Comparison of 2D and 3D torsion measured from tagged cardiac MRI

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INTRODUCTION

Cardiac left ventricular (LV) torsion is the difference between rotation of the apex and base. The evolution of LV torsion through time can provide important information about both systolic and diastolic myocardial function [1]. In tagged MRI, torsion vs. time data is typically measured using by tracking an annular mesh in an apical and a basal slice with two-dimensional (2D) HARP analysis [2,3]. 2D-techniques may not take into account the through plane myocardial motion that may significantly affect torsion measurements. Recently, a method for computing 3D torsion vs. time was presented [4]. The purpose of this study was to quantitatively compare 2D and 3D LV rotation and torsion measurements computed from tagged MRI.

METHODS

A group of 40 subjects were imaged consisting of 10 normal volunteers (NRM), 10 diabetics with myocardial infarction (DMI), 9 patients with mitral regurgitation (MRR), and 10 patients with hypertension (HTN). All participants underwent MRI on a 1.5T MRI scanner (GE, Milwaukee, WI) optimized for cardiac application. Both cine and tagged images were acquired in standard views (2 and 4 chamber long axis and short axis) with a fast gradient-echo cine sequence with the following parameters: FOV = 300 mm, image matrix = 224x256, flip angle = 45, TE = 1.82ms, TR = 5.2ms, number of cardiac phases = 20, slice thickness = 10 mm. A 2D spatial modulation of magnetization tagging preparation was done with a tag spacing of 7 pixels.

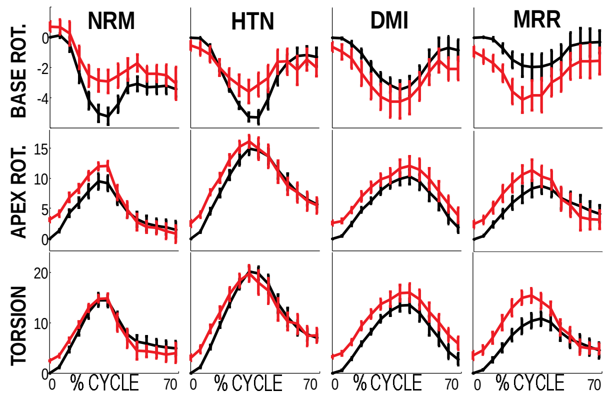

Fig.1: Plots of average base and apex rotation, and torsion obtained from 2D (black) and 3D (red) methods through 70% of the cardiac cycle. Error bars represent ± one standard error. All angles are in degrees

2D LV torsion was measured using the procedure described in [2]. One slice each at the basal and apical levels was used to compute torsion. The basal slice chosen was the slice closest to and below the mitral valve at the end-systolic (ES) phase. The apical slice chosen was the slice closest to the apex where the blood pool could be identified. A mesh consisting of 3 concentric rings and 24 circumferential points was defined in each slice at end-diastole (ED) from semi-automatically-drawn contours. Each mesh was tracked through all time frames using the improved harmonic phase (HARP) method for motion tracking [3]. Drawing contours and mesh tracking took approximately 5min per study.

3D LV torsion was measured using the method described in [4]. Myocardial contours were semi-automatically drawn at ED and end-systolic (ES) time frames for all slices and then propagated to all time frames [6]. 3D LV deformation in each timeframe was computed by fitting the 1D displacement measurements derived from unwrapping the HARP phase in each image to the affine prolate spheroidal B-spline method in [5]. Drawing contours and other processing took approximately 30 min per study.

Displacement of the mitral annulus toward the apex during systole was measured by tracking a user-specified point on the mitral annulus through each frame of a 4-chamber view using non-rigid registration [6].

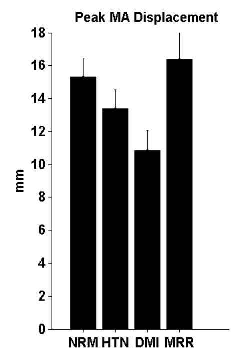

Fig. 2: Peak mitral annulus displacement.

RESULTS AND DISCUSSION

Fig. 1 shows rotation and torsion versus time curves averaged over the studies in each of the four patient groups. Differences between 2D and 3D curves can be attributed to two factors. First, a few degrees of rotation occur between tag pattern application and the first images. The 3D method corrects for this initial deformation, but the 2D method does not because it is based on tracking points identified in the first image. This factor shifts the 3D curves by a constant angle through time. The second factor is through-plane motion – primarily motion of the base toward the apex during systole and back again during diastole. The 3D method corrects for this motion, but the 2D method tracks points in a given slice through time. In the 2D method, the tracked points in the basal slice start out near mid-ventricle and become more basal through systole. Since the base typically rotates more than the mid-ventricle, though-plane motion can distort the rotation and torsion curves.

The effect of through-plane motion can be seen by comparing the measurements of mitral annulus displacement (MAD) in Fig. 2 with the curves in Fig. 1. The DMI patients had the lowest amount of MAD, and the 3D rotation and torsion curves are shifted versions of the 2D curves. Normals and MR patients had largest amount of MAD, and 2D curves are more distorted relative to 3D. Table I shows the difference between 2D and 3D peak torsion/rotation and peak torsion/rotation rates. The significant differences are primarily in the normal and MR patient groups because of the relatively high through-plane motion.

Table I: Comparison of differences between 3D and 2D rotation and torsion (3D-2D). *p<0.05 relative to 3D.

	Peak (deg)	Sys Rate (deg/s)	Early Dia Rate (deg/s)
Base Rotation			
NRM	4.3 ± 0.8*	7.4 ± 4.8	-47.1 ± 18.8*
HTN	3.1 ± 1.3	7.4 ± 6.3	-23.1 ± 11.5
DMI	3.1 ± 1.1	6.1 ± 6.0	-1.1 ± 14.5
MRR	3.9 ± 1.4	11.3 ± 7.8	-34.6 ± 7.4*
Apex Rotation			
NRM	1.9 ± 0.4*	6.6 ± 2.4	-6.8 ± 2.8
HTN	1.3 ± 0.8	7.6 ± 2.5	-14.4 ± 3.8*
DMI	-0.9 ± 1.0	-3.1 ± 4.4	2.7 ± 3.4
MRR	-2.1 ± 0.9	-7.9 ± 5.1	6.2 ± 4.8
Torsion			
NRM	1.8 ± 1.0	-3.6 ± 6.2	-36.3 ± 18.2
HTN	1.2 ± 1.8	-0.9 ± 6.8	-8.0 ± 15.2
DMI	4.0 ± 0.9	9.0 ± 6.3	-7.6 ± 13.5
MRR	5.8 ± 1.6*	21 ± 5.5*	-43.5 ± 6.1*

CONCLUSION

While 2D and 3D rotation and torsion measurements were similar in subjects with low base-to-apex motion such as patients with MI, The 3D method measured larger and probably more accurate rotation and torsion in subjects with normal or elevated base-to-apex motion. 3D torsion measurements may allow improved assessment of cardiac mechanics in patients with a variety of myocardial diseases.

REFERENCES

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