

Stitch positioning influences the suture hold in supraspinatus tendon repair

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Received: 6 March 2012 / Accepted: 5 June 2012 / Published online: 17 June 2012
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Abstract

Purpose This study was designed to compare the pull-out strength of simple suture stitches in human supraