INTRODUCTION: Clinically, a correlation between massive rotator cuff tears and glenohumeral arthritis has often been observed [1]. This may be due to a disruption in the balance of forces at the shoulder, resulting in superior and antero-superior migration of the humeral head and subsequently, abnormal loading of the glenoid [2]. Our lab has previously demonstrated changes in ambulation [3] and intact tendon mechanical properties following a supraspinatus and infraspinatus rotator cuff tear in a rat model [4], but have not examined the effect of this rotator cuff injury on the glenoid cartilage (including the articular cartilage and labrum). Therefore, the objective of this study was to investigate the effects of supraspinatus and infraspinatus rotator cuff tears on the glenoid cartilage. We hypothesized that the glenoid cartilage: (H1) thickness and (H2) modulus will both decrease in the superior and antero-superior regions, as a result of the altered loading due to the supraspinatus and infraspinatus rotator cuff tear.

METHODS: Sample Preparation and Study Design: Nine adult male Sprague-Dawley rats (400-450 grams) underwent unilateral detachment of the supraspinatus and infraspinatus tendons in the left shoulder (IAUC approved). All rats were sacrificed 4 weeks after detachments and frozen. The animals were thawed and the scapula was dissected out. The scapula was secured in a custom designed fixture and immersed in PBS containing a protease inhibitor cocktail (5 mM Benz-HCl, 1mM PMSF, 1 M NEM) at room temperature.

Thickness Measurement: Specimens were scanned at 0.25 mm increments using a 55 MHz ultrasound probe (Visualsonics, Inc) in plane with the scapula. Captured B-mode images of each scan were segmented by selecting the glenoid and bony surfaces. The 3D positions of these surfaces were reconstructed and used to determine cartilage thickness maps. Each thickness map was divided into six regions (center (C), postero-superior (PS), postero-inferior (PI), antero-superior (AS), antero-inferior (AI), and superior (S)) and an average thickness was computed for each region for both injured (left) and control (right) shoulders (Fig. 1).

Mechanical Testing: Utilizing a 0.5 mm diameter, non-porous spherical indenter tip, cartilage indentation testing was performed: preload (0.005 N), 8 step-wise stress relaxation tests (8 um/s followed by a 300 s hold). The scapula was repositioned for each localized region (Fig 2) using angular, rotational, and linear stages such that the indenter tip was perpendicular to the cartilage surface. Equilibrium elastic modulus was calculated, as described previously [5], at 20% indentation and assuming Poisson’s ratio (v=0.30).

Statistics: For the first hypothesis, significance was assessed using a Wilcoxon signed rank test. For the second hypothesis, significance was assessed using a paired t-test (significance at p<0.05).

RESULTS: Cartilage thickness significantly decreased in the antero-superior region of injured shoulders (Fig 3, LEFT). In addition, equilibrium elastic modulus significantly decreased in the center, antero-superior, antero-inferior, and superior regions (Fig 3, RIGHT). No other regional changes were identified.

DISCUSSION: This is the first study to demonstrate decreased thickness and mechanical properties of glenoid cartilage following a supraspinatus and infraspinatus tear in an animal model, consistent with degeneration observed in the human condition. Clinically, glenohumeral joint stability is provided by a dynamic balance of rotator cuff forces, in particular the subscapularis anteriorly and the infraspinatus posteriorly. An intact rotator cuff allows for concentric rotation of the humeral head on the glenoid. However, a massive rotator cuff tear involving the infraspinatus and supraspinatus disrupts the normal balance of forces at the joint, often resulting in altered joint function and cartilage degeneration. In this study, detachment of the postero-superior dynamic restraints (supraspinatus and infraspinatus) resulted in alterations consistent with cartilage degeneration (decreased thickness and decreased modulus) localized anteriorly and superiorly. Decreased cartilage compressive modulus and decreased tissue thickness have both been observed in previous animal models of osteoarthritis following joint instability [6].

Specifically, from our previous studies, this animal model of rotator cuff injury has been shown to decrease shoulder function [3], decrease biceps and subscapularis tendon mechanical properties [4] and, as demonstrated in the current study, result in thinning and decreased modulus of the glenoid cartilage.

Future studies will examine additional time points to examine the progression of cartilage changes as well as tissue biological properties, in order to gain insight into the relationships between, and mechanisms governing, cuff tears and subsequent joint damage.

CLINICAL SIGNIFICANCE: Results of this study suggest that altered loading after rotator cuff injury leads to comprehensive damage to the shoulder joint with potentially broad implications. By increasing scientific understanding of the mechanical processes involved in joint damage, this will allow physicians to better advise patients.

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