Muscle functional magnetic resonance imaging using ultrafast imaging

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Introduction

Muscle activity induced exercise is essential in sports medicine and rehabilitation medicine. Magnetic resonance imaging (MRI) can estimate not only the superficial muscle but also the deep muscle. And, transverse relaxation time (T2) of exercised muscle increases compared to that of the rest muscle [1]. Akima et. al. proposed the muscle functional magnetic resonance imaging (mfMRI) [2, 3] which visualized muscle activity. However, for calculating T2, the mfMRI using the spin echo (SE) sequence. SE requires a few minutes for the acquisition time, and the body parts of the mfMRI were limited the limbs. The purpose of this study is to indicate the feasibility of the mfMRI using ultrafast imaging (fast-acquired mfMRI: fast-mfMRI) applying for abdomen.
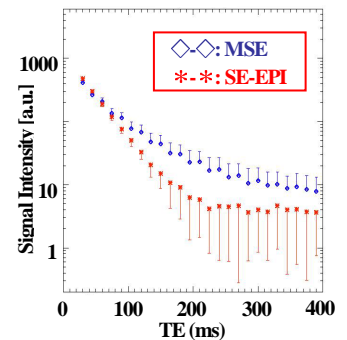

Figure 1: T2 relaxation curve of m. medial gastrocremius.
In shorter TE (<75ms), signal intensities from SE-EPI are corresponded with that from MSE.

Methods

The right calf of four subjects (20.5±1.7 years, 174.8±8.7 cm, 59.0±2.7 kg) on rest and after exercise was performed on a 1.5T Siemens MRI Symphony Scanner. Three protocols were prepared (a) true fast imaging with steady precession (TrueFISP) with TR 4.72 ms, TE 2.36 ms, matrix size 256×256, FA 50, BW 501 Hz/Px, acquisition time 12 seconds. (b) spin-echo echo planar imaging (SE-EPI) with TR 2000 ms, TE 30, 45, 60, …, 390 ms (25 echoes), matrix size 256×256, FA 90, BW 1392 Hz/Px, acquisition time 2 seconds (in 1 echo). (c) multiple spin echo (MSE) with TR and TE were equal to SE-EPI, matrix = 256×256, FOV 240×240 mm, acquisition time 4:20 minutes. The common condition were prepared slice thickness 10mm, FOV 240mm×240mm, NEX 1, receiving coil with extremity coil. Four subjects performed 100 times or 200 times of ankle plantar flexion using training-gum-belt (Thera-Band). ROIs were placed in m. medial gastrocremius (MG) from the SE-EPI and the MSE images. T2 relaxation curve of MG were calculated using mono-exponential linear least-squares of the SE-EPI and the MSE images. The areas of activated muscle were subtracted from T2 image of after-exercised to T2 image of rest. The mfMRI on this study was the images which the subtraction images fused in the TrueFISP images.

Results and Discussion

Figure 1 shows the T2 relaxation curve of MG from the MSE and the SE-EPI. Signal intensities from the SE-EPI were corresponded with that from the MSE in short TE (< 75 ms). The results of agreement of signal intensity in the short TE revealed that it was no problem to calculate T2 from SE-EPI in the range of short TE. Figure 2 shows the MR images of the right calf in rest and after-exercised. Induce of foot ankle's inner rotation, it was activated in m. tibialis anterior (TA) from changes of signal intensity (SI). However, it is difficult to distinct the areas of activated muscle in Figure 2(d) that is great space resolution. And then, though Figure 2(e) and 2(f) are great image contrast of the areas of activated muscle, the adjustments of image contrast are limit to describe the areas. Figure 3 shows the fusion images (fast-mfMRI) from the SE-EPI and the MSE images. The areas of activated muscle in the fast-mfMRI from the SE-EPI were in good agreement with that in the fast-mfMRI from the MSE images. The areas of deep red color shows that the activation of muscle is greater. The areas of red color except muscle are nearly vessel, and we can distinguish the areas of activated muscle. In geometric location of the fast-mfMRI, there is no major difference between the anatomy image (TrueFISP) and the functional image (SE-EPI). The scan time of the fast-mfMRI is 22 seconds in comparison with mfMRI, it can acquire under a single absence of apnea.
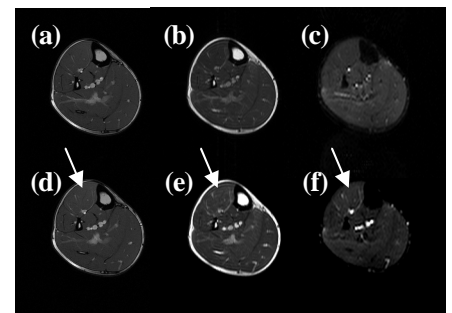

Figure 2: MR images in lower leg at rest (in a, b, c) and after-exercised (in d, e, f). (a, d) TrueFISP. (b, e) MSE.. (c, f) SE-EPI. Arrows denote the areas of activated muscle.

Conclusion

We presented the fast-mfMRI with the shorten acquisition time of 1/12 of the previous method. With not only the anatomical, but also the functional information the fast-mfMRI can be applied for the human trunk that has limitation of scan time.
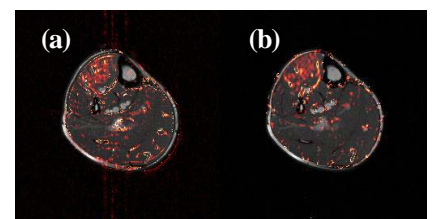

Figure 3: The fusion image (fast-mfMRI). (a) MSE. (b) SE-EPI.. A comparison between Figures (a) and (b) shows an excellent agreement between the two bright areas.

References

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