Cardiac Magnetization Transfer Imaging Using SSFP at 3T

O. M. Weber[1,2], P. Speier[3], K. Scheffler[1], and O. Bieri[1]

[1]Radiological Physics, University of Basel, Basel, Switzerland, [2]Siemens Healthcare, Zurich, Switzerland, [3]Siemens Healthcare, Erlangen, Germany

Introduction: It has been shown recently that the balanced steady-state free-precession (bSSFP) cine sequence, as it is used routinely for the assessment of myocardial function, shows effects of magnetization transfer (MT). These effects were successfully exploited at 1.5 Tesla [1] and at 3 T [2], offering a novel technique for myocardial tissue characterization, e.g. in acute myocardial infarct. However, SSFP at 3 T poses considerable difficulties due to increased susceptibility to off-resonance banding artefacts and limitations in flip angle as mandated by specific absorption rate (SAR) regulations. On the other hand, increased SNR and/or improved spatial resolution achievable at 3 T promise increased diagnostic value compared to 1.5 T. In this work we explored cardiac MT imaging at 3 T.

Materials and Methods: A prospectively triggered balanced SSFP sequence was adapted to acquire two cine data sets with different MT weighting, as previously described [1,3]. In short, strong MT weighting was achieved using shortest possible radiofrequency (RF) pulses with high power, whereas lower MT weighting was achieved by stretching the RF pulses in time and reducing their power accordingly to achieve identical flip angles. For both acquisitions, the shortest possible repetition time (TR) was chosen in order to maximize the difference in MT. MTR was then calculated according to $MTR = (SI_{weakMT} - SI_{strongMT}) / SI_{weakMT} \times 100\%$, where SI_{weakMT} and $SI_{strongMT}$ are the signal intensities in the images with weak and strong MT weighting, respectively.

Normal volunteers with no known cardiac disease were imaged in a 3 T MR imager (Magnetom Verio, Siemens Healthcare, Erlangen, Germany). As is common procedure prior to 3 T cine SSFP imaging, a frequency scout scan was performed to minimize interference of off-frequency banding artefacts with the volume of interest, i.e., the heart. The frequency scout scan (single-shot SSFP, spatial resolution 1.7 x 1.9 x 6 mm^3, acquisition time 426 ms per image, acquired in diastole) covered different frequency offsets between -300 Hz and +300 Hz at intervals of 50 Hz. TR was chosen to correspond to the one of the weakly MT weighted acquisition (i.e., TR=4.15 ms). The optimal frequency offset was determined visually and used for subsequent SSFP acquisitions.

The two data sets with strong and weak MT weighting were acquired in a single breathhold of 18 heart beats duration in standard orientations (short axis, four chamber view, and two chamber view). A matrix of 256 x 146 was used to cover a field-of-view of 340 x 276 mm^2 at 8 mm slice thickness, resulting in a spatial resolution of 1.3 x 1.8 x 8 mm^3. RF pulse durations were 0.3 and 1.9 ms for strong and weak MT weighting, respectively. Corresponding echo times were 1.07 ms and 1.87 ms, respectively; repetition times, 2.65 ms and 4.15 ms, respectively. In order to stay within permitted SAR limits, maximum flip angle was 30°. Fifteen k-lines were acquired per heart-beat, resulting in frame durations of 40 ms and 62 ms, respectively. The frequency offset was linearly adjusted to the two different TR's to provide artefact-free images at both TR's. Signal intensities were determined in regions of interest drawn manually in the septum of the myocardium and in the blood in the left ventricular cavity.

Results and Discussion: Imaging was successful in all subjects. The frequency scout images indicated optimal frequency offsets in the range -100 Hz to +50 Hz. The cine bSSFP images with strong and weak MT weighting were of good quality (Fig. 1). Banding artefacts were present only outside of the myocardium. For normal myocardium, MTR values were 26.7 % ± 1.2 % (mean ± stdev). MTR values reported for 1.5 T using a similar method were approximately 32% [1]. The difference might be explained by the reduced flip angle allowed at 3 T (30°, as compared to 45° at 1.5 T) and a slightly longer RF pulse, leading to a reduced MT effect in the strongly MT-weighted image. On the other hand, shortening TR as much as possible provides an increased MTR compared to identical TR's for both measurements, as reported in [2], where a maximal MTR value of 15% was found. For arterial blood, mean MTR value was 5.6 % ± 6.2 %, which is in agreement with absence of MT in blood.

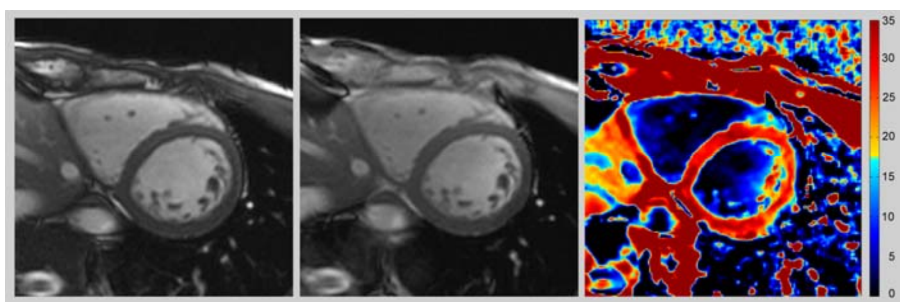

Fig. 1: *Short axis images with strong (left) and weak (middle) MT weighting. Note the difference in signal intensity of the myocardium. Right: The corresponding MTR map.*

Conclusions: MT imaging in the myocardium using a cine bSSFP sequence is possible at 3 T. In comparison to 1.5 T, a slight reduction in MTR values is seen. However, the MT effect is expected to be sufficient to allow the distinction between normal and acutely infarcted myocardium, where MTR is reduced by approximately 50%. In addition, the increased SNR available at 3 T might allow for higher spatial resolution and thus bears the potential to prove beneficial for diagnostic purposes.

References

[1] Weber O et al, Proc ISMRM 2007, 2518 [2] Sung K et al, Proc ISMRM 2008, 1401 [3] Bieri O et al, MRM 56:1067 (2006)