In vivo mapping of the peak B1+ field strength on a conventional scanner

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Introduction: The maximum achievable B_1^+ (amplitude of the circularly polarized transmit field rotating in the same sense as the magnetization) is a function of the radiofrequency (RF) coil, RF amplifier, patient size and shape, and local dielectric effects. Knowledge of the maximum B_1^+ field enables one to optimize RF pulses and pulse sequences and has become increasingly important at high field strengths. We present a rapid method for mapping the peak B_1^+ field using prescan variables and a rapid relative B_1^+ mapping pulse sequence. This approach is applied to human cardiac imaging on a commercial 3T system.

Methods and Results: The vendor supplied automatic prescan calibrates a transmit gain to determine the amount of RF power that will produce a 90º excitation. The maximum achievable B_1^+ field (***Peak B_1^+***) can be conversely computed (assuming the maximum RF amplifier power is applied):

$$Peak\ B_1^+ = B_{1max,seq} \times 10^{(200-TG)/200}$$

where $B_{1max,seq}$ is the highest B_1 amplitude among all the RF pulses used in the pulse sequence and TG is the transmit gain ranging from 200 to 0, representing an attenuation of 0 to -20 in dB [1]. For example, if $B_{1max,seq}$ is 0.146G and TG is 180 (-2dB), then *Peak* B_1^+ is 0.1838G. The parameter TG is measured by the overall signal strength from the prescribed scan plane, and therefore *Peak* B_1^+ represents the gross maximum B_1^+ in the prescribed scan plane. A local region, however, can comprise different maximum B_1^+ fields due to B_1^+ inhomogeneity. B_1 mapping is able to provide the spatial information of relative spatial B_1 scales ($b_1(x,y)$; actual flip angle divided by nominal flip angle). The local maximum B_1^+ can then be computed as multiplying $b_1(x,y)$ by *Peak* B_1^+.

Experiments were performed on two GE 3T scanners. Quadrature birdcage body coils were used for RF transmission and an 8-channel cardiac phased array coil was used for signal reception. The maximum RF amplifier power was 20kW. The maximum B_1 fields were measured in 21 subjects (7 cardiac patients and 14 healthy volunteers) using prescan information (TG and $B_{1max,seq}$) and the saturated double-angle method (SDAM) [2,3]. Slice profile imperfections were compensated when computing $b_1(x,y)$ [4]. Basal, medial, and apical slices were chosen for each subject, and the left ventricular (LV) myocardium was manually segmented in 3 short-axis slices.

Fig 1 shows a representative example of maximum B_1^+ maps. The histograms of maximum B_1^+ fields over the LV myocardium are shown on the bottom. The gross maximum B_1^+ (***Peak B_1^+***) was computed from TG and $B_{1max,seq}$. while minimum (***Min B_1^+***), maximum (***Max B_1^+***), and average (***Mean B_1^+***) maximum B_1^+ over LV were computed from TG, $B_{1max,seq}$, and $b_1(x,y)$. Table 1 contains all the statistical data (mean ± SD) for maximum B_1^+. The *Peak* B_1^+ for all 21 subjects was 0.189 ± 0.017G while the minimum and maximum *Peak* B_1^+ were 0.157G and 0.224G, respectively. Maximum B_1^+ fields over LV in each column (*Min vs. Max vs. Mean*) were significantly different between each other ($p < 0.05$) while maximum B_1^+ fields in each row (*a vs. b vs. c*) were not significantly different.

The reproducibility of maximum B_1^+ within the same subject was investigated in 4 healthy subjects. Five separate measurements were performed on different days with random orders. Only the medial short-axis slice was chosen. Fig 2 shows the maximum B_1^+ fields (mean ± SD) for all 4 subjects. *Max* B_1^+ and *Min* B_1^+ were significantly different for all 4 subjects ($p < 0.05$) while *Peak* B_1^+ and *Mean* B_1^+ were not significantly different for subject 2 and 3. The statistical values (*Peak* B_1^+, *Min* B_1^+, *Max* B_1^+, and *Mean* B_1^+) for each subject were not significantly different between each subject, but were well within the boundary of the previous result in Table 1. This indicates the maximum B_1^+ fields can vary within the same subject as much as they do across different subjects. This may suggest the scan plane prescription can be an important factor in the maximum B_1^+ fields.

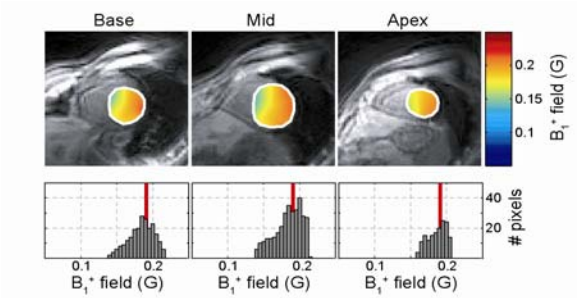

Figure 1: (Top) Maximum B_1^+ field maps in one representative subject, and (Bottom) the histogram of corresponding gross (red line) and spatially varying maximum B_1^+ fields. Compared to what is reported in [3], all units are in Gauss, and reflect the maximum achievable B_1^+ with the given hardware.

	Base	Mid	Apex
Peak B_1^+	0.189±0.017 (0.157 - 0.224)		
Min B_1^+	0.139±0.032[a]	0.134±0.030[b]	0.147±0.027[c]
Max B_1^+	0.200±0.031[a]	0.198±0.029[b]	0.192±0.026[c]
Mean B_1^+	0.177±0.030[a]	0.171±0.028[b]	0.172±0.024[c]

Table 1: Maximum B_1^+ fields over the LV myocardium (base, mid, and apex) in 21 subjects. *Min* B_1^+, *Max* B_1^+, and *Mean* B_1^+ in each column were statistically different from each other ($p < 0.05$). All units are in Gauss.

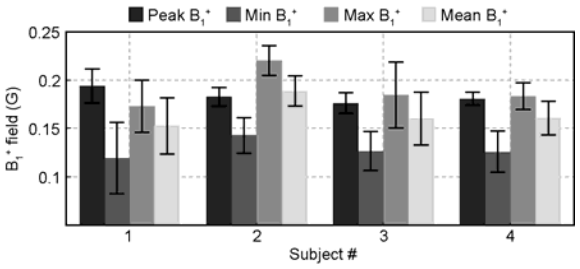

Figure 2: The reproducibility test of maximum B_1^+ fields within the same subject.

Discussion: We have shown that it is possible to utilize prescan information to map the maximum achievable B_1^+ *in vivo*. The prescan variables used in this work were specific to the GE systems, and other B_1 mapping methods could be incorporated to provide relative B_1^+ amplitude [5]. The knowledge of the available maximum B_1^+ field can increase the bandwidth of 180º pulses in spectroscopy reducing chemical shift errors, and can estimate how much to overdrive adiabatic pulses. In conclusion, the maximum B_1^+ in the chest (gross) was 0.189 ± 0.017G, and the maximum B_1^+ across the heart varied from 0.134 ± 0.030G (-29%) to 0.200 ± 0.031G (+5.8%) with body coil transmission on GE 3T systems. The repeated measurements performed on the same subjects showed the variability of maximum B_1^+ within the same subject was high.

References: [1] Barker GJ, et al. Br J Radiol 1998 [2] Cunningham CH, et al. MRM 2006, [3] Sung K, et al. JMRI 2008, [4] Schar M, et al. ISMRM 2008 p358 [5] Yarnykh VL. MRM 2007