Spinal fusion induced increase of energy demand in lower back muscles - A functional ^{31}P-MRS study

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Target audience: Researchers in MR spectroscopy and muscle physiology**Purpose:** Spinal fusion is a surgical technique to join two or more vertebrae segments for stabilization of the spine after trauma or in case of degenerative diseases. Despite being a common technique, a subset of patients suffers from chronic pain that is suspected to emerge from instabilities in adjacent vertebrae segments, which in turn may cause increased stress in corresponding affected back muscles. This has recently been demonstrated in electrophysiological studies [1, 2]. Functional phosphorus MR spectroscopy (^{31}P-MRS) allows quantitation of high-energy phosphate turnover in loaded back muscles *in vivo* and thus provides a unique, non-invasive opportunity to characterize fatigue induced metabolic activity [3]. In the present study, we applied ^{31}P-MRS in healthy controls and patients after spinal fusion during a standardized isometric exercise to evaluate differences of metabolic alterations in back muscles close to the fused vertebrae segments.

Methods: Five patients with spinal fusion (2-4 weeks after surgery, 3 open and 2 percutan fusions of two or more lumbar segments) and five age,- gender- and BMI-matched healthy subjects (3m/2f, 31-59y, BMI: 22 - 28) were examined on a clinical 3 T whole-body MR scanner (TIM Trio, Siemens, Germany) with a flexible double-tuned ^{1}H/^{31}P transmit/receive coil (RAPID Biomedical, Germany). 2D chemical shift imaging (CSI) ^{31}P-MRS data were collected in prone position with a 30 mm thick slice in coronal orientation covering the left and right back muscles (M. multifidus + M. erector spinae) below the fused segments (matrix 8 × 8, voxel size: 30×30×30 mm³, TR: 1 s) (Fig. 1c). Spectra were continuously recorded with temporal resolution of 29 s prior (N = 4), during (N = 10) and after (N = 38) a 5 min isometric exercise. The latter consisted of a slight lift of the upper body from the scanner table while legs and pelvis were fixated (Fig. 1a). Load level was adjusted to 50% of the subject's upper body weight and monitored by means of integrated scales in the scanner table with visual feedback to the volunteer (Fig. 1b). For post-processing a MATLAB routine was applied, including frequency-, phase- and baseline corrections and spatial averaging of four CSI voxels each covering the left and right back sides (blue boxes in Fig. 1c). Sliding-window avaraging was performed with a kernel size of 3 dynamic measurements of the time course of the MRS data. Spectra were quantified using the AMARES tool of jMRUI package (www.mrui.uab.es) to analyse time courses of PCr intensities and pH values [3].

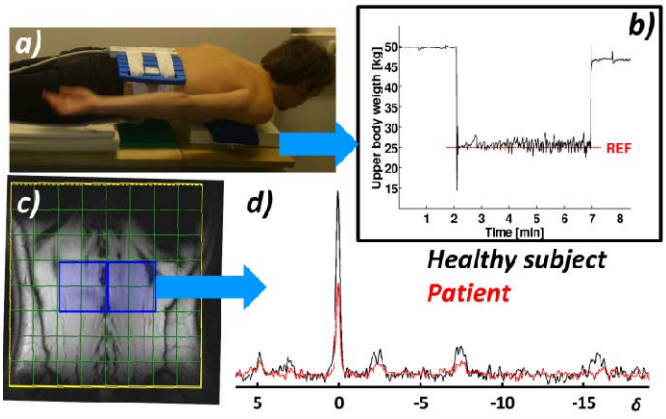

Fig. 1 a) Subject position during the examination with a surface ^{31}P/^{1}H coil on the back. **b)** Time course (black) of upper body weight during the execercise relative to the refererence line (red) indicating the 50% upper body weigth. **c)** Spectroscopic region of interests covering the left and right back muscles with **d)** representative noise normalized single shot ^{31}P-MR spectra of patient (red) and healthy volunteer (black).

Results: Fig. 2 shows mean time courses of load induced PCr intensity changes, which were normalized to the corresponding pre-load value. Obviously, patients show stronger PCr depletions during exercise indicating higher energy demand and thus higher muscle activation under comparable load conditions (patients: -61 ± 17 % *vs.* controls: -37 ± 11 %). Interestingly, the PCr time course in the left back muscle during load differs between patients and controls: patients show a monotonic PCr depletion that lasts until the end of the exercise whereas controls reach a steady state approximately 2 min into the load. In the right back muscle the time courses were more similar between patients and controls. No obvious differences in pH changes were detected between the two groups.

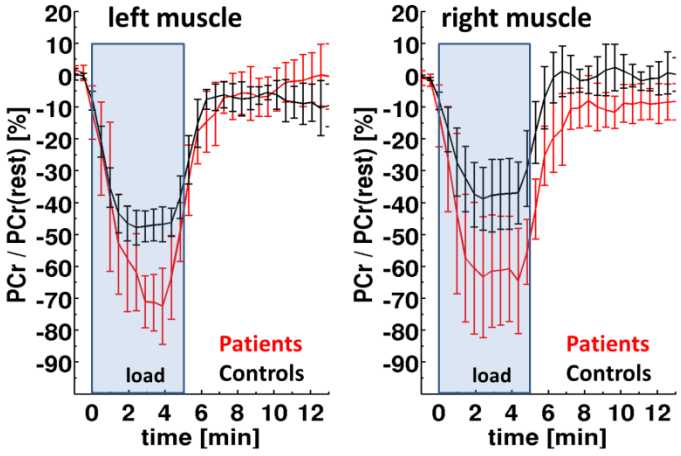

Fig. 2 Mean time courses of PCr intensities of patients (red curves) and healthy subjects (black curves) in left and right back muscles.

Discussion and conclusion: Our pilot study demonstrates the possibility to monitor and quantify load induced changes in high energy metabolism even in tissues close to adjacent metal implants. We also observed the expected higher PCr depletions in patients compared to controls, which is in line with recent simulation results of increased activation in muscles stabilizing the spine segments close to the fused spine segments [2]. Future examinations will aim to evaluate the changes in metabolic changes at later time points after surgery to evaluate the expected, therapy induced improvements of the muscles' ability to better compensate for increased loads.

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