IMPROVEMENT IN B1+ HOMOGENEITY OF 3T CARDIAC MRI IN SWINE WITH DUAL-SOURCE PARALLEL RF EXCITATION

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Introduction: Conventional MRI scanners up to a magnetic field strength of 3T use an integrated birdcage quadrature coil to generate a radio frequency (RF) excitation field (B_1+). At 3T, Sung et al. observed a flip angle variation ranging from 31 to 66% over the entire left ventricular volume in humans [1]. They further reported a flip-angle distribution from 34° to 63° across the left ventricle, for a nominal flip angle of 60°. This not only demonstrates that the B_1+ field over the left ventricle is inhomogeneous but also that the average flip angle (RF power setting) can be 20% lower than the one requested. Such erroneous flip angles may lead to local signal reduction, artifacts, failure of magnetization preparation pulses, and eventually to biased quantitative measures. Recently, it has been shown that multi-channel transmit systems can be used to reduce these inhomogeneities in humans by the use of RF-shimming [2-5].

Purpose: To quantify improvements in B_1+-homogeneity at 3T when using dual-source parallel RF excitation as correlated to cross-sectional body size.

Methods: *Swine Imaging:* Twenty-two swine were imaged repeatedly and at different times as part of other imaging studies. Time between scans ranged from 2 days to 11 months. Animal weight varied between ~25 and 125 kg. Overall, *N=44* independent imaging sessions were analyzed. B_1+-mapping was carried out before and after RF-shimming using a cardiac-triggered, breath-hold, saturated dual-angle method [6]. Data were acquired in diastole. A volume manually drawn over the heart, primarily through the ventricles was used to localize the shimming. B_1+-maps parameters were: 4x4 mm^2 pixels, 10 mm slice thickness. All imaging used a 3.0T MR system (Achieva TX, Philips Healthcare, Best, The Netherlands) and a 32-channel cardiac array (InVivo, Gainsville, FL). Animals were placed in a left lateral decubitus position for imaging, resulting in the heart resting on the left chest wall, very close to areas of consistent dielectric shading. *Image analysis:* Both magnitude images produced from B_1+-mapping and the B_1+-maps were used in the analysis. An elliptical ROI was drawn using the magnitude image as a guide, and aimed to cover the whole heart. Pixel values where then extracted from the B_1+-map, and represent the percent of the desired flip angle achieved. For example, a value 75% on the B_1+ map implies that for that pixel 75% of the desired flip angle was achieved. Cardiac ROIs had an average of (±sd) 361±91 pixels. Since B_1+ depth penetration is expected to be worse for larger or more ellipse-shaped animals, animal size was characterized by drawing an additional elliptical ROI encompassing the whole animal. These larger ROIs had 2416±472 pixels (surface area of ~0.039±0.008 m^2) (Fig 1). Statistical significance was established using paired two-tailed Student's T-tests.

Results: Typical B_1+-maps acquired before and after RF-shimming can be seen in Figure 1. Superimposed are the elliptical ROIs used to cover the heart as well as to estimate the cross-sectional area of each animal. A breakdown of the comparison of pre- and post-RF-shimming values can be seen in Figure 2. In all cases, the average percent flip angle achieved increased after RF-shimming. Without B_1+-shimming, cardiac ROIs had a mean value of 76.1%±8.0, while B_1+-maps with shimming had a mean value of 96.4%±5.36 ($p<<1e-10$). The average coefficients of variation (CV, std/mean) within each ROI on the B_1+-map were 0.118±0.035 and 0.068 ± 0.018 ($p<<1e-10$) without and with the use of the dual transmit shimming, respectively, indicating that fields were significantly more homogeneous after RF-shimming. The cross-sectional area of each animal is correlated to both pre-and post achieved flip angle (R^2=0.71, 0.51, respectively) but less so for values measured after RF-shimming. The relative improvement, ratio of post-to-pre achieved flip angle percentage, was also positively correlated to cross-sectional area (R^2=0.54), as can be seen in Figure 2.

Conclusion: The use of localized RF shimming with dual transmit sources significantly increases the effective flip angle achieved and reduces the B_1+ variations in the targeted area. Though not shown here, these improvements should have significant effects in SNR and the predictability of image quality since current cardiac imaging involves high flip angle RF pulses (i.e. IR, T2-Prep) whose performance can be affected by B_1+ heterogeneity. Here we show that not only does the degree of loss due to dielectric effects depend on animal size, so does the magnitude of the improvement in B_1+ homogeneity.

References: [1] Sung K, et al. JMRI 27(3), 2008. [2] Mueller A, et al. Radiology 263(1), 2010. [3] Nelles M, et al. Radiology, 257(3), 2010. [4] Rahbar,H. et al. JMRI 35, 2012. [5] Willinek W., et al. Radiology 256(3). 2010. [6] Cunningham CH, et al. MRM 55(6) 1326–1333, 2006.

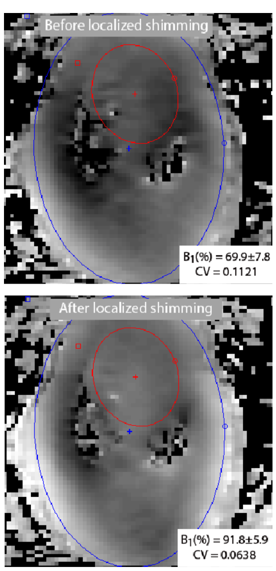

Figure 1: Sample B_1+-maps obtained before and after RF-shimming. Red ROIs cover the heart, while the blue ROIs are used for estimation of animal cross sectional area.

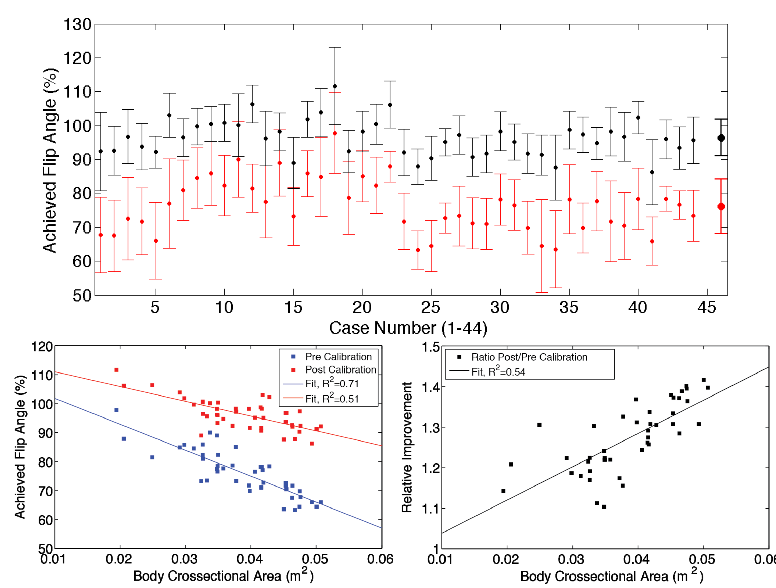

Figure 2: Top: Case by case breakdown (N=44) of B_1+-mapping results. Values represent the percentage of the desired flip angle achieved in the cardiac ROI. Blue and red points correspond to ROI mean values before and after RF-shimming, respectively. Error bars indicate ROI standard deviation. Mean values are shown at the far right. **Bottom**: Correlation of cross-sectional area with achieved flip angle (%) (left) and with ratio of post-to-pre RF-shimming improvement in achieved flip angle (right). Significant correlations are observed indicating that animal size reduces achieved flip angle (as expected), but also that RF shimming has a more positive effect when imaging larger animals.