INTRODUCTION:
Prior research has examined complex methods of biologic augmentation during rotator cuff repair, including tendon transplants and extracellular matrix grafts. Our proposed procedure utilizes local autogenous bone marrow delivered to the repair site via a cannulated humeral implant. Such marrow delivery channels could be developed for suture anchors and other surgical hardware and may offer a strategy of autogenous biologic augmentation that is no more invasive or time-consuming than current repair procedures.

METHODS:
Twenty-three adult male Sprague Dawley rats (350-450 g) underwent bilateral cuff surgeries, in which the supraspinatus tendon was sharply cut and repaired at its insertion on the humerus. Prior to repair, each shoulder received a nitinol implant (Memry, Betherl, CT) which was press-fit into the humeral bone marrow beneath the repair site. The implant was either a solid cylindrical implant or a hollow, cannulated cylinder (OD=0.64mm, ID=0.51mm, L=4mm). Rats were euthanized after four and eight weeks. Ten four-week and nine eight-week rats underwent biomechanical testing of both supraspinatus tendons, and four specimens of the eight-week group underwent histological analysis. Each of the biomechanical specimens was tested to failure, with failure force, stiffness, energy to failure, failure mode and energy to complete pull-off recorded. Tendon supero-inferior thickness and antero-posterior width were also measured. A two-way ANOVA was performed to determine the effects of time and treatment (solid vs. cannulated implants). Specimens for histological analysis were fixed, decalcified with acid, and embedded in paraffin. Sections of 5 µm thickness were stained with H&E or safranin O, and semi-quantitative scoring was completed in a blinded fashion. Specimens were scored for continuity of the tendon, presence of a gap within the tendon, fibrocartilage morphology, and intensity of safranin O staining at the tendon-bone insertion.

RESULTS:
The most common mode of biomechanical failure was an avulsion tear off the footprint (19 of 38), followed by mid-substance tear (8 of 38). Failure force, stiffness, energy to failure (Figure 1) and pull-off energy all showed statistically significant increases over time but did not demonstrate any differences with treatment. A post-hoc power analysis found 80% power to detect a 25% difference in failure force, stiffness and energy to pull-off between solid and cannulated implants. Tendon length also increased with time but not treatment, while tendon width did not change with either time or treatment. Histologically, there were large variations in the quality of repair achieved within each group, with some specimens showing continuity at the tendon insertion site (Figure 2), and others with fibrous or vascular tissue between tendon and bone. Consequently, there was no significant difference in healing between the treatment groups at 8 weeks.

DISCUSSION:
Our results suggest that a cannulated humeral implant does not strengthen cuff repair in a rat model. Local autogenous bone marrow itself may improve healing, but the diminutive size of the cannulated implant may prevent sufficient marrow delivery in rats, whose marrow components are similar in size to those of humans. Therefore, these data may not necessarily extrapolate to larger animals or a typical middle-aged or elderly patient with a rotator cuff tear. Our acceptance of the null hypothesis between treatment cohorts is well-powered and bolstered by the finding that post-operative biomechanical properties and tendon thickness increase over time. Interestingly, unlike thickness, supraspinatus tendon width did not change over time post-operatively. This finding was previously reported in an MRI study and suggests that supraspinatus width recovers more slowly than its thickness in the post-operative period.

SIGNIFICANCE:
This study found that there was no improvement from possible autogenous bone marrow infiltration in supraspinatus tendon healing in a rat model. This infiltration was intended to model the infiltration that may occur through suture anchors used in certain rotator cuff repair techniques. However, the small size of the rat necessitates such a small cannulation diameter that the amounts of infiltration around both the cannulated and noncannulated devices were most likely of the same order of magnitude as the amount of infiltration through the cannulated device, making it difficult to clearly assess the effect of autogenous bone marrow infiltration. To more definitively ascertain the effect of autogenous bone marrow on healing by infiltration, a large animal model is needed.

REFERENCES: