Muscle Microvascular Function in Fat Free Tissue and Muscle Energetics following a Rotator Cuff Tear

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Summary

This study examined the post-contractile blood oxygen level-dependent (BOLD) response and energetic status in adults with and without chronic rotator cuff tears. Our findings indicate an impaired BOLD response in fat free tissue and an altered energetic status of the muscles surrounding the shoulder joint.

Introduction

Histological studies demonstrate that the degenerative process following a rotator cuff tear disrupts the vascularity and energetics of the shoulder muscles [1]. Inadequate oxygen delivery can impede muscle healing and recovery and contribute to an altered energetic status [2]. Magnetic resonance (MR)-based post-contractile blood oxygen level-dependent (BOLD) response and ^{31}phosphorus magnetic resonance spectroscopy (^{31}P-MRS) signals offer a method to assess muscle microvascular function and energetic status non-invasively. However, muscle composition (i.e. fat tissue) can confound these signals [3]. This study aims to examine the BOLD response in fat free tissue and energetics in shoulder muscles of individuals with chronic full-thickness supraspinatus tears compared to those without tears.

Methods

We recruited 19 participants with full-thickness supraspinatus tears (65.8 ± 7.7 years, 8 males), and 16 controls with intact rotator cuffs confirmed by ultrasound imaging (63.7 ± 5.4 years, 6 males). Using a 3T MR Phillips system, the BOLD response was measured following five brief (2s) maximal isometric shoulder abduction contractions using a customized MR-compatible dynamometer. Dixon fat/water scans were used to estimate the fat free mass in the supraspinatus muscle [i.e., 1-Fat Fraction (FF)]. On both the Dixon and BOLD images, a region of interest (ROI) was drawn on a single slice at the supraspinatus maximal cross-sectional area. Care was taken to only include visible muscle tissue. These ROIs were used to plot the BOLD signal intensity and calculate peak BOLD response. The peak BOLD response was normalized by the FF, to better reflect the BOLD response relative to muscle mass. A surface ^{31}P-MRS coil (14 cm diameter) was placed behind the scapula to acquire ^{31}P-MRS spectra from the shoulder muscles surrounding the scapula. Relative concentrations of inorganic phosphate (Pi), phosphocreatine (PCr), phosphodiester (pde), gamma adenosine triphosphate (ɣATP), and intracellular pH were measured and expressed as ratios. Unpaired, one-tailed t-tests compared the normalized peak BOLD response, FF, and ^{31}P-MRS ratios ($\alpha = 0.05$).

Results and Discussion

Our results (Table 1) indicate that individuals with rotator cuff tears had a reduced normalized peak BOLD response suggesting impaired microvascular function in the supraspinatus muscle. The FF being comparable between groups also suggests that fat composition within the muscle tissue is not directly responsible for this impairment. Additionally, greater pde/PCr and pde/ɣATP ratios in the rotator cuff group reflect an altered energetic status consistent with muscle membrane damage.

Conclusions

These results advance the field of quantitative rotator cuff imaging by evaluating the post-contractile BOLD response in shoulder muscles for the first time. They also highlight its potential use as a non-invasive tool for characterizing degenerative changes in the supraspinatus muscles after tendon tears. Our findings provide insights into vascular and metabolic mechanisms of muscle degeneration (rather than structural), informing us of the healing potential of the muscle. This is valuable for future studies assessing novel therapeutic interventions to improve outcomes after a rotator cuff tear.

Acknowledgments

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References

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Table 1: Torn rotator cuff and healthy group means for normalized peak BOLD response, fat fraction, and phosphate metabolites ratios.

Group	Normalized peak BOLD response*	FF	Pi/PCr	pde/PCr*	PCr/ɣATP	pde/ɣATP*	pH
RCT	3.3 ± 1.9%	0.3 ± 0.1%	0.1 ± 0.03	0.01 ± 0.03	6.5 ± 1.6	0.7 ± 0.3	7.2 ± 0.05
Healthy	6.7 ± 2.7%	0.2 ± 0.1%	0.1 ± 0.03	0.08 ± 0.03	6.0 ± 2.2	0.4 ± 0.2	7.2 ± 0.05
p value	*p < 0.001*	*p = 0.14*	*p = 0.08*	*p = 0.02*	*p = 0.22*	*p = 0.01*	*p = 0.37*

RCT - Rotator Cuff Tear Group
* Statistically significant