Prediction of RF burning: mapping of high-SAR areas using a low-RF power scan

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TARGT AUDIENCE
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PURPOSE
Prediction of the RF burning that may occur during an MRI examination is one of the key issues in MR safety. Although several methods have been developed for mapping the specific absorption rate (SAR), few practical methods for predicting RF burning have been demonstrated because of the difficulty in actualizing RF burning in a phantom study. In this study, we developed a method of mapping high-SAR areas using a low-RF power scan. We also established a setup of a phantom with an RF resonant loop to actualize RF burning, and demonstrated the prediction of RF burning.

METHODS
Gradient echo imaging of a phantom of aqueous KCl solution (0.3, 1.5, 3.0, 10, 15, 20%) was performed using a 1.5T MRI with a head coil by varying the FA (10°, 50°, 90°). To derive the phase (Φ_{RF}) of the MR signal just after the excitation pulse, the phase caused by B_0 inhomogeneity was removed using images of two TEs (10, 20 ms). We developed a theory that the spatial derivative of Φ_{RF} yields a value ($SAR' = |(\nabla\Phi_{RF})_z|^2 + 0.5\,|(\nabla\Phi_{RF})_x + (\nabla\Phi_{RF})_y|^2$) that is roughly proportional to the local SAR, where z is the direction of B_0, and we mapped the value of SAR'. A self-resonant RF loop was constructed and placed in several configurations on a phantom with egg white covered by thin film. The resonance property, the Q value, was measured using two search coils and a network analyzer[1]. This phantom with a self-resonant RF loop was imaged by a body coil with a gradient echo pulse sequence (total scan time: 2 min) by varying the FA (10°, 50°, 90°), and the value of SAR' was then mapped.

RESULTS
Changes in Φ_{RF} at the center of the phantom increased with an increase in the KCl concentration, but the value of Φ_{RF} did not depend on the FA. Although the Q value of the self-resonant RF loop itself was 183, the Q value of the RF loop that was placed flat on the egg white phantom decreased to 6.8. The SAR' value in this flat-placed case was small and did not show any RF burning, even for imaging with a large FA (90°). When the edge of the RF loop touched the egg white phantom and the configuration of the RF loop on the phantom was adjusted so that the Q value was half that of the self-resonant RF loop itself, the SAR' mapping from low-FA (10°) imaging predicted RF burning without actual burning (Fig. 1a). This prediction was proved by large-FA (90°) imaging that showed actual burning of the egg white phantom (Fig. 1b).

DISCUSSION
The value of Φ_{RF} reflects the RF field perturbation caused by RF eddy currents; the KCl concentration dependence of Φ_{RF} at the center of the phantom was in accordance with the previous results[2]. To obtain Φ_{RF} for the SAR' mapping, low-FA imaging that does not cause RF burning can be used because Φ_{RF} does not depend on FA. To validate the accuracy of the prediction of RF burning, actualization of artificial RF burning was essential. We found that a flat configuration of an RF resonant loop on a phantom does not cause burning. Because the RF loop setup with decreasing by double of the intrinsic Q of the self-resonant RF loop theoretically produces the maximum heat, the imaging experiment with such a configuration validated the accuracy of the prediction of RF burning. The signal-to-noise ratio obtained in the SAR' mapping in this experiment was sufficient, and the imaging time of the mapping can be reduced.

CONCLUSION
SAR' mapping by Φ_{RF} measured by low FA imaging can practically and safely predict RF burning prior to MRI examination.

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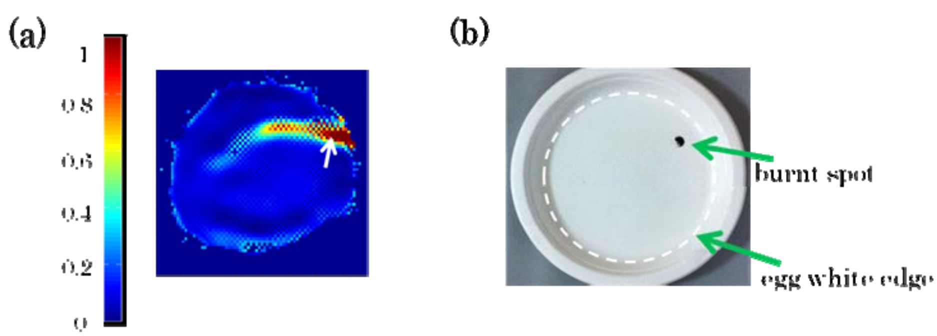

Figure 1. SAR prediction mapping from low-power imaging (FA = 10°) (a) and RF burning after high-power imaging (FA = 90°) (b).