In Vivo Functional and Imaging Assessment of Muscle Quality after Rotator Cuff Tear and Repair in a Rabbit Model

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INTRODUCTION: Rotator cuff tears (RCTs) are common shoulder injuries that lead to pain, weakness, and long-term loss of function. If left untreated, they often result in muscle atrophy and fatty infiltration—both of which impair shoulder performance and complicate surgical repair. While surgery can restore tendon integrity and reduce pain, it does not consistently reverse muscle degeneration. In fact, muscle degeneration and fatty infiltration may continue to progress after repair, increasing the risk of re-tear and limiting functional recovery. Our goal is to establish how muscle atrophy and fatty infiltration evolve over time; such information is essential for developing effective treatments. In this preliminary study, we used a rabbit surgical model of rotator cuff tear combined with a new method of *in vivo* neuromuscular functional testing, and post-hoc MRI imaging and muscle histology, to relate shoulder function to its muscle quality and fat infiltration. Future works will apply these methods to evaluate the effects pharmacological and neuro-stimulation interventions towards improving muscle function and reducing fatty infiltration.

METHODS: Six skeletally mature female New Zealand White rabbits (6-8 months old) underwent unilateral left tenotomy of the supraspinatus and infraspinatus tendons, with the unoperated contralateral limb serving as control. Two rabbits received surgical repair after 4 weeks, while four remained unrepaired, and all animals were euthanized 1.5 weeks later. Nerve evoked function was quantified *in vivo* at baseline, 1-week post-tenotomy, and 1-week post-repair (or equivalent for unrepaired). In the anesthetized animal the forelimb was affixed by a nylon cord to a torque motor (Aurora Scientific) under positive tension. The suprascapular nerve was stimulated via subcutaneous needle electrodes at the suprascapular notch with 500 msec trains of 0.2 msec square pulses at increasing frequency (1-150 Hz) and peak isometric torque evaluated. Following euthanasia, shoulder girdles were harvested and imaged using 3-point Dixon MRI (9 Tesla, 0.2 mm resolution). Fat fraction (FF), total cross-sectional area (CSA), and contractile CSA were quantified for supraspinatus and infraspinatus muscles using axial slices of fat and water MRI images. All procedures were approved by the Institutional Animal Care and Use Committee. The use of only female rabbits reduces variability in early-stage modeling, with future work planned to include both sexes.

RESULTS:
We established reliability of *in vivo* nerve evoked isometric torque in the right vs left limb at baseline (Fig 1, left). Compared to baseline, we show that the torque of injured limbs declined by ~65% (Fig 1; middle). We further demonstrate that isometric torque remained similarly depressed 1-week post-repair (Fig 1, right). MRI revealed marked fatty infiltration (Fig 2, Fig 3a,3b) in repaired muscles (supraspinatus FF: ~19% vs. control ~9%; infraspinatus FF: ~15% vs. control ~8%). Contractile CSA was reduced in both repaired and unrepaired groups (Fig 3c,3d), with the greatest deficit in repaired muscles (supraspinatus CCSA: ~1.2 cm² repaired vs. ~2.0 cm² control). These findings demonstrate that repair alone does not restore contractility and may coincide with greater fatty infiltration.

DISCUSSION:
This pilot study establishes the longitudinal assessment of rotator cuff neuromuscular function in a rabbit model of rotator-cuff injury/repair. We further confirm reports that surgical repair alone may be insufficient to reverse muscle atrophy and fatty infiltration, particularly in chronic rotator cuff tears.
Our findings suggest that muscle function remained impaired and fatty infiltration worsened after surgical repair—a possible "second hit" effect.
We propose this model and methods as a strong foundation for future testing of pharmacological and electrical stimulation therapies aimed at mitigating muscle degeneration and enhancing recovery.

SIGNIFICANCE/CLINICAL RELEVANCE:
Our approach integrates in vivo muscle contractility measurements and advanced MRI to provide translational insights. This model supports future research into interventions that preserve muscle quality, reduce the risk of re-tear, and improve surgical outcomes.

IMAGES AND TABLES: