In Vivo Conductivity Imaging of Human Knee using 3 mA Imaging Current

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Purpose

We performed *in vivo* MREIT human imaging experiments to validate the technique in terms of its capability to produce high-resolution conductivity images of a human knee using 3 mA imaging currents.

Materials and Methods

Four healthy volunteers (2 males, 2 females, 23 to 29 years old) participated in the human experiments. All human experiments were performed following the protocol approved by the Institutional Review Board (IRB). After attaching four electrodes around the knee, we chose one pair of electrodes to inject current. Starting from zero mA, we gradually increased the amplitude of the imaging current pulse. The subject's oral response was recorded to mark the current amplitudes for the thresholds of sensation and pain. The same procedure was repeated for the other pair of electrodes. The amplitude of imaging current was determined as the 90% of the smaller pain threshold.

Carbon-hydrogel electrodes were attached around the knee for current injections (Fig. 1). We injected 3 mA currents in two mutually perpendicular directions using two pairs of electrodes. Imaging parameters using the multi-echo sequence were as follows: TR/TE = 900/30 ms, FOV = 220×220 mm^2, slice thickness = 6 mm, NEX = 12, matrix size = 128×128, number of slices = 8, and total imaging time = 100 min.

After acquiring the first magnetic flux density (B_z) data set for the first imaging current I_1 in 8 axial slices, the second current I_2 with the same amplitude and pulse width was injected through the other pair of opposing electrodes to obtain the second data set. We used the single-step harmonic B_z algorithm implemented in CoReHA (conductivity reconstructor using harmonic algorithms) for multi-slice conductivity image reconstructions.

Results and Discussion

Figure 2(a) is a MR magnitude image of the knee from the normal male subject. Figure 2(b) and (c) show B_z images from the same slice subject to the horizontal and vertical current injections, respectively. Figure 3 compares the anatomy of the knee in (a) with magnitude image in (b) and conductivity image in (c). Conductivity images well distinguish different parts of the subcutaneous adipose tissue, muscle, synovial capsule, cartilage and bone inside the knee. Conductivity images of the compact bone showed a comparable contrast with surrounding adipose tissues.

Figure 4 show the anatomy of the knee in (a) with magnitude image in (b) and conductivity image in (c) from the normal female subject. In (b), we can see that MR signal void occurred at the outside of the bones. The conductivity image in (c) exhibits spurious noise spikes there. We observed no significant conductivity difference between male and female subjects.

Conclusion

The present MREIT technique can produce *in vivo* conductivity images of the human knee using 3 mA imaging currents. Numerous previous MREIT experiments of postmortem and *in vivo* animals enabled us to design the human experiment and successfully produce *in vivo* conductivity images of the human knee with a pixel size of 1.7 mm. We are still facing a few technical difficulties to reach the stage of clinical applications. They include an improved conductivity image reconstruction algorithm and numerous ways to reduce the amplitude of imaging currents through latest MR imaging techniques and parameters. We plan to perform numerous *in vivo* animal and human experiments to advance the MREIT technique to the stage of clinical uses.

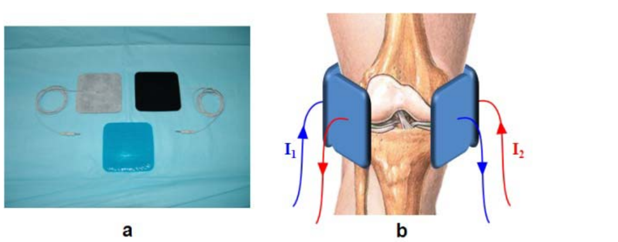

Fig. 1. (a) Carbon-hydrogel electrodes and (b) electrode attachment around the human knee.

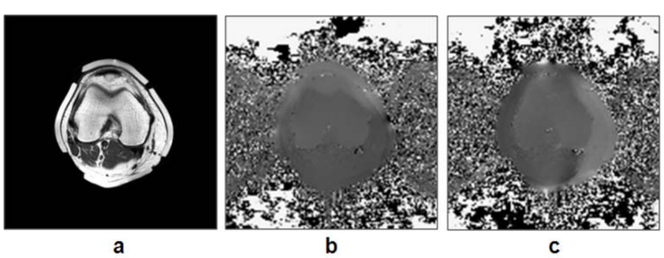

Fig. 2. (a) MR magnitude image of the knee from the male subject. (b) and (c) are magnetic flux density images subject to the horizontal and vertical injection currents, respectively, using 3 mA imaging currents.

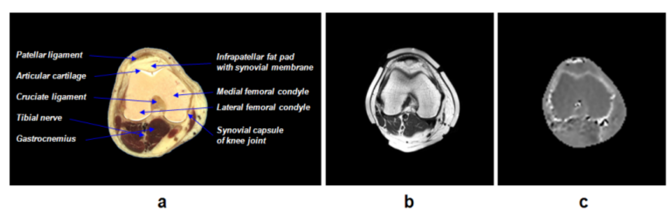

Fig. 3. (a) Anatomy of the male knee. (b) and (c) MR magnitude and reconstructed conductivity images.

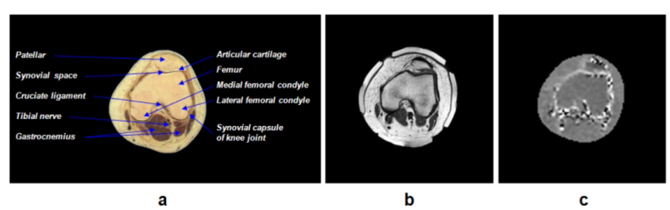

Fig. 4. (a) Anatomy of the female knee. (b) and (c) MR magnitude and reconstructed conductivity images.

References

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