High-resolution MRI to assess skeletal muscle damage after controlled compressive loading

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Introduction

To obtain more insight in the aetiology of deep pressure sores a rat model has been developed [1]. The aim of this model is to relate controlled external loading to local muscle damage. Until now, the amount and location of muscle damage were assessed by histological examination, excluding follow-up studies and clinical applications. MRI is considered an alternative, since it has proven to be a valuable tool in diagnosing muscle diseases [2] and evaluating non-healing pressure sores [3].

In the present study the possibility of MRI for assessing local skeletal muscle damage after controlled compressive loading was determined. Histological examination revealed that damaged areas show complete lysisation of muscle fibres (fig. 1). It was hypothesised that this results in a change in the fraction of mobile water within the damaged area and hence in a different T2 relaxation time as compared to undamaged muscle tissue.

Methods

Experiments were performed on three male Brown Norway rats weighing 180-220 grams. An anaesthetised rat was placed supine in a loading apparatus, consisting of a unit for fixation of the foot and knee of the right hindlimb, and a unit for load application (fig. 2). Loading was applied using a pneumatically driven indentor with a rounded contact surface (diameter: 3 mm). The indentor was placed halfway between foot and knee perpendicular to the skin overlying the m. tibialis anterior (TA), at an angle of approximately 40° with the horizontal. In this way the TA and overlying skin were compressed between the indentor and the tibia. A load of 250 kPa at skin surface was applied during 2 hours. This loading protocol results in approximately 4 mm³ muscle damage, which can histologically be detected after twenty-four hours [1].

Results

Twenty-four hours after the loading session in vivo MR images of the rat hindlimb were obtained on a 4.7 Tesla Varian 200/400 system, operating at 200 MHz. The transverse imaging was planned on a longitudinal section of the hindlimb. A T2-weighted spin echo sequence was applied (TE=16, 30, 40 and 50 ms; TR=5 s). For comparison with previous histological findings, the TAs were then dissected and processed for histological examination.

When comparing in vivo MR images of unloaded (fig. 3A) and loaded areas (fig. 3B), signal intensity appears higher in the loaded area. Just outside the loaded area the signal intensity is comparable to the unloaded muscle tissue implying localised damage. In ex vivo MR images the loaded area shows lower signal intensity (fig. 3C). The location of the area with different signal intensity in the MR images is in agreement with the location of muscle damage assessed from histological examination (fig. 3D). Moreover, the shape of the damaged area in the MR images corresponds to the shape of the damaged area in the histological examination. This holds for all three muscles, although intraspecimen differences in the shape of damaged area are observed.

Discussion

Local skeletal muscle damage after controlled compressive loading can be assessed with T2-weighted high-resolution MRI. The signal intensity change of the damaged tissue differs between in vivo and ex vivo MR images. Most likely this results from the formalin fixation. A further study of the components in the multi-exponential T2 relaxation in vivo as well as ex vivo could supply more insight into the water compartmentation in the damaged area and hence in the damage mechanisms. Currently, the possibility of MRI for quantifying muscle damage and the correspondence with histological quantification is studied. Because MRI is non-destructive, it has potential in follow-up studies to evaluate the development of muscle damage in time and to assess injury mechanisms.

References