INTRATENDINOUS STRAIN FIELDS OF THE SUPRASPINATUS TENDON: THE EFFECT OF A BURSAL SIDE PARTIAL-THICKNESS ROTATOR CUFF TEAR

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Introduction
Partial-thickness rotator cuff tears are a common shoulder injury, causing significant pain and disability. Traditional techniques for quantifying rotator cuff mechanics have relied on optical analyses of surface strains [1-3], though it has recently been shown that tissue strains vary considerably through the tendon’s thickness [4,5]. Previous research has investigated the effects of an articular side partial-thickness tear [1], but the effects of the more common bursal side partial-thickness tear are unknown. Thus, this study’s purpose was to investigate the effect of a bursal side partial-thickness rotator cuff tear by comparing intratendinous strain fields under intact and torn conditions. Given that the bursal side fiber orientation is primarily aligned with the supraspinatus tendon’s long axis [6], we hypothesized that a bursal side tear would significantly increase intratendinous strain at all joint positions.

Methods
Following IRB approval and validation studies to assess reliability and accuracy of a MRI-based strain-measuring technique [4,5], four healthy shoulders (70 ± 16 years) were dissected, retaining the humerus, scapula, glenohumeral ligaments, biceps and rotator cuff tendons. Specimens were positioned in 15°, 30°, 45°, and 60° of glenohumeral abduction with 4.5 N loads applied to the rotator cuff tendons. Two scapular-plane MRI’s (6 mm thickness, 0.137 mm/pixel) were taken at each position. The first MRI was taken under “unstrained” conditions with a 4.5 N load on the supraspinatus, while the second MRI was taken under “strained” conditions with a 31 N load on the supraspinatus. A bursa side partial-thickness rotator cuff tear was then created by releasing the lateral third of the supraspinatus tendon from its insertion. A second set of MRI’s were then collected under the previously described testing conditions. 2-d finite strains (εxx, εyy, εxy) were quantified from image pairs using custom texture correlation software [4,5]. Strains were grouped into superior, middle, and inferior regions of the supraspinatus tendon’s “critical zone” [7] where most rotator cuff tears occur (Fig. 1). Each specimen produced 24 measures of strain: two conditions (intact, torn), three regions (superior, middle, inferior) and four positions (15°, 30°, 45°, 60°). The effects of tendon region and joint position were assessed with a repeated measures 2-way ANOVA and Fisher’s post-hoc test. The effect of the rotator cuff tear was assessed with a paired t-test. Significance was set at p < 0.05.

Results
Validation studies report an average displacement accuracy of 24 µm and a strain accuracy of ± 0.6% (95% confidence interval). Figure 1 shows an example of intact specimen intratendinous strains, with average strains for all specimens shown in Figures 2-3. At 15°, superior region strains significantly exceeded inferior region strains under intact and torn conditions. In general, strains increased after creating the partial-thickness tear, though this result was not statistically significant. Consistent with previously reported results [4], the data suggest a trend of increasing strain with increasing joint angle.

Discussion
The data demonstrated a significant difference between superior and inferior region strains at the 15° position under intact and torn conditions. This result not only supports the notion of strains varying through the depth of the supraspinatus tendon, but also further supports the assertion that inferior region tissue mechanics may be, at least in part, governed by its interaction with the humeral head [4]. Although these data failed to support the hypothesis that a bursal side tear would cause increases in strains across all joint positions, the data showed a trend toward increased strains in the superior and middle regions. In particular, the middle region showed the greatest relative increase in strain, suggesting that the imposed load was preferentially supported by this region after the tear was created.

The measuring system employed in this study overcomes many of the limitations associated with traditional strain-measuring techniques by providing high-resolution, intratendinous measures of strain without using markers or instrumentation that compromise the tissue of interest. Limitations include testing under static conditions, and creating a rotator cuff tear that does not mimic the biologic events associated with chronic rotator cuff tears. Future efforts will pursue an approach that provides three-dimensional tissue strains under in-vivo conditions.

References

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