

An Automated Method for Extraction of Tissue Doppler Like Myocardial Motion Parameters from Conventional Cine Cardiac MR - A Feasibility Study

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Introduction

The assessment of myocardial function in Cardiac Magnetic Resonance (CMR) imaging is largely focused on the evaluation of ventricular function and is primarily restricted to the use of ejection fraction and myocardial mass as indices of cardiac function. More detailed evaluation of conventional MR cine data also allows the extraction metrics of contractility and relaxation derived from the rate of change of volume when parameters such as peak ejection rate and peak filling rate can be established. This, however is rarely practiced outside the research arena. In echocardiography, there is growing interest in the diagnostic and prognostic implications of measuring the velocity of myocardial tissue using Tissue Doppler Imaging (TDI) which derives values for peak velocities during systole (s'), diastolic relaxation (e') and during atrial contraction (a') [2]. The hypothesis behind this feasibility study was that the same anatomical points typically used in TDI could be tracked automatically in a conventional four chamber cine MRI sequence and the velocity of these anatomical landmarks towards and away from the apex be derived and the same velocity parameters (e' , a' specifically) could be extracted and used as an index of cardiac health.

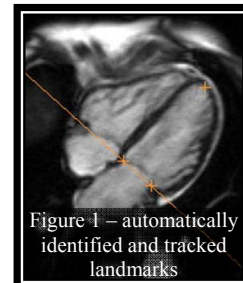


Figure 1 – automatically identified and tracked landmarks

Methods

The automated mechanism for tracking the insertion points of the mitral valve on cine MR images (figure 1) was already available as a component of an automated contouring mechanism used in a commercial implementation of a completely automated ventricular function tool. (In-line VF, Siemens Healthcare)[1]. As part of this method the mitral valve insertion points are identified and tracked throughout the cardiac cycle in order to delimit the left ventricle at the mitral valve plane when calculating the ventricular volume. The spatial location of these tracked landmarks can therefore be identified and the speed of the landmark towards and away from the apical landmark derived.

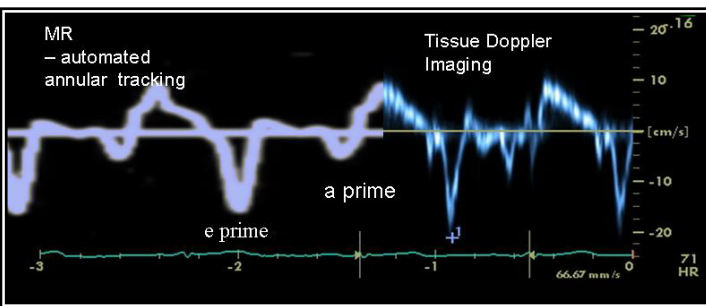


Figure 2 Hybrid image of a subject where TDI data and data derived from the new automated annular tracking method is presented – key features of the time velocity wave form are clearly preserved in the new automated method.

A cohort of 13 healthy volunteers was recruited under an IRB approved protocol (7 female, mean age 36.8+/-12.2). Each subject was scanned using an established method to identify the four chamber orientation of the heart. Then a cine TrueFISP sequence was acquired in a breath-hold while varying the temporal resolution (7,10,20,30,40 and 50ms) other parameters were maintained other than for the higher temporal resolution protocols the parallel imaging acceleration factor was increased to ensure that the breath-hold duration was manageable. (TR/TE 2.4/1.2 ms. Matrix 192 x 192 Field of view 380mm BW 930 Hz/pixel).

In addition for sub-cohort of six subjects a phase contrast protocol was used with through plane velocity encoding of 20 cm/s to assess correlation of the landmark tracking results with an alternative method. The slice was positioned in the short axis orientation on the ventricular side of the mitral annulus so that the mitral valve did not move into or through the slice during the cardiac cycle.

For the landmark tracking method the automatically generated velocities for each temporal frame in the cine sequence were plotted against time and the e' value was identified as the peak velocity at the time of early diastolic relaxation for the lateral

mitral valve insertion point. The corresponding data was derived from the phase contrast measurements by measuring velocity within a region of interest at the intersection of the four chamber cine at the free wall of the LV with the short axis PC data. For both methods e' was extracted and compared.

Results

-The mean e' velocity across all subjects was calculated for each temporal resolution and the expected increase in peak velocity was observed.

-Determination of e' visually from the time velocity graphs became more difficult at higher temporal resolution as the data became 'noisy' in retrospect as a result of the deterioration of image quality so that the automated tracking of the landmarks became less robust

-Taking the derived e' velocity from the 30 ms temporal resolution data to avoid the effects of degraded image quality, a negative correlation with age was observed ($r=-0.75$, $p 0.003$)

-A good, but non-significant correlation with the Phase Contrast data was observed in the six subjects where it was available ($r=0.8$) (figure 3).

-A significant negative correlation with age was observed for ($r=-0.75$, $p < 0.003$)

-In one subject it was possible to obtain TDI results on the same day (fig 2) this demonstrated clear preservation of wave form features, in particular e' and a' were identifiable and measurable.

Discussion

The method presented, where a completely automated detection and tracking of the mitral valve insertion points is used to derive tissue velocities from conventional MR cine imaging is compared with Phase contrast methods and correlated with age. The method was evaluated with differing temporal resolutions from 7 to 50 ms and the expected increased detected velocity was observed with improved temporal resolution. The strategy to accommodate increased breath-hold duration with improved temporal resolution was to use higher parallel imaging acceleration factors which resulted in the introduction of some artifact in some subjects (slice orientation and coil configuration dependent) as well as loss of SNR which resulted in degradation of the performance of the tracking algorithm. For moderate temporal resolution (30ms) the results were stable but underestimated peak velocities compared to published TDI data [2] and on the one individual where TDI was also available. These initial results, however, suggest that in view of the simplicity of the method and fully automated approach using conventional cine scans, that further exploration of this method is warranted to establish dependence on other parameters such as spatial resolution as well as temporal resolution. The nature of the method lends itself to retrospective analysis of existing data in normal and abnormal subjects to establish normative values and to identify differences in specific patient populations. The correlation of decreasing E' velocity with age might indicate that this method would be a method for quantifying diastolic function in a manner similar to TDI. The current study is limited by small sample size for different age ranges and further work is required to determine the optimal acquisition protocol, establish reproducibility and normal values for e' and a' .

References

- [1] M.-P. Jolly, C. Guetter, J. Guehring, "Cardiac Segmentation in MR Cine Data Using Inverse Consistent Deformable Registration", Proc. ISBI, Rotterdam, 2010.
- [2] Navtej S. Chahal, Tiong K. Lim, Piyush Jain, John C. Chambers, Jaspal S. Kooner, and Roxy Senior; Normative reference values for the tissue Doppler imaging parameters of left ventricular function: a population-based study; European Journal of Echocardiography (2010) 11, 51–56

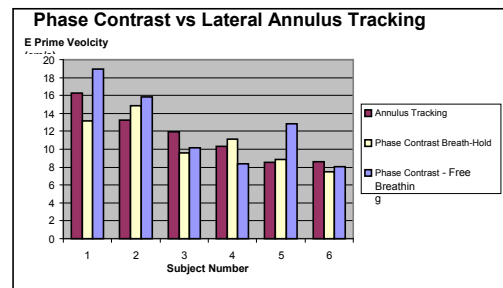


Figure 3 In 6 subjects the annular tracking method was compared to a phase contrast method demonstrating reasonable correlation ($r=0.8$) in this small sample