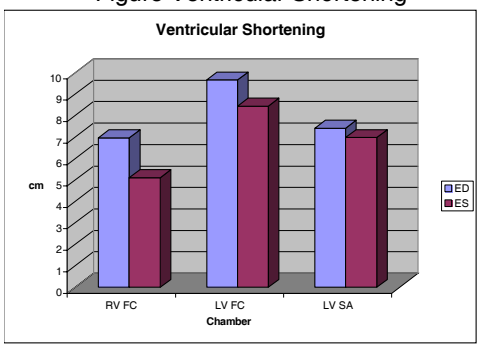


Figure Ventricular Shortening



Discussion/Conclusion

In a closed system the cardiac output of the ventricles should be dynamically matched in the absence of intra-cardiac shunts and significant valve leakage [2]. In order to quantify the effects of intra-cardiac shunts and valvular disease CMR measurements should be reproducible and differences between the ventricular chambers should reflect the disease process rather than methodological inconsistencies. In our study LV and RV SV's were well matched in a patient population when measured with contiguous FC sections and poorly matched with contiguous SA sections. One possible explanation for the differences in SV measurements between orientations in our study is suggested by the morphologic changes that occur in each ventricular between ED and ES. These morphologic changes vary depending on the imaging plane and ventricle. Our results show that the diameter of the LV in the SA view has minimal variability whereas ventricular length in the FC views has significant variability with the RV demonstrating the greatest fractional change. This phenomenon equates to greater misregistration of matched slices in the SA compared to the FC images. Because the apex of the ventricles are relatively fixed in position by pericardial attachments to the diaphragm and due to the unique orientation of ventricular myofibers [3] the atria are pulled towards the apex in systole when ventricular length shortening is maximal. Because the thickness of the wall of the RV and RA are similar, inadvertent inclusion of right atrium into the volume measurements of ES may occur. This effect may be more problematic in a patient population compared to healthy adults because myocardium may be thinned and study quality less than optimal. Including portions of the RA inadvertently will result in an artifactual increase in RV ESV in the SA views but have little effect on EDV as confirmed in our data set. Because SV = EDV-ESV the overall effect of this error is to reduce SV as occurred in our study. This effect is less likely to occur for the left ventricle due to less atrial shift and greater differences in wall thickness between the LV and left atrium preventing inadvertent inclusion of the left atrium into the ESV measurements. Tracing of the endocardial margin in the FC view is relatively simplified by clear visualization of the valve plane in all slices and in both ED and ES. This factor combined with minimal slice misregistration probably accounts for insignificant differences between RV and LV SV measurements acquired in the FC plane. Our results indicate that assessment of contiguous FC compared to SA views is more likely to generate true differences in ventricular function in a patient population when simultaneous ventricular calculations of SV, EDV and ESV are necessary.

References:

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