Development of a method for imaging tissue elasticity using tagged magnetic resonance imaging

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Purpose

It is well known that the tissue elasticity is altered depending on the diseased state of tissues. Young's elastic modulus is one of the indices of elastic properties. Tagged magnetic resonance imaging (MRI) provides a direct and noninvasive means of displaying the internal motion of tissues with high accuracy (1), (2). The purpose of this study was to develop a noninvasive and convenient method for generating the maps of Young's elastic modulus in internal soft tissues using tagged MRI.

Methods

We made three homogeneous cylindrical silicone gel phantoms (70 mm in diameter and 40 mm in height) with different hardness and a heterogeneous phantom with a spherical hard silicone gel (10 mm in diameter) placed in the center. The cyclic pressure device with an electrocardiographic (ECG) generator was also made, by which the compressive load was applied to the phantom repeatedly during experiments. The pressure was measured with MRI-compatible optical force sensors (3). The pulse sequence of two-dimensional spatial modulation of magnetization (2D-SPAMM) was used for tagging lines in two orthogonal directions (0 and 90 degrees), with the R wave of ECG being triggered simultaneously. Tagged MRI was performed on a 3.0T MRI scanner with a flip angle of 12 degrees, a field of view of 160 x 160 mm^2, a matrix size of 256 x 256, a slice thickness of 8 mm, a tag space of 3 pixels, a heart rate of about 60 beats per minute, and 20 phases per heartbeat.

The strain maps were generated based on the first phase images obtained from tagged MRI using harmonic phase analysis in the pressure and orthogonal directions separately (1), (2). The maps of Young's elastic modulus were generated using the strain maps in the pressure direction and the stress distribution within the phantom. In this study, the stress distribution was assumed to be homogeneous within the phantom for simplicity. The above processing was automatically performed.

To evaluate the accuracy of our method, the relationship between the pressure and strain was actually measured with a material testing machine in each phantom and we compared the results obtained by our method using tagged MRI and those measured actually.

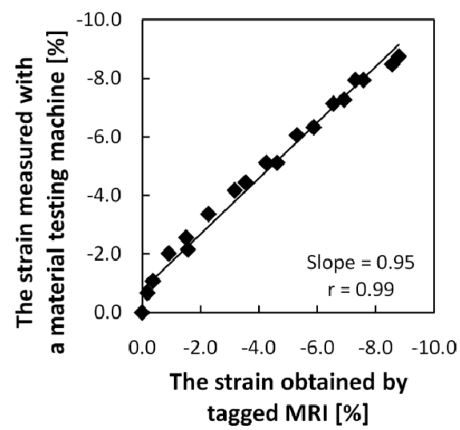

Fig. 1. Correlation between the strains obtained by our method using tagged MRI and those measured with a material testing machine.

Results and Discussion

There was a good correlation between the strain obtained by our method using tagged MRI and that measured using a material testing machine (r=0.99 and slope=0.95) (Fig. 1). Figure 2 shows examples of the maps of strain (a) and Young's elastic modulus (b), which were automatically generated by our method. Although some artifacts were observed in the periphery, the spherical hard silicone gel located in the center was clearly demonstrated in their maps (Fig. 2). The artifacts observed in the maps of strain and Young's elastic modulus (Fig. 2) might be due to the fact that the stress distribution was assumed to be homogeneous, which will be solved by using a method such as the finite element method.

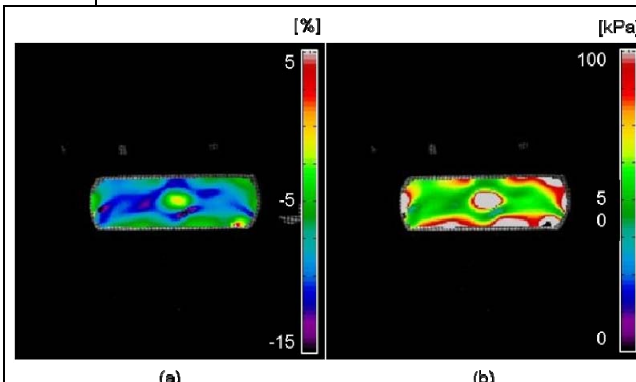

Fig. 2. Examples of the strain map in the pressure direction (a) and the map of Young's elastic modulus (b). A silicone gel phantom with a spherical hard silicone gel placed in the center was used.

Conclusion

We developed a noninvasive and convenient method for imaging tissue elasticity using tagged MRI. Our method will be useful for evaluating the tissue elasticity, because it allows us to automatically and easily generate the maps of Young's elastic modulus.

References

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