Muscle functional MRI of exercise-induced rotator cuff

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Introduction

Strengthening of the rotator cuff muscles is one of the most integral parts of a rehabilitation program for athletes with shoulder injuries who must perform throwing motions during sports. Additionally, exercise-induced muscle activity is essential in sports medicine and rehabilitation medicine. Magnetic resonance imaging (MRI) can evaluate muscle activity; transverse relaxation time (T2) of the exercised muscle is increased compared to that of rested muscle [1]. Therefore, evaluation of muscle activity using T2–weighted MRI will facilitate identification the most effective exercises for strengthening the rotator cuff [2]. However, it is empirically considered that the detectability of T2 change is limited if exercise is not performed until fatigue. Therefore, it is difficult to use this approach efficiently for evaluation during rehabilitation. We considered that the problem of detectability seems to involve the temporal resolution of image acquisition for calculating T2. To reduce the acquisition time in order to increase the temporal resolution, we theorized and then verified that T2 values calculated from SE-EPI images provided high detectability of slight muscle activities induced by acute exercise [3]. This study evaluated the detectability of rotator cuff muscle activity induced by acute exercise.

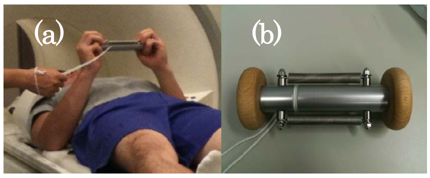

Figure 1: The exercise schema external rotation exercises of the shoulders were repeated 50 times starting from a neutral position. (a) Practical landscape of exercises, (b) training equipment.

Methods

The right rotator cuffs of five male subjects (21.4±1.1 years, 173.0±3.6 cm, and 64.8±8.5 kg) were scanned at rest and after exercise using a 1.5T whole body scanner (Magnetom Symphony; SIEMENS AG, Erlangen, Germany) with a Shoulder Array Coil small. Two protocols were employed: (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; and (b) multi-shot spin-echo echo planar imaging (MSSE-EPI) with TR 2000 ms, TE 20, 30, 40, 50 ms (4 echoes), matrix size 128×128 interpolated into 256×256, FA 90, BW 1392 Hz/Px, acquisition time 30 seconds (for 1 echo). Slice thickness 5mm, FOV 240mm×240mm, NEX 1 were common factors. Subjects performed 10 sets of an exercise while fixing the elbow at 90 degrees flexure and lying supine on the bed (Figure 1). One exercise set consisted of the subject performing external shoulder rotation 50 times using training equipment (Arm Twista; Sanriki Corporation, Tokyo, Japan). T2 images were calculated using mono-exponential linear least-squares of MSSE-EPI images. In extracting the MR signal from TrueFISP images (TrueFISP signal), and muscle T2 from T2 images, Areas of Interest were set at several places in the musculus subscapularis (sub), musculus supraspinatus (sup), musculus teres minor (ter), and deltoid muscle (del), respectively. Those data were used to calculate averages and standard deviations. A previous study reported that there are 10% changes in T2 in the same muscle [4]. Based on this finding, the obtained data were subjected to one-way repeated-measures ANOVA with Scheffe's test post hoc test. Differences with $P < 0.05$ were considered significant.

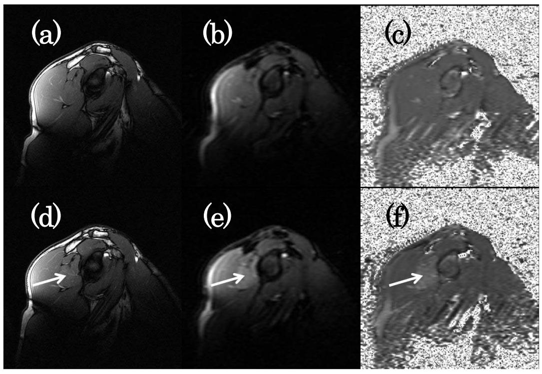

Figure 2: Representative MR images. (a) TrueFISP image at rest, (b) MSSE-EPI image at rest, (c) T2 image at rest, (d) TrueFISP image after 10 sets, (e) MSSE-EPI image after 10 sets, (f) T2 image after 10 sets. In (b) and (e), the echo is 50 ms. Arrows denote the activated musculus teres minor.

Results and Discussion

Figure 2 shows representative MR images of the right shoulder at rest and after 10 sets. In the images obtained after 10 sets, especially on MSSE-EPI image and T2 image, the areas of activated musculus teres minor were well enhanced and the details were preserved. Figure 3 shows changes in TrueFISP signals after each set, and changes in T2. All subjects showed the same findings. Although most of the TrueFISP signal was not changed by exercise, there was no significant difference at rest. Only T2 in ter was increased after 1 set and the change was shown on T2 images. Additionally, except for those after 1 set and 2 sets, the changes in T2 were significant compared to those at rest ($P<0.01$). Figure 3(a) shows that the shoulder is a region that is susceptible to inhomogeneity of B0. Conversely, it is an advantage that the spin echo sequence can correct the inhomogeneity of B0 to some extent. Additionally, we showed that muscle activity due to slight exercise could be detected if we use MSSE-EPI to obtain excellent T2 measurement in relation to temporal resolution. Therefore, it was suggested that when a site is susceptible to inhomogeneity of B0, T2 calculation using MSSE-EPI could resolve a problem of image distortion.

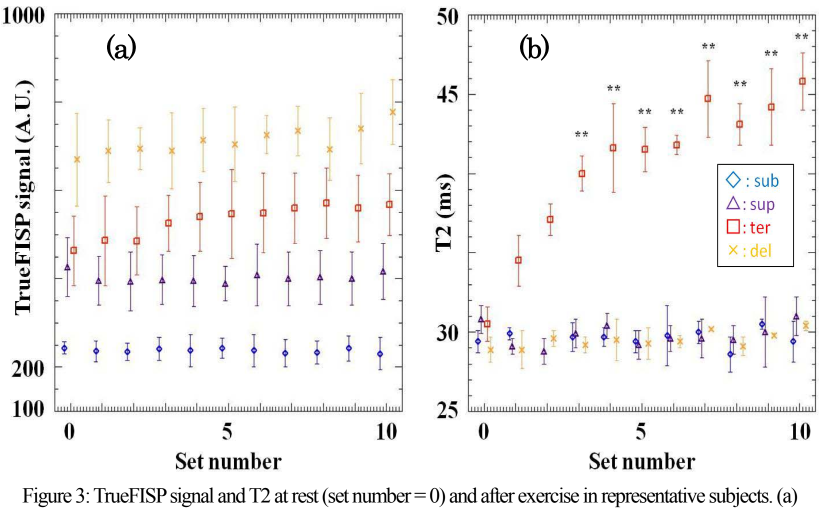

Figure 3: TrueFISP signal and T2 at rest (set number = 0) and after exercise in representative subjects. (a) TrueFISP signal. (b) T2. Significantly different from the value at rest, * : $P<0.05$, ** : $P<0.01$.

Conclusion

In this study, we demonstrated the detectability of rotator cuff activities using T2 calculated from MSSE-EPI images and showed the high detectability of muscle activity in a region, such as the shoulder, which is susceptible to inhomogeneity of B0.

References

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