Multichannel RF Transmission Improves Cardiac Cine bSSFP MRI at 3.0T

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Introduction Cardiac magnetic resonance (CMR) imaging has proven to be an important clinical application in a number of diagnostic questions and is now routinely used at many sites. After initial development on 1.5T MR imagers, an increasing number of CMR examinations is now performed on 3T systems, which have seen a recent boost in number of installations. Especially contrast-enhanced sequences, such as the assessment of myocardial perfusion by means of first-pass CMR and the depiction of non-viable myocardium on late enhancement images, profit from the higher signal to noise ratio (SNR) provided by the higher field strength, as well as from the inherently longer T_1 relaxation times. On the other hand, quality of the balanced steady-state free-precession (bSSFP) images, routinely used in cine mode for the visualization of myocardial function, is frequently inferior on conventional 3T systems as compared to 1.5T systems [1]. This is caused by a number of effects. Higher radio frequency (RF) power deposition leads to the need for reduced flip angle and/or longer repetition times (TR) in order to stay within the specific absorption rate (SAR) limits, compromising the resulting contrast and shifting the banding artifacts closer to the volume of interest, respectively. Reduced B_1 homogeneity affects the steady-state condition and leads to an increased level of flow artifacts. Recently, the first clinical 3T systems with multi-channel transmission for RF excitation became available. Aimed primarily at increasing the homogeneity of the B_1 excitation field, the technology also reduces peak RF power deposition and thus imposes less stringent limits on RF management [2]. The aim of the present study was to examine the effects of two-channel RF transmission on cine bSSFP images of human hearts in vivo.

Methods Six normal volunteers (mean age, 33.6±6.3 yrs, 5 men) without known cardiovascular disease were imaged in a clinical 3T whole body MR imager equipped with two-channel multi-transmit (MTx) technology (Achieva TX; Philips Healthcare, Best, the Netherlands). Images with different spatial in-plane resolutions (1x1 mm^2, 1.5x1.5 mm^2, and 2x2 mm^2) were acquired using a 32-channel receive coil in several short axis and four-chamber view orientations. Further imaging parameters included: field of view, 32 cm; number of heart phases, 20; slice thickness, 8 mm; flip angle, 45 degrees; SENSE acceleration, 2. TR was chosen as short as the system allowed with maximal readout bandwidth; echo time (TE) was set to half of TR. Imaging was performed once with MTx switched on, and once while MTx was switched off. Prior to MTx acquisition, a cardiac triggered B_1 reference scan based on the saturated double-angle method [3] was performed for automatic determination of the optimal MTx settings.

For quantitative evaluation of the resulting images, regions of interests (ROIs) were manually drawn in the septal myocardial wall and the left ventricular blood pool on images depicting end-diastolic and end-systolic images. Contrast-to-noise ratio (CNR) between blood and myocardium was calculated according to

$$CNR = \frac{SI_{blood} - SI_{myocardium}}{0.5\ (SD_{blood} + SD_{myocardium})}$$

where SI indicates signal intensity and SD, standard deviation. Significance of differences was evaluated using a paired t-test with a significance level of p=0.05.

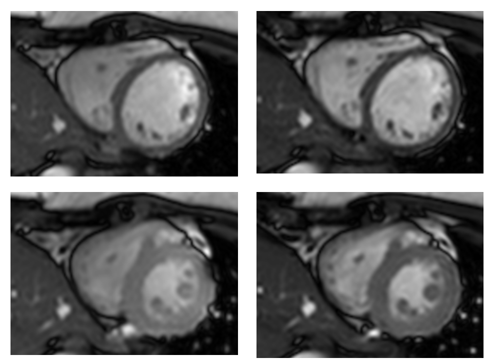

Fig 1: Example short axis bFFE images from one volunteer acquired in diastole (top) and systole (bottom), without (left) and with (right) multi-channel transmission. Note the difference in contrast between images on the left and on the right.

Results Imaging was successful in all subjects. TR varied in dependence of spatial resolution, of whether MTx was switched on or not, as well as of geometrical orientation of the imaging slices. With MTx activated, minimal TR times were 3.4 ms - 3.8 ms at 1 mm resolution; 2.9 ms - 3.2 ms at 1.5 mm; and 2.6 ms - 2.8 ms at 2 mm. Without MTx, TR times were 0.3 ms - 0.4 ms longer. Myocardium in MTx images showed darker and with strongly increased contrast to the blood, depicting myocardial function more clearly. CNR between blood and myocardium was significantly higher with activated MTx (14.0±4.8 vs. 11.6±6.8; p=0.0016). Looking at the different spatial resolutions separately revealed significant differences at 1 mm spatial resolution (p=0.0001) as well as at 1.5 mm (p=0.0002), but not at 2 mm (p=0.24). Artifact levels due to blood flow and B_1 inhomogeneity were considerably reduced in MTx images, resulting in more homogeneous apparition of the blood pool and in more uniform signal intensity over the entire field of view. Furthermore, the shorter TR available with the use of MTx moved the banding artifacts farther away from the heart.

Discussion Activation of the MTx option increased B_1 homogeneity and reduced TR by 0.3-0.4 ms, leading to better contrast between myocardium and blood pool and fewer image artifacts caused by flowing blood. Resulting images were drastically improved and showed cardiac function more clearly. The effect was more pronounced at higher spatial resolution, as the effects become more severe at longer TRs and reduction in TR obtained with MTx proved to be particularly beneficial. Alternatively, the gain in TR could be traded in for a higher flip angle, which would also increase CNR.

Conclusions RF transmission using multiple channels significantly improves the image quality of cine bSSFP of the heart at 3T and greatly enhances its diagnostic value, allowing for routine usage of CMR also at 3T.

References [1] Oshinski J et al., *JCMR* **12**:55 (2010) [2] Willinek WA et al., *Radiology* **256**:966 (2010) [3] Cunningham CH et al., *MRM* **55**:1326 (2006)