INTRODUCTION: Following rotator cuff repair, shoulder motion is typically restricted by placing the arm in a sling, and passive motion begins in the first week [1]. This post-operative protocol has evolved, with recognition of the negative effects of immobilization on joint stiffness, particularly based on tendon repair studies in the hand [2]. In these studies, periodic passive motion was found to greatly reduce joint stiffness, the primary complication following hand surgery. However, the primary complication for the rotator cuff, is not joint stiffness, but rather re-rupture of the repaired insertion site [3]. A previous animal study demonstrated that immobilization improved the mechanical properties of the repaired insertion site [4]; however, joint stiffness was not evaluated. Therefore, the objective of the current study was to determine if immobilization following rotator cuff repair surgery would increase shoulder stiffness. We hypothesized that immobilization would decrease the range of motion and increase stiffness in the shoulder following rotator cuff repair and that these parameters would improve with time.

METHODS: In 10 rats (IACUC approved), injury and repair surgery consisted of sharp detachment of the supraspinatus tendon from bone, burring the original insertion site and reapposing the tendon with suture passed through a bone tunnel using a modified Mason-Allen technique [4]. Shoulder mechanics were measured (as described below) in all animals prior to surgery. Immediately following surgery, 5 animals had their shoulders immobilized in casts (IMM) and the remaining 5 animals served as control (CTL). Four weeks post-repair, the casts were removed from the IMM group and shoulder mechanics were measured for both groups. Shoulder mechanics were measured again 5, 6 and 8 weeks post-repair. Parameters (range of motion and toe- and linear-region stiffness) of three loading cycles were averaged for both internal and external directions and compared using a repeated measures 2-way ANOVA overall model with treatment (IMM or CTL) and time (4, 5, 6 and 8 weeks post-repair) as the fixed effects (Prism, GraphPad). Lastly, all pairwise comparisons were performed using a Bonferroni post-hoc analysis.

A continuous passive motion device for measuring internal and external rotational mechanics of the rat shoulder was constructed (see FIG1). At each time point, the injured arm of the anesthetized animal was placed in the device at 90 degrees of elbow flexion. Torque (Futec 51755) and orientation (Microstrain 3DM-DHI) data were collected, displayed and stored using LABVIEW (National Instruments), while a user applied three internal/external loading cycles to targets of 20 N-mm.

Neutral rotation was defined as the angle at which torque was near zero and the subsequent torque-rotation data were analyzed separately for each direction using a bi-linear curve fit (FIG2), where the maximum deviation from linearity defined the break point between toe and linear regions.

RESULTS: The overall effect of immobilization on external range of motion (FIG3-A) and toe-region stiffness (FIG3-B) was not significant, but linear-region stiffness was significant (FIG3-C). Subsequent post-hoc analysis however did not detect any significant differences between immobilized and control linear-region stiffness at any time point (FIG3-C). The overall effect of time (post-repair) was significant for all external parameters, and subsequent post-hoc analysis indicated that: the range of motion was significantly less than uninjured at all time points, linear-region stiffness was significantly higher than uninjured for three (IMM) and two (CTL) time points (FIG3-C) and toe-region stiffness was significantly higher at two time points (FIG3-E).

The overall effect of immobilization on internal range of motion (FIG3-B) and toe-region stiffness (FIG3-F) was not significant, but linear-region stiffness was significant (FIG3-D). Subsequent post-hoc analysis indicated that linear-region stiffness of the immobilized group was significantly larger than control at eight weeks post-repair. The overall effect of time (post-repair) for the range of motion and toe-region stiffness was significant and subsequent post-hoc analysis indicated that: the range of motion was significantly larger than uninjured for two (IMM) and three (CTL) time points (FIG3-B) and toe-region stiffness was significantly larger than uninjured at 8 weeks post-repair (both groups).

DISCUSSION: Contrary to our hypothesis, immobilization did not increase shoulder stiffness following rotator cuff repair. With the exception of one of six parameters at only one of four post-repair time points (denoted by * in FIG3), there were no significant differences in any shoulder mechanics measures between immobilization and control groups. This suggests that the loss in external range of motion (~1/2) and increased rotational stiffness (~2X) is primarily due to the injury and repair, rather than to immobilization. As a result, a period of immobilization following rotator cuff repair which improves insertional mechanical strength [5], without a negative impact on joint stiffness as demonstrated here, should be considered clinically.

It should be noted that we did not assess the biological source of this increase in joint stiffness which could be done in future studies. In addition, it will be important to determine the effect of immobilization on shoulder mechanics in other degrees of freedom than those measured in the current study. Lastly, the apparent increase in the range of internal motion following repair (FIG3-B) can be explained as a shift in 'neutral' towards external rotation, which recall was defined as the angle at which the applied torque was near zero (see FIG2). Further studies will evaluate such changes in torque-rotation symmetry in order to develop a physiologic explanation for the observed non-linear behavior.

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