The effects of locomotor training on the skeletal muscle following spinal cord contusion injury using magnetic resonance imaging

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INTRODUCTION:

Spinal cord injury (SCI) results in a general atrophic response below the level of the lesion in a variety of muscles. The objective of this study was to investigate the quantitative changes in muscle cross sectional area following spinal cord contusion injury and the impact of treadmill and cycling training on the recovery using 3D MRI. In addition, T_2 imaging was used to monitor skeletal muscle degeneration and the subsequent regeneration during locomotor training.

METHODS:

Sprague Dawley rats (20-week old, weighing 260-320 g at the start of this study) were studied in this project. The contusion injuries were produced using a MASCIS (Multicenter Animal Spinal Cord Injury Study) impactor and protocol. The animals were equally divided (randomly) into three groups. Two groups were assigned for treadmill locomotor or cycling training, whereas, the third group served as a control (injury without training). Animals in both training groups were trained continuously for 3 months, 5 days a week, 20 minutes/session, 2 sessions/day. All the imaging procedures were performed in a horizontal, 4.7 Tesla magnet (Bruker), using a 3.3 cm birdcage extremity coil. Data were collected at pre-injury as well as at 1, 2, 4, 8, and 12 weeks post injury. 3D images were acquired using a fast gradient-echo sequence, with TR=100ms, TE=10ms, flip angle of 30 degree, encoding matrix of 516x256x64 and a field of view of 2.5x2.5x4cm. The cross-sectional area (CSA) of the anterior and posterior muscle groups of the lower hindlimb was determined for each slice and the maximal CSA was recorded. At the same time, T_2 measurements were acquired using multiple slice, single spin echo images (TR = 2000 ms, TE = 14, 40 ms, FOV = 2.5 cm, 256x128, 2 nex). T_2 maps were created by using the decay in pixel signal intensity as a function of TE.

RESULTS:

Two weeks after spinal cord injury, both anterior compartment and posterior compartment muscles in the control group showed significant atrophy with decreases in max-CSA ranging from 24 to 31%. In addition, the degree of atrophy appeared to be muscle-specific, with extensor muscles showing greater atrophy. Both cycling and treadmill training diminished the extent of atrophy and accelerated the rate of recovery. The most significant impact of training was observed at the second week post injury, with max-CSAs of 91.8±2.6% in the cycling group, 90.7±2.0% in the treadmill trained animals and 69.8±5.16% in the control group. Analysis of the T_2 weighted images, 1 week after SCI, showed an increase in T_2 contrast across different muscles, with the largest T_2 changes in the soleus muscle. In addition, muscle T_2 values showed a progressive recovery over the 12-week period.

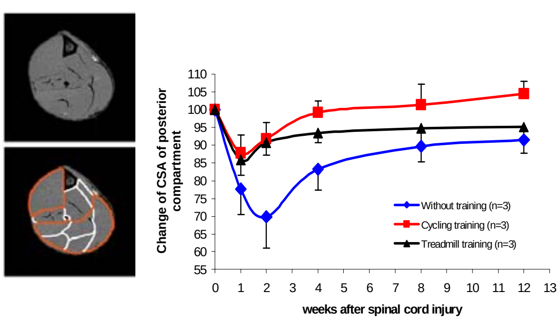

Figure1: Quantitative changes of muscle cross-sectional area following spinal cord contusion injury and training

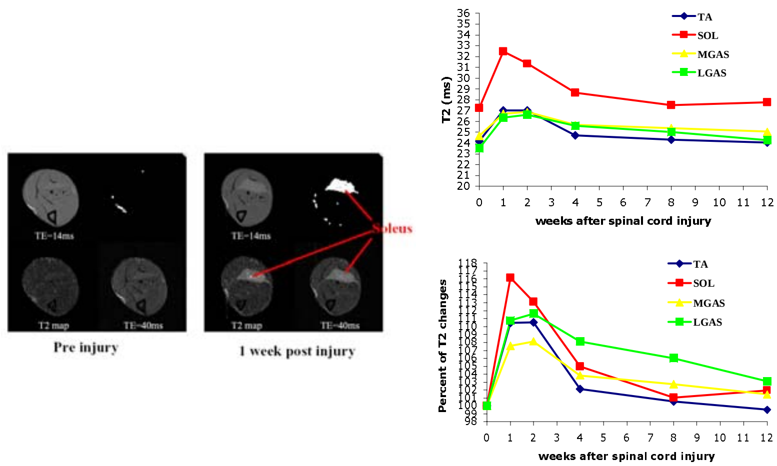

Figure2: Representative T_2 weighted MRIs acquired pre- and 1week post injury (left) and the relative changes in T_2 with time (right).

CONCLUSION:

This study demonstrates that rats with spinal cord contusion injury show a typical pattern of spontaneous recovery and early intervention strategies can be effectively used to enhance the recovery of muscle mass after spinal cord injury. In addition, these data show a significant shift in muscle T_2 relaxation properties, particularly in the soleus muscle, a predominantly oxidative postural muscle, known to be highly susceptible to oxidative stress.

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