Biventricular strain analysis at 1.5T and 3.0T cardiac MR imaging: a comparison of derived strain values by field strength and temporal resolution.

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Introduction: Myocardial strain has shown promise as a sensitive biometric for identifying early changes in myocardial function preceding overt onset of systolic or diastolic dysfunction in patients receiving cardiotoxic chemotherapy regimens at transthoracic echocardiography. Strain analysis at echocardiography can be limited by acoustic windows and difficulty visualizing the entire heart for regional strain analysis. Cardiac MRI is the reference standard for biventricular systolic function assessment and early work has demonstrated promise for quantification of diastolic function. Myocardial strain analysis at cardiac MRI has shown promise with myocardial tagging. However, due to the thin right ventricular myocardium, strain analysis with this technique is challenging. Recently, a technique has been developed to calculate Lagrangian strain from cine balanced steady state free precession (bSSFP) images. Preliminary work by our group has shown good agreement between myocardial strain parameters derived from deformation field analysis of bSSFP cinegraphic MRI and speckle-tracking echocardiography in patients with diastolic heart failure[1]. The purpose of this study was to assess the effect of field strength and temporal resolution on the derived myocardial strain parameters. We hypothesized that average and peak strains would be similar between field strengths and that greater peak and average strain values would be obtained from sequences with superior effective temporal resolutions.

Sequence abbreviation	In-Plane resolution (mm x mm)	Slice thickness (mm)	Views per segment	Acceleration technique and factor	Effective temp res (msec)	Acquisition time (sec)
5-Seg iPat2	1.5x2.1	6	5	iPAT GRAPPA factor 2	12.5	17
14-Seg iPat2	1.5x1.5	6	14	iPAT GRAPPA factor 2	39.2	8.4
14-Seg tPat4	1.5x1.5	6	14	t-PAT SENSE factor 4	38.1	3

Table1: Sequence parameters.

Methods: 9 healthy volunteers (6 males, 44.3±13.5yrs) underwent imaging at 1.5 T (MAGNETOM Aera, Siemens AG, Healthcare Sector, Erlangen, Germany) and 3.0T (MAGNETOM Skyra, Siemens AG) under an IRB approved protocol. Pulse sequences were acquired in the short axis and 4-chamber orientations using three bSSFP sequences with varied temporal resolutions (Table 1). Strain values were derived from deformation field analysis on prototype software (Siemens Corporation, Corporate Technology, Princeton, NJ). The deformation fields are computed using an inverse consistent deformable registration algorithm which determines the displacement of each pixel from one time frame to another (Figure 1)[2]. The myocardial borders on short axis slices are automatically extracted using the algorithm described in Jolly et al. which combines registration, gray level modeling, and optimal paths[3]. LV global and RV lateral wall longitudinal strains were obtained from 4-chamber cine acquisitions with manual endocardial contour delineation performed by a single reviewer on two separate occasions. LV circumferential and radial strains were obtained from short-axis acquisitions with automatic endocardial contour detection. Derived global strain values were compared for each technique between field strengths (1.5T vs 3.0T) and between sequences at each field strength using the student's t-test. Intraobserver variance was assessed for CMR-derived RV and LV longitudinal strain analysis using the intraclass correlation coefficient (ICC).

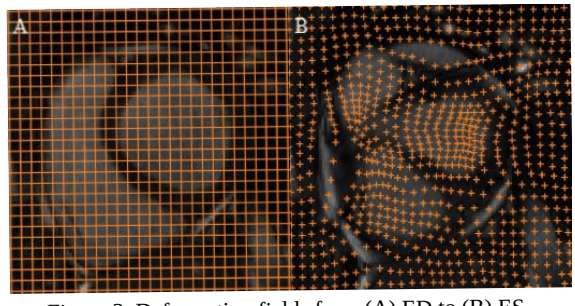

Figure 2. Deformation fields from (A) ED to (B) ES.

Results: Myocardial strain analysis was successful for all sequences at both field strengths. Average and peak systolic strains by region and sequence are shown in Table 2. No significant differences were found between or within field strengths for LV Radial and LV Circumferential strains across all acquisitions ($p>0.05$). The following significant differences were found for longitudinal strain between field strenghts: 5-Seg iPat 2 peak LV global longitudinal strain (-24.8 vs -25.3, $p=0.047$); 14-Seg iPat 2 average RV lateral wall longitudinal strain (-19.5 vs -16.0, $p=0.025$), peak RV lateral wall longitudinal strain (-26.4 vs -20.4, $p=0.041$) (Table 2). Comparison between lower resolution acquisitions and 5-Seg NIR were significantly different only when compared across the following segments at 3T: 14-Seg iPat 2 average LV longitudinal strain (-13.9 vs -16.6, $p=0.007$) and 14-Seg t-PAT 4 peak strain LV longitudinal strain (-20.9 vs -25.3, $p=0.022$)(Table 2). ICC values showed excellent Intra-rater reliability (ICC > 0.8) for both average and peak LV and RV longitudinal strain analysis at 1.5T and 3.0T, with the exception of only adequate reliability for RV lateral wall peak strain using the 14-Seg iPat 2 acquisition at 1.5T (ICC=0.65).

Discussion: Our results demonstrate that Lagrangian strains calculated from deformation field analysis are similar between 1.5T and 3T. This suggests that strain data obtained from either field strength is comparable, although there was a non-significant trend towards higher strain values at 1.5T. In addition, improvements in the temporal resolution from 39.2 to 12.5 msec did not result in significantly different peak or average myocardial strains. This suggests that temporal resolutions greater than 12.5 msec may be necessary to improve resolution of myocardial strain values.

Conclusion: Lagrangian strain values calculated from deformation field analysis on bSSFP sequences are regionally similar across field strengths and temporal resolutions ranging from 12.5 to 39.2 msec. Our results suggest that routine clinical bSSFP sequences are of adequate temporal resolution for myocardial strain analysis.

References: 1. Smith et al. SCMR 2014. 2. Guetter et al. Proc. ISBI, 2011. 3. Jolly et al. Proc. ISBI, 2010.

Strain	Sequence	LV Long	RV Long	LV Circ	LV Radial
Average	5-Seg iPat 2	-16.6, -17.6	-17.8, -17.3	-17.3, -17.5	41.5, 40.8
	14-Seg iPat 2	-16.9, -13.9	-19.5, -16.0	-17.7, -15.9	43.7, 37.1
	14-Seg tPat 4	-16.9, -16.6	-15.0, -13.9	-16.3, -16.9	34.2, 36.0
Peak	5-Seg iPat 2	-24.8, -25.3	-22.7, -22.8	-24.4, -25.0	77.3, 75.0
	14-Seg iPat 2	-24.0, -21.3	-26.4, -20.4	-24.6, -23.1	73.4, 70.6
	14-Seg tPat 4	-23.5, -20.9	-21.8, -20.4	-24.3, -25.1	66.0, 65.2

Table 2: Derived myocardial strain values (%) (1.5T, 3.0T) by strain type and sequence. Yellow cell shading indicates a significant difference was found between field strengths. Red text indicates that a significant difference was found compared to 5-Seg ipat 2 strain value at the same field strength.