THE CARP STUDY: TRANSLATING MOTOR UNIT MRI (MUMRI) TO NHS SCANNERS FOR MOTOR NEURON DISEASE ASSESSMENT

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INTRODUCTION

Motor Neuron Disease damages both upper and lower motor nerves, causing progressive muscle weakness and loss of movement (Feldman et al., 2022). One of the earliest signs is fasciculation, which means small, involuntary twitches in the muscle (Kiernan et al., 2011). Detecting these early may give doctors an important window to begin care sooner (Bashford et al., 2020).

Traditional diagnostic tests, such as inserting a needle to record electrical signals in the muscle, are uncomfortable and only capture surface muscles (Menkes & Pierce, 2019). Other tests like high-density electrical recordings and ultrasound scans improve accuracy (Nishikawa et al., 2022; Liu et al., 2021) but cannot see deep muscle activity.

Motor Unit MRI uses a normal MRI machine in a new way to pick up the tiny movements of muscle fibres. Earlier studies showed that this approach could:

- Detect muscle twitches in both deep and surface muscles, such as the tongue and back.
- Distinguish patients with Motor Neuron Disease from healthy people with high accuracy.
- Follow changes over time, showing that the number of twitches increases as the illness progresses.

The CARP Study builds on this work to find out if this new technique can be used in standard National Health Service hospitals, without the need for specialist research equipment.

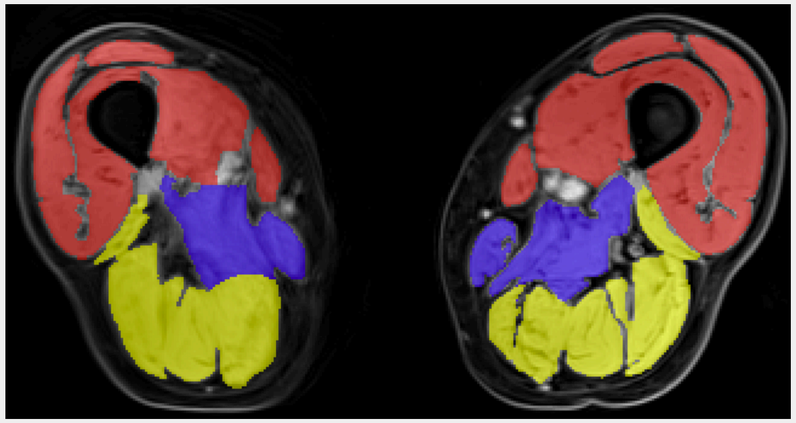

Figure 1: Shows muscle compartment segmentation in the thighs for fat fraction analysis

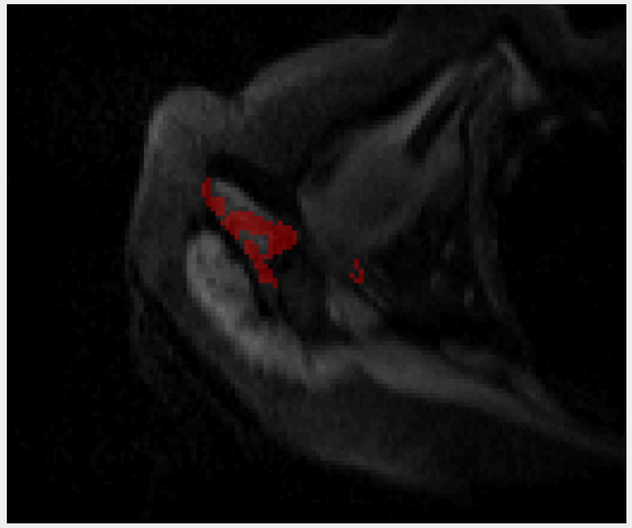

Figure 2 : Shows fasiculation activity within a left shoulder of the patient (RED = Fasiculation)

AIMS

- To test whether Motor Unit MRI, originally developed using specialist research scanners, can be carried out using normal hospital MRI scanners.
- To compare Motor Unit MRI with ultrasound and surface electrical recordings for detecting small muscle twitches.
- To explore whether this new scan could serve as a reliable, non-invasive early warning sign for Motor Neuron Disease.
- Assess fatty imfiltration in ALS patient's muscles.

METHODOLOGY

Participants: Nineteen people with Motor Neuron Disease were recruited from a specialist clinic between March 2023 and February 2024.

Inclusion: Definite or probable diagnosis according to international standards (de Carvalho et al., 2008).

Exclusion: Conditions making MRI unsafe or patients with advanced disease.

Each participant took part in one study visit including:

1. Clinical examination — doctors looked for visible muscle twitches in the tongue, shoulders, back, thighs, and legs.
2. Ultrasound and surface recordings — to observe and measure muscle twitches from the skin surface (de Carvalho & Swash, 2024).
3. Motor Unit MRI scanning — carried out on a 3-Tesla Siemens MRI scanner using a specific imaging sequence sensitive to motion.
   - Scans were performed on the tongue, shoulders, back, thighs, and calves.
   - Each scan took about one minute per region.
   - Images were processed to create maps showing how often small muscle twitches occurred.

DISCUSSION AND RESULTS

- MUMRI sequences were successfully performed on all participating NHS scanners without the need for hardware or software modification. The resulting fasciculation-related signal fluctuations were consistent with those reported by Bashford et al. (2024), particularly in the lower limbs and paraspinal regions, confirming that the NHS-compatible protocol can reproduce research-grade data quality.
- The fat-fraction analysis similarly demonstrated patterns of muscle degeneration comparable to previously published quantitative MRI studies, with increased fat infiltration observed in regions exhibiting heightened MUMRI activity. Both MUMRI and fat-fraction findings followed the expected distribution of motor unit involvement in MND, reinforcing the validity of the technique when applied on standard NHS MRI systems.

CONCLUSION

- Motor Unit MRI can be performed on normal hospital MRI scanners without any hardware changes.
- It safely detects tiny muscle twitches in both deep and surface muscles.
- Earlier research shows it can distinguish patients from healthy individuals and track disease progression.
- This approach could one day become part of routine hospital testing, helping to detect Motor Neuron Disease earlier and monitor how it changes over time.

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