Non-Invasive Imaging of Human Motor Units

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Introduction

• Muscle contractions are controlled by our nervous system. Motor units (MUs) facilitate this contraction, a MU consists of the innervating nerve and the all muscle fibres innervated by that nerve.

• MUs are split into fast and slow twitch MUs. A characteristic of sarcopenia (age related loss of skeletal muscle strength and mass) is a loss of fast twitch MUs, where after surrounding muscle fibres are then re-innervated by the surviving slow twitch MUs, causing an increase in MU size.

• Current clinical techniques to measure MU morphology such as glycogen depletion experiments and needle electromyography (EMG) are inadequate as they are: invasive, have a low diagnostic yield & time consuming.

• Recently, we have shown that MU activation by electrical muscle stimulation, which results in muscle fibre contraction, leads to discreet signal voids on diffusion weighted MRI images, a technique called Motor Unit MRI (MUMRI)1 2 ...

Methods

• Ten healthy subjects (8 male, age = 26 – 84 years; 2 female, age = 30 – 32 years) were scanned using a 3 T Achieva X scanner (Philips Medical Systems, Best, The Netherlands).

• A pair of 10 cm elliptical flexible surface coils were positioned above and below the lower leg muscles.

• A pair of stimulating electrodes were placed over the left common peroneal nerve or tibial nerve.

• It is non-invasive and sufficiently sensitive to detect physiologically relevant changes in motor unit morphology with age.

• Motor unit MRI (MUMRI) is a novel technique capable of revealing the size, shape and position of multiple motor units in human muscles.

Study Aim: Apply MUMRI in a group of healthy volunteers to investigate MU morphology with normal ageing

Results

• From ten volunteers we analysed 31 motor units.

• Motor units were categorised into 5 different shapes: ellipse, crescent, circular, spider and split (into two or more parts) (Fig. 3). The most common shape was elliptical.

• Average CSA: 26.7 ± 11.2 mm²; Average maximum & minimum Feret diameters: 10.7 ± 3.3 mm and 4.5 ± 1.2 mm respectively.

• Splitting volunteers by median age (40 yrs.) into two groups showed a statistically significant increase in maximum Feret diameter in subjects over 40 yrs. (p = 0.011). A similar trend was observed in the other two however neither reached significance (p = 0.138 & p = 0.541 respectively) (Fig. 4).

Discussion

• Majority of MUs were elliptical in shape, this agrees with data from glycogen depletion experiments3.

• MU metrics: CSA & diameters agree with ranges from scanning EMG literature (3-10 mm)4.

• We have observed an age related increase in the maximum Feret diameter of motor units demonstrating that motor units undergo heterogeneous remoulding with age.

• Motor unit MRI (MUMRI) is a novel technique capable of revealing the size, shape and position of multiple motor units in human muscles.

Conclusions

• It is non-invasive and sufficiently sensitive to detect physiologically relevant changes in motor unit morphology with age.

• Results provide the first direct measurement of human motor unit morphology. The technique shows promise both as a diagnostic tool and as a biomarker in sarcopenia.


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Methodology

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• Recently, we have shown that MU activation by electrical muscle stimulation, which results in muscle fibre contraction, leads to discreet signal voids on diffusion weighted MRI images, a technique called Motor Unit MRI (MUMRI)1 2.

Motivation

• To study single motor units, we scanned increasing the current by small increments of 0.01 mA. This allowed us to detect each void separately. Motor unit activity maps were then created by taking the difference between images with and without signal voids.

• Cross sectional area and maximum and minimum Feret diameters of the regions of activity were calculated.

Figure 1: Effect of denervation on motor unit morphology. A fast twitch MU is denervated, causing two muscle fibres (blue cylinders) to lose innervation. The slow twitch MU attempts to re-innervate muscle fibres, increasing in size.

Figure 2: Above - Example axial diffusion weighted images of the lower leg showing signal voids in stimulated (right hand) image due to motor unit activity in the anterior compartment (indicated by red arrows). Bottom- Sequence parameters.

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