Transmit Power Reduction and B_1^+ Homogenization Using 4-channel Regional RF Shimming for Shoulder Imaging at 3T

Yukio Kaneko[1], Yoshihisa Soutome[1,2], Kosuke Ito[2], Masahiro Takizawa[2], Hideta Habara[1,2], Yusuke Seki[1], Tetsuhiko Takahashi[2], Yoshitaka Bito[2], and Hisaaki Ochi[1]
[1]*Central Research Laboratory, Hitachi Ltd., Kokubunji-shi, Tokyo, Japan,* [2]*Hitachi Medical Corporation, Kashiwa, Chiba, Japan*

TARGET AUDIENCE RF engineers or scientists with an interest in RF shimming

INTRODUCTION

The B_1^+ inhomogeneity in a human body increases as the strength of a static magnetic field increases. Various methods of multi-channel RF transmission to reduce the B_1^+ inhomogeneity have recently been developed. One of these methods, RF shimming [1, 2], is currently used for commercial MRI systems. The impact of the number of RF transmit channels (ch) has been investigated experimentally and numerically [3, 4], and the effect of the regional RF shimming for torso and breast imaging has been shown [5,6]. On the other hand, the effect for the shoulder imaging, especially in the case in which a human body is positioned off-center and one side of the shoulder is observed, has not yet been investigated. In this study, the effect of the number of RF transmit channels between 2ch and 4ch RF shimming for the shoulder imaging was investigated using numerical simulation. It was confirmed that 4ch RF shimming can contribute to improve the B_1^+ homogeneity and reduce the transmit RF power more than 2ch RF shimming.

METHOD

The effect of the number of RF transmit channels at 3T was confirmed with numerical analysis of an electromagnetic field. The spatial distributions of B_1^+ in the human model were calculated using an electromagnetic simulation tool (CST Microwave Studio™). The simulation model is shown in Figure 1. A four-channel coil was used for RF transmission [7]. The inner bore size (x-y plane) was 74 x 65 cm. Hanako (height: 160 cm, weight: 53.0 kg) [8] and Fats (height: 182 cm, weight: 120 kg) were used as human models. The landmark position was set at the shoulder joint in the z-direction. The human models were set off-center, and the position of the shoulder joint was moved as close as possible to the center of the RF coil in the x-direction. Figure 2 shows the schematic of the position of the ROIs used in RF shimming. The whole ROI covered the entire shoulder region in an axial plane, the 1/2 ROI covered the right side of the entire shoulder region, and the 1/4 ROI covered the region of the right shoulder joint. B_1^+ map data in each region was used to optimize B_1^+ homogeneity. The value of B_1^+ homogeneity (U_{SD}) was defined as $U_{SD} = \sigma/\overline{B}_1$, where σ is the standard deviation of B_1^+ and $\overline{B}_1$ is the average of B_1^+ in an axial slice at z = 0 mm. The normalized value of the total RF transmit power (P_{SUM}) was defined as below:

$$P_{SUM} = \sum_{i=1}^{N} |\omega_i|^2 \Big/ P_{QD}$$

where ω_i represents the RF parameter, i represents the channel number, N represents the number of the channels (2 or 4), and P_{QD} represents the total RF transmit power in the case of quadrature (QD) drive. RF transmission mode was QD drive / 2ch RF shimming / 4ch RF shimming. 2ch RF shimming was conducted by combining B_1^+ maps of two channels (ch1 and ch3 / ch2 and ch4). 4ch RF shimming was conducted by using a B_1^+ map of each channel. The U_{SD} or P_{SUM} was minimized in the RF shimming algorithm.

RESULTS AND DISCUSSION

The B_1^+ maps in the case of RF shimming (minimization of U_{SD} for 1/4 ROI) are shown in Figure 3. Cases (a) and (b) represent the B_1^+ map in QD drive; cases (c) and (d) represent that obtained in 2ch RF shimming; and cases (e) and (f) represent that obtained in 4ch RF shimming. The $\overline{B}_1$ in each ROI was normalized to 1 µT. The values of B_1^+ homogeneity (U_{SD}) for all ROIs are shown in Figure 4. The U_{SD} in the case of 4ch RF shimming is smaller than that in the case of 2ch RF shimming.

