THE REASONS FOR DIFFERENCES BETWEEN 2D AND 3D ECHOCARDIOGRAPHY STRAIN MEASUREMENTS

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Introduction

Echocardiographic strain measurements can be performed in 2D or 3D. Specific patterns of discrepancy between 2D and 3D measurements are reported, but the exact mechanism for this is unclear [1]. Further, strain measurements in fetal hearts varies substantially in magnitude among different studies [2]. We aim to demonstrate possible reasons for these discrepancies.

Methods

4D echocardiography images (STIC mode) were obtained from 26 heathy fetuses at 22 and 32 weeks of gestation with IRB approval and consent. A validated cardiac motion estimation algorithm [3] was used to track the motion of fetal left and ventricles (LV & RV) and ventricular septum in 3D, and to calculate myocardial strains. 2D planar images were extracted from 3D images and quantifications were repeated in 2D for controlled comparison. Cardiac Finite Element (FE) simulations [4] were used to validate findings.

Results

<u>2D versus 3D longitudinal strain</u> (LS): 3D LS was found to be significantly lower than 2D LS in LV free wall (by 2% in strain magnitude) and septum (by 1.7%). This is due to LV twist, which causes out-of-plane and highly 3D motion in the longitudinal view, but in 2D, an inevitable projection to the 2D plane exaggerates myocardial longitudinal shortening (Fig 1a). FE modelling showed a significant correlation between twist magnitude and the 2D versus 3D LS error (R>0.87). The RV does not twist significant, and no 2D vs 3D LS difference was observed. This demonstrates the role of LV twist in causing this difference.

<u>2D versus 3D circumferential strain (CS)</u>: 3D strain was found to be significantly higher than 2D circumferential strain (CS) by 3%, 3.6% and 2.5% in the LV free wall, RV free wall and septum, respectively. This can be explained by the systolic motion of heart towards the apex. This motion creates errors for 2D imaging as it introduces wider transverse cross-sections of the heart into the imaging plane, which negates contraction deformations (Figure 1b). FE results showed significant correlation between longitudinal displacement and 2D versus 3D CS error (R>0.98).

<u>Timing Mismatch between CS and LS:</u> Further, we observed a timing mismatch between when the longitudinal and circumferential lengths are at their peaks. The was thus no natural zero strain reference time point for 3D strain quantification, and favouring any one direction when specifying this reference will reduce strain magnitude of the other direction. For 2D quantification, strain in each direction is assigned its own zero-strain reference time point. This factor accounted for a further difference of strain 0.7-0.8% difference between 2D and 3D strains.

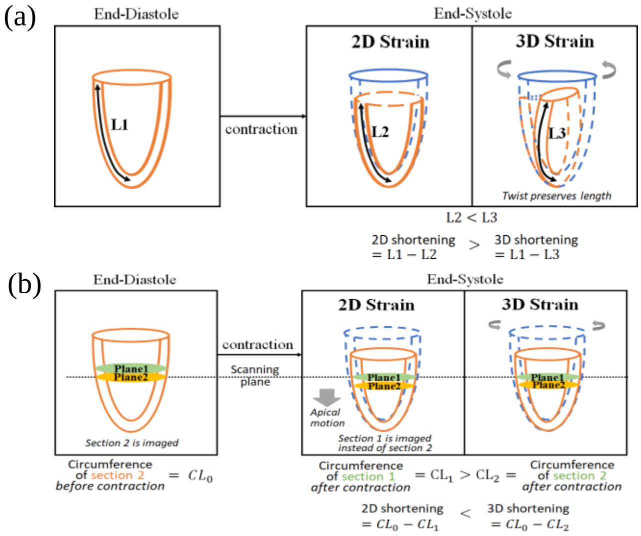

Figure 1: Schematic explanation of differences between 2D and 3D LS *(a) and CS (b)*

<u>Spatial variability of strains:</u> Strains at epicardial versus endocardial locations differed substantially, accounting for 7% longitudinal and 8.9% circumferential strain magnitude differences. Since strain quantifications often require manual controls clinically, this can explain wide discrepancies between the different studies by reputable groups [2] (up to 6.3-7.1% strain magnitude difference). We further find that different smoothing extent during motion tracking can also substantially affected strain magnitudes.

Discussion

2D strains have significant error, while 3D strains is more representative of cardiac physiology, and we advocate 3D strains. Our finding suggests that caution is necessary in interpreting strain results in the literature, due to several reasons for discrepancies, and that future standardization of strain measurements is necessary. Our findings in fetal echo is likely applicable to adult echo as well.

References

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