The role of deformation and (re)perfusion on damage development after compressive muscle loading, as studied using Magnetic Resonance Imaging

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Introduction

Pressure ulcers (decubitus) are a serious health problem and are defined as localized areas of degenerated skin and underlying soft tissues, caused by sustained mechanical loads. Prevalence figures are very high: 20% of the patients in general hospitals up to 29% in nursing homes develop pressure ulcers. Prevalence is highest among elderly patients and patients with mobility impairment such as spinal cord injury. A lack of knowledge on the aetiology makes prevention difficult. Hypotheses associated with the pathogenesis of pressure ulcers involve localised ischemia, reperfusion injury, and sustained deformation of cells [1]. In this study MRI was used to measure the influence of controlled compressive loading on the location and severity of muscle injury and on the perfusion status in rat hindlimb muscle.

Method

A novel experimental set-up was designed and built to enable controlled mechanical loading of the tibialis anterior (TA) of anaesthetized Brown Norway rats, while the animal resided inside a 6.3 Tesla magnet. The TA was loaded with a plastic indenter (diameter 3mm) for 2 hours. A multi echo spin echo sequence (TE=12-96ms, 8 echoes, TR=4.5 s, FOV=3x3 cm^2, matrix 128x128) was used to detect damage [2]. Images were taken before, during and after loading for up to 3 hours and after 24 hours (n=8). To determine the kind of muscle damage histological examination was performed at 1 hr after unloading (n=4), 4 hr after unloading (n=4) and 24 hr after unloading (n=4). An index of tissue perfusion was obtained by injection of Gd-DTPA (0.2mmol/kg) (n=6). A gradient echo sequence (TE=2.5ms, TR=35ms, α=30°, FOV=3x3 cm^2, matrix 128x64) was used to measure signal increase after injection, which is a measure for the perfusion [3]. Perfusion indices were measured before (t=0), during loading (t=1hr) and 30 minutes after loading (t=2.5hr). In the perfusion study, two loading protocols were used, with large indentation (n=3) and modest indentation (n=3).

Results

A series of T2-weighted MR images collected before, during and after indentation is shown in figure 1. It is evident that after a loading period of two hours, the signal intensity was increased in the loaded region of the TA compared with images taken prior to loading. This signal change was not yet visible in the image taken just before unloading (Figure 1b). Locations of signal increase in MR-images correlated with loss of cross striation (t=1, 4 and 24 hours) and infiltration of monocytes (t=24h) in histological slices (not shown). The perfusion index maps measured before, during and 30 min after unloading are shown in figure 2 for large (a-c) and modest (d-f) indentation respectively. These data indicate that during large indentation the perfusion in the whole TA region was very low (Figure 2b), while only a small region was affected during modest indentation. The perfusion indices 30 minutes after removal of the large indentation were very high in the TA region, while after modest indentation the perfusion indices were essentially identical to those in the pre-loading situation. The first series of perfusion maps (figure 2a-c) were taken during the same experiment as the T2-weighted images in figure 1. This shows that the area of high perfusion indices upon reperfusion correlated well with the area with high signal intensity in the T2-weighted image. The latter is known to reflect damaged muscle tissue [2]. The T2-weighted images taken after modest indentation did not show any signal increase (not shown).

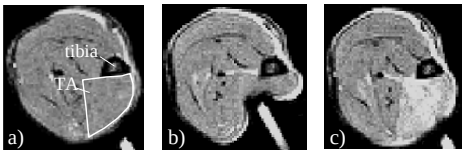

Figure 1. *T2-weighted transversal slices of the hind limb showing a) the indenter applied to the skin, b) indenter applied to the muscle, and c) image taken 1 hr after the 2 hr loading period showing higher signal intensities in the TA region.*

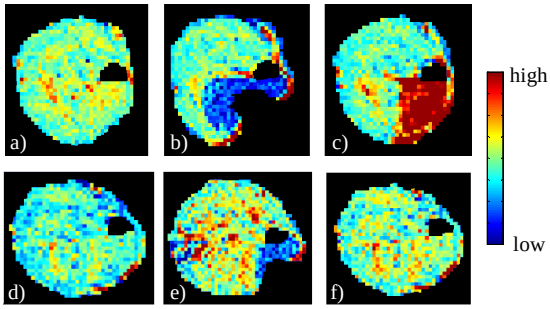

Figure 2. *Perfusion index maps taken before (a,d), during (b,e) and 30 minutes after loading (c,f) for resp. large and modest indentation. The perfusion maps with large indentation are obtained in the same experiment as the T2-weighted images in figure 1.*

Discussion

The different factors that may play a role in the onset of damage can be measured in this experimental set-up by a multi-parametric MRI. It was shown that during indentation large deformations and ischemia occurred in the muscle. Furthermore, the damage became evident after unloading, and not during loading, suggesting that large deformations and ischemia for 2 hours alone do not lead to damage. This indicates that reperfusion may play an important role in injury initiation. Experiments with smaller indentation did not lead to any damage. To separate the effects of ischemia/reperfusion and deformation, experiments will be performed with a cuff around the leg (ischemia but no deformation).

references

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