The B_1^+ maps in the case of RF shimming (minimization of P_{SUM}, maintaining the U_{SD} and $\overline{B}_1$ for 1/4 ROI in the case of QD) are shown in Figure 5. The values of the total RF transmit power (P_{SUM}) for all ROIs are shown in Figure 6. In the case of the Hanako model, the P_{SUM} in the case of the 2ch RF shimming is almost the same as that in the case of QD. On the other hand, the P_{SUM} in the case of the 4ch RF shimming for 1/4 ROI is 32 % less than that in the case of QD or 2ch RF shimming. In the case of the Fats model, the P_{SUM} in the case of the 4ch RF shimming for 1/4 ROI is 53 % less than that in the case of QD and 43 % less than that in the case of 2ch RF shimming. The higher the reduction ratio of the P_{SUM} is, the narrower the setting of ROI is. The spatially asymmetric B_1^+ field can be created by using a four-channel transmit coil. Specifically, B_1^+ outside 1/4 ROI becomes smaller than that inside the ROI in Fig. 5. This is considered to contribute to the reduction of transmit RF power.

CONCLUSION

The effect of the number of RF transmit channels for regional RF shimming in shoulder imaging has been investigated using numerical simulation. The results show that 4ch RF shimming can contribute to improve the B_1^+ homogeneity and reduce the transmit RF power more than 2ch RF shimming.

REFERENCES

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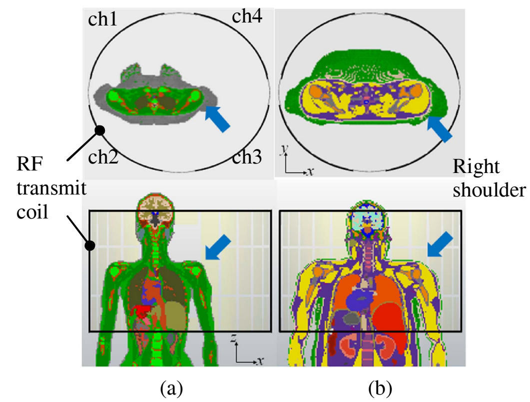

Fig.1: Simulation model for off-center shoulder imaging (a)Hanako model (b) Fats model.

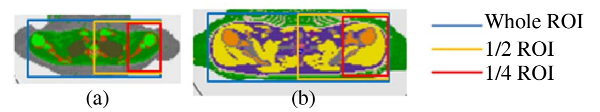

Fig.2: ROI for B_1^+ homogenization (a) Hanako model (b) Fats model.

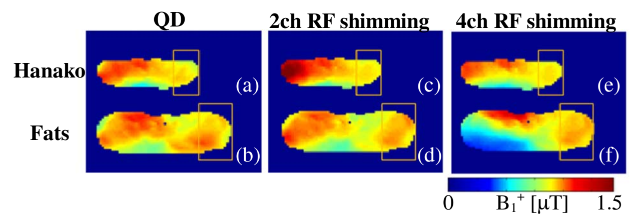

Fig.3: B_1^+ maps in the case of RF shimming (minimization of U_{SD}) (a)QD in Hanako (b) QD in Fats (c)2ch RF shimming in Hanako (d)2ch RF shimming in Fats (e) 4ch RF shimming in Hanako (f) 4ch RF shimming in Fats.

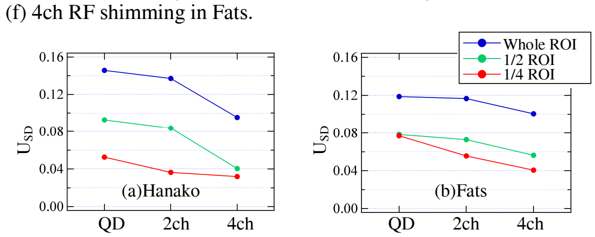

Fig.4: The relationship between U_{SD} and the number of channel.

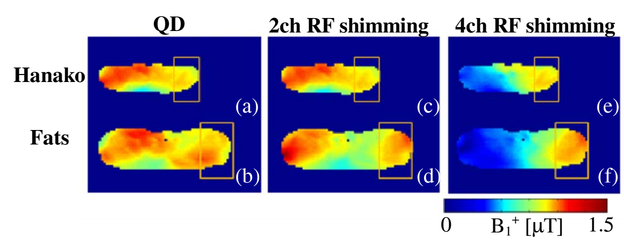

Fig.5: B_1^+ maps in the case of RF shimming (minimization of P_{SUM}).

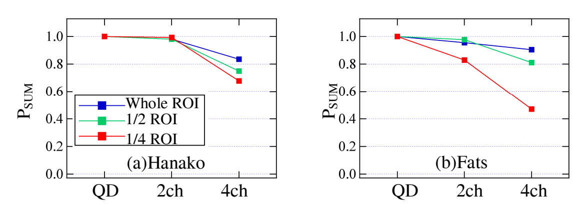

Fig.6: The relationship between P_{SUM} and the number of channel.