Evaluation of CSPAMM with steady state free precession for myocardial tagging at 3T

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Introduction: Imaging at 3T significantly improves myocardial tagging using spoiled gradient echo based sequences (GRE) [1]. Tagging sequence with steady state free precession (SSFP) readout offers, at 1.5T, high contrast and robust quantification of contraction, similar to what is achieved at 3T using GRE sequences [2]. Complementary spatial modulation of the magnetisation (CSPAMM) further improves myocardial tagging persistency by subtracting complementary tagged images at cost of a lower temporal resolution [3]. The purpose of this study is to evaluate the performance of CSPAMM balanced SSFP tagging sequence at 3T.
Methods: 6 volunteers and 10 patients were imaged at 3T and 1.5T (Siemens Medical Solutions, Erlangen, Germany), using both spatial modulation of the magnetisation (SPAMM) and CSPAMM (single breath hold balanced SSFP line tagging with linearly increasing start-up angles (LISA))[4]. The temporal resolution was 39ms for CSPAMM and 21ms for SPAMM (respectively 27 and 50 phases per RR interval). The field of view was 340 x340 mm, matrix 256 with 32% phase resolution, bandwidth 850 Hz, slice thickness 7 mm, TE 1.28 (TE 1.54 @ 3T) and Flip angle 20° (15° @ 3T). We evaluated for every sequence contrast to noise ratio (CNR) and relative tag contrast. As we did not use any parallel imaging technique, contrast to noise ratio (CNR) was defined as difference of signal in the myocardium (S_line) and in an adjacent tag (S_tag) over the standard deviation of the background noise. The relative tag contrast was: (S_line- S_tag) / S_line . Images were analyzed using Extrema Temporal Chaining (ETC) [5]. Myocardial strains were computed from the tracked contours at endocardium, mid-wall and epicardium in six cardiac sectors and averaged over the 6 volunteers. The diagnosis accuracy of the technique was finally evaluated on the 10 patients.
Results: For all volunteers and patients, CSPAMM gave very good image quality at 3T (Fig.1). The complex subtraction to obtain CSPAMM images lead to a suppression of the stationary banding artefacts seen on SPAMM images at 3T (fig.1). As expected, we measured an improved absolute CNR when imaging at 3T, both for CSPAMM and SPAMM (Fig.2). In addition, CSPAMM demonstrated an improved tag contrast persistency versus SPAMM, at both field strength (Fig. 2). The strain measurements were successfully performed in every case with CSPAMM, whereas for SPAMM analysis failed in 3 patients due to artefacts. No significant differences were found between the different techniques, regarding circumferential shortening (CS) in volunteers (fig. 3). No discrepancies were found between quantitative CS measurements with CSPAMM at 3T and expert analysis based on the complete clinical and imaging examination.
Conclusion: CSPAMM with balanced SSFP is feasible at 3T and even more improves considerably myocardial tagging MRI. It combines gain of absolute CNR from the field strength with improved relative tag contrast, easing thus the post processing. Sensitivity to typical SSFP banding artefacts is drastically reduced with CSPAMM. Moreover our study seems to show that the lower temporal resolution of the CSPAMM technique (compared to SPAMM) does not affect the accuracy of the CS measurements. CSPAMM with balanced SSFP at 3T appears, then, to be a powerful technique to study myocardial function including diastolic relaxation.
References 1.Valeti, V.U., et al., J Magn Reson Imaging, 2006. 23(4): p. 477-80; 2. Johnson, T.R., et al., Eur Radiol, 2007. 17(9): p. 2218-24; 3. Fischer, S.E., et al., Magn Reson Med, 1993. 30(2): p. 191-200; 4. Zwanenburg, J.J., et al., Magn Reson Med, 2003. 49(4): p. 722-30; 5. Jacob, J.P., et al., LNCS, 2006. 4179: p. 897-908.

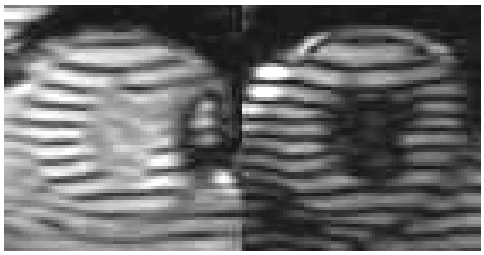

Figure 1: Mid ventricular short axis view of the heart (end systole) in one patient using SPAMM (left) and CSPAMM (right) at 3T.

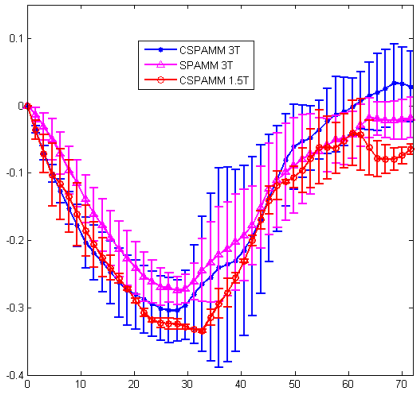

Figure 3: CS at endocardium in one sector (infero-lateral) for all volunteers and all sequences, showing no loss of accuracy for CSPAMM at 3T.

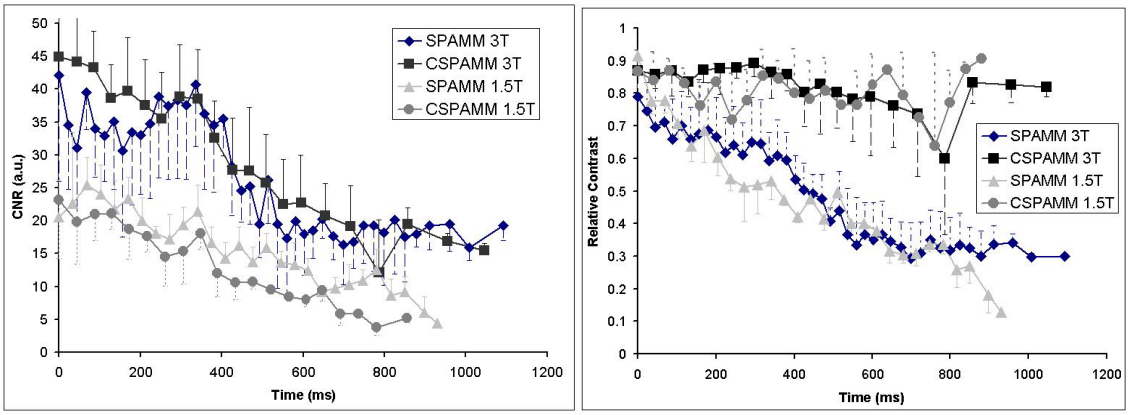

Figure 2: Mean ± SD contrast to noise (CNR) values (left) and relative tag contrast values (right) for all volunteers and patients (n=16). Tag imaging at 3T improves significantly the CNR by comparison to tag imaging at 1.5T. Advantage of the CSPAMM sequence over the SPAMM in terms of tag persistency is well demonstrated at both 1.5T and 3T.