Evaluation of Liver Radiofrequency Ablation Lesions using MREIT Conductivity Imaging

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Target audience

This study may provide new contrast information of radiofrequency (RF) ablation lesion detection. It might be helpful to the people who are interested in the clinical applications of electromagnetic tissue property mapping.

Purpose

The purpose of this study is to evaluate the potential of MREIT conductivity imaging in terms of its capability in detecting ablated lesions and differentiating tissue conditions in liver RF ablation.

Methods

RF ablation was performed in bovine livers using a LeVeen RF needle electrode. Ablation lesions were created using a power-controlled mode at 30, 50, and 70 W for 1, 3, and 5 minutes of exposure time, respectively. After ablation, the liver was cut immediately into 7×7×7 cm^3 blocks. A cylinder-shaped acrylic phantom was used for the imaging experiment. Inside the phantom, the liver block was positioned in the center and filled with agarose gel for supporting the position of the liver block. Four carbon-hydrogel electrodes were attached on the sides of the phantom and was placed the phantom inside the bore of 3T MRI scanner. Using a constant current source, the first current I_1 was injected between one opposing pair of electrodes. The injection current amplitude was 9 mA with the total pulse width of 81 ms. Multi-echo ICNE pulse sequence was used to obtain the MR magnitude and magnetic flux density (B_z) images.[1] The imaging parameters were as follows; TR/TE = 900/20, 40, 60 ms (3 echoes), FOV = 180×180 mm^2, slice thickness = 3 mm (8 slices), NEX = 8, matrix size = 128×128, and total imaging time = 40 min. After acquiring the first B_z data set for I_1, the second injection current I_2 with the same amplitude and pulse width was injected through the other pair of opposing electrodes. The single-step harmonic B_z algorithm implemented in CoReHA was used for multi-slice conductivity image reconstructions.[2] The relative conductivity contrast ratio (rCCR, %) between normal and ablated liver tissues was introduced as a quantitative criterion in the reconstructed conductivity images.

Results and Discussion

Figure 1 shows typical MREIT images of ablated liver during the 3 minutes of exposure time with the power of 50 W. The reconstructed conductivity image (Fig. 1b) clearly shows the ablated lesions which are not apparent in T2-weighted MRI (Fig. 1a). The measured conductivity values of the ablated lesions increased in both the coagulation necrosis (white arrow) and hyperemic rim (black arrow). Figure 2 represents a time-course variation of liver tissue before and after RF ablation during the 1, 3, and 5 minutes of exposure time with the same RF power. The conductivity images reveal increased contrast and well-defined lesions with more than 3 minutes of exposure time. In particular, the conductivity of the coagulation necrosis was higher than that of the hyperemic rimes. Figure 3 summarizes the quantitative analysis of MREIT conductivity images in liver RF ablation. The conductivity values in both the coagulation necrosis and hyperemic rim were significantly changed according to the increase of exposure time ($p < 0.01$). In RF powers of 30 and 50 W, significant differences between the coagulation necrosis and hyperemic rim were observed for more than 5 minutes, 3 minutes of exposure time, respectively ($p < 0.01$). In 70 W, all cases showed significant differences except 3 minutes ($p < 0.01$). The relationship between the exposure time and conductivity was significant in both two ablation lesions ($p < 0.01$).

Conclusion

This feasibility study demonstrates that current MREIT conductivity imaging can detect liver RF ablation lesions without using any contrast media and additional MR scan.

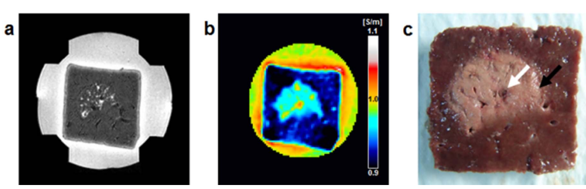


Fig. 1. (a) T2-weighted MR, (b) reconstructed conductivity images, and (c) photography of ablated liver tissue.

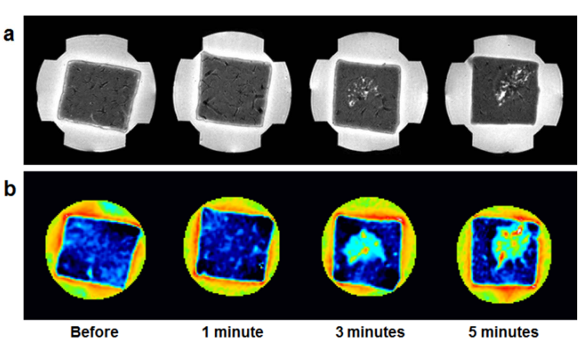
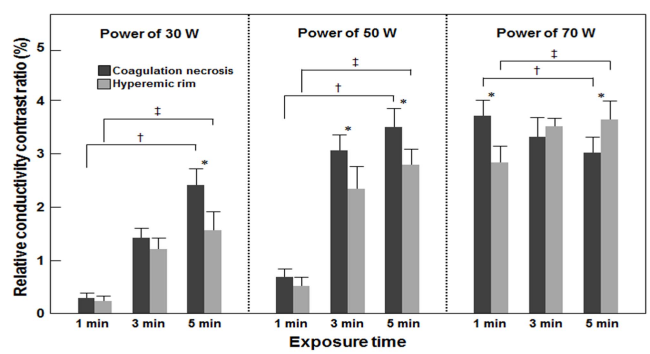


Fig. 2. Time-course images of liver tissue before and after RF ablation with the RF power of 50 W. (a) T2 weighted and (b) conductivity images obtained before and after three different exposure times.



* p value (< 0.01, Mann-Whitney test) was obtained with comparison between the coagulation necrosis and hyperemic rim.
†, ‡ p value (< 0.01, Kruskal-Wallis test) was obtained with comparison among 1, 3, and 5 minutes of exposure times.

Fig. 3. Bar graph shows the relative conductivity contrast ratio (rCCR, %) of liver tissues by different exposure times and RF powers after RF ablation.

References

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2. Jeon K, Minhas AS, et al. MREIT conductivity imaging of postmortem canine abdomen using CoReHA. Physiol. Meas. 2009;30:957-966.