Introduction: It is unclear whether shoulder strength loss simply increases with the size of a rotator cuff tear or if there is a threshold in dimension. Apart from the size of a rotator cuff tear its shape could determine its effects on shoulder strength. While simple detachment of the tendon from its bony insertion could cause decreased shoulder strength, a tendon substance defect could be required before shoulder strength loss becomes clinically symptomatic. Also, retraction could be a causative factor in shoulder strength loss following a rotator cuff tear. The purpose of this study was to compare the effects of supraspinatus tendon detachment, defect and muscle retraction on in-vitro force transmission by the rotator cuff to the humerus.

Methods: 10 cadaver shoulders were tested. A rigid fiberglass rod was cemented into the medullary canal of the humerus and connected to a three-component load cell for the measurement of the forces transmitted by the rotator cuff to the humerus. Testing was performed with the arm in hanging arm position (Fig 1). The distance from the load cell to the center of rotation of the glenohumeral joint was kept constant throughout the experiment. Through pulleys, that were carefully adjusted so that the strings imitated the line of action by running through the centroids of each muscle (Johnson 1996), the rotator cuff muscles were loaded in proportion to their cross-sectional area (Veeger 1991). The transmitted forces were recorded under the following conditions:

1) Incision of 1/3 of the supraspinatus width near the insertion.
2) Defect of 1/3 involving half of the medial extent of the tendon substance, simulating tendon substance loss without muscle retraction.
3) Excision of 1/3 involving the total medial extent of the tendon, simulating tendon substance loss with muscle retraction.
4) Side to side repair of the tendon.
5) Complete repair of the tendon.

Forces transmitted under the different conditions were expressed as percentages of the force transmitted by an intact rotator cuff. The effect of cut size (1/3, 2/3, and 3/3) was evaluated separately for each state (incision, flap, retraction, partial repair, and complete repair) using repeated measures ANOVA and post hoc testing.

Results: Detachment needed to involve the full width of the supraspinatus before a significant (p<0.05) decrease in transmitted force (11.0%) could be detected.

A tendon defect needed to involve the anterior two thirds to produce a significant (p<0.05) decrease in the transmitted force (4.1%). A defect involving the whole tendon further reduced the transmitted force significantly (p<0.05) by 17.0%.

Simulated muscle retraction by excision of the anterior third of the supraspinatus muscle and tendon had a major effect (18.7%) on the transmitted force. Excision of two thirds of the musculotendinous unit led to a significant (p<0.05) decrease in the transmitted force of 45.8% and resection of the whole supraspinatus muscle and tendon reduced the force transmitted by the rotator cuff substantially and significantly (p<0.05) by 58.4%.

After excision of one and two thirds of the musculotendinous unit, side-to-side repair restored the force transmission to nearly normal (99%±97%), while after complete resection of the supraspinatus muscle and tendon and partial repair a significant (p<0.05) deficit of 9.4% remained. The forces transmitted after each complete repair of the supraspinatus tendon were not significantly different (p>0.05) from the intact state.

Discussion: Obviously, the rotator cuff muscle forces are transmitted around small and medium size supraspinatus tendon detachments. According to Burkhart the muscle forces are effectively transmitted by the rotator cuff as long as the rotator cable is intact (Burkhart 1992). Our results indicate that the threshold for a substantial decrease in force transmission is detachment of the whole supraspinatus tendon affecting the rotator cable.

The effect of muscle retraction on the force transmission was significantly higher than that of tendon defects (p<0.05). Therefore, muscle retraction is probably a major factor for strength loss following medium to large size rotator cuff ruptures.

Our results correspond with the clinical observation that patients with small rotator cuff ruptures present without strength loss and support the rotator cable concept. In cases of irreparable rotator cuff defects, partial repair may be worthwhile to restore muscle pretension and the integrity of the rotator cable.

Acknowledgements: The first author was supported by the Max Biedermann Institut, Berlin. This study was funded by the Mayo Foundation, and NIH grant AR41171.