Transverse Relaxation Time (T2) Measurements of the Human Thigh Muscles at High Magnetic Field using Segmented Echo-Planar imaging.

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Introduction: Transverse relaxation time (T_2) measurements have been largely used to distinguish activated from non activated muscles as a result of exercise. Considering that T_2 usually reaches its maximum immediately at the end of the exercise and starts to decrease[1], there is a real interest in performing the measurements within the shortest possible acquisition time. Classic multiple Hahn echoes (spin echo, SE) technique, considered as the reference method, would provide the most accurate T_2 values but its long acquisition time is not compatible with the assessment of muscle activation after exercise. CPMG-based sequences (e.g. MSME), although largely used, provide overestimated T_2 values compared to the reference method and require moderately long acquisition time. Moreover, these techniques are prone to artifacts arising from B_1 inhomogeneities, especially at high magnetic field[2]. A recent study based on True-FISP imaging has demonstrated very good capabilities in providing rapidly quantitative T_2 values in post-exercise muscle conditions. This technique was however limited to single-slice acquisition, required B_1 mapping calibration scan and specific post-processing[1]. In this study, we proposed a very simple multislice approach based on segmented SE echo-planar imaging (SE-EPI) to rapidly measure T_2 values in pre/post exercise muscle conditions. The proposed technique combines the advantages of being low-sensitive to B_1 inhomogeneities and based on the multiple Hahn echoes strategy. Segmented SE-EPI was first validated on a phantom study where T_2 values and image quality were evaluated and then, used for *in vivo* T_2 measurements in exercising muscle.

Methods: Experiments were carried out on a 3T MR system (Verio, Siemens).

Phantom study: Classic SE, MSME and segmented SE-EPI (ETL=13, 9 shots) sequences were applied on a 3T calibrated phantom (*TO5-Diagnostic Sonar*, 12 gel tubes, T_2 relaxation times ranging from 25 to 148 ms) with the following parameters: single slice, FOV=250 mm, matrix=192 × 192, slice thickness= 10 mm, 1NEX, TR=4800ms. Eight TE values (20, 30, 40, 50, 60, 70, 80 and 100 ms) were used for both SE and segmented SE-EPI, and a 9 echo train length (TE=20, 30, 40, 50, 60, 70, 80, 90 and 100 ms) for MSME.

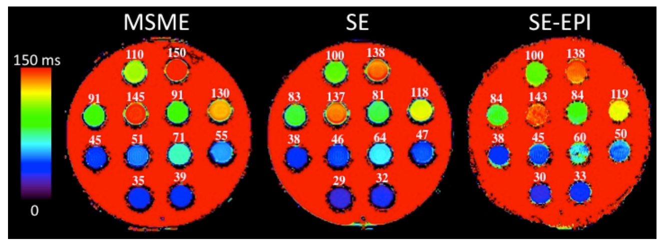

Fig. 1. T_2 map of the calibrated phantom obtained by fitting for each sequence: MSME, SE, SE-EPI. Measured T_2 values of each tube are indicated.

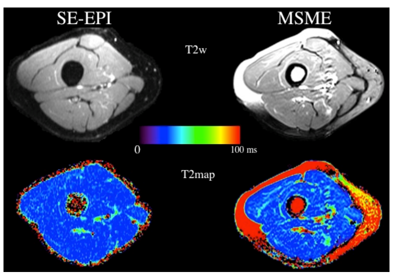

Fig. 2. T_{2w} and T_2 maps of the thigh obtained by fitting for a representative subject at rest.

In Vivo study: segmented SE-EPI (ETL=13, 9 shots) and MSME sequences were applied on seven healthy subjects. Images of the right thigh (11 slices) were acquired at rest for both SE-EPI and MSME and immediately after a standardized exercise performed inside the magnet for SE-EPI. The exercise consisted of 80 isometric contractions (2 s on / 2 s off) at 60% of the maximal force of each subject. MR imaging parameters were similar than those used for the phantom study. TE values of 20, 30, 40, 50 and 60 ms were used for SE-EPI and TE values of 10, 20, 30, 40, 50, 60, 70 and 80 ms for MSME. The acquisition time of each sequence was ~ 5 min. For each sequence, T_2 values were obtained either by fitting the logarithm of the data to a linear equation in $1/T_2$: $Log(S(TE)) = Log(S_0) - TE/T2$ or by calculating the previous equation with 2 different TE values, 30ms and 60 ms (standard values used for muscle T2 studies [3]).

Results: Fig. 1 shows T_2 maps of the phantom obtained by fitting the MSME, SE and segmented SE-EPI data. Despite the segmented acquisition, few distortions can still be seen on the SE-EPI images. For all the calibrated tubes, T_2 values obtained with SE and SE-EPI were statistically not different whereas those obtained with MSME were significantly higher compared to both SE and SE-EPI ($P < 0.05$). Moreover, for segmented SE-EPI, no significant difference was noticed whether the T_2 values were obtained by fitting or by 2-TE calculation ($P = 0.8$). For MSME though, T_2 values obtained by 2-TE calculation were significantly higher than those obtained by fitting ($P < 0.05$). Fig 2 shows typical thigh T_{2w} images and T_2 maps obtained with segmented SE-EPI and MSME. Segmented SE-EPI images were very slightly distorted and corresponding T_2 maps presented homogenous T_2 values distribution compared to the maps obtained with MSME. Quantitative analyses performed in the thigh muscles (Fig 3) show significant higher T_2 values for MSME independently of the calculation mode. Finally, Fig 4 shows T_2 maps obtained with segmented SE-EPI before and after exercise for one subject, showing a large T_2 increase in the overall quadriceps femoris muscle (+14 ± 8%, p<0.05, N=7).

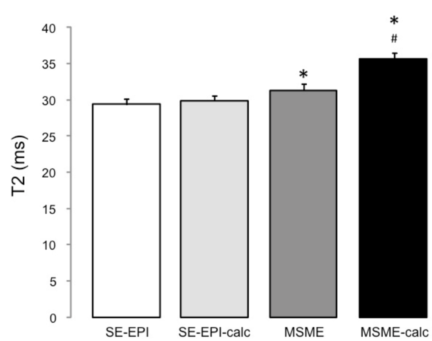

Fig. 3. Absolute T_2 values measured in the thigh muscles obtained by fitting (SE-EPI, MSME) and 2-TE calculation (SE-EPI-calc, MSME-calc). Mean ± SD. *significantly higher than SE-EPI and SE-EPI-calc. # significantly higher than MSME.

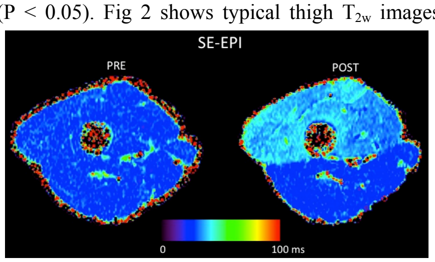

Fig. 4. T2 maps of the thigh for a representative subject before and after a standardized exercise.

Discussion: We demonstrated that segmented SE-EPI, a widespread technique, can be used as a very simple method to measure accurately T_2 values on human muscle at high magnetic field. T_2 values obtained either by fitting or by 2-TE calculation were similar to those obtained with the classic SE reference method (Fig 1). The degree of EPI segmentation was chosen in order to achieve a balance between the image quality and the acquisition time. In the present study, the 9-shot SE-EPI produced multislice slightly distorted images (Fig 2 and 4) in an acquisition time of ~1 minute. Therefore, by using the 2-TE calculation strategy, two minutes are required to obtain accurate T_2 maps (against ~5 min for MSME based techniques), a time scale fully compatible to study physiologic changes occurring in exercising muscle.

***References*: [1] Loureiro De Sousa et al., JMRI (2011), [2] Poon & Henkelman, JMRI (1992) [3] Prior et al., JAP (1999)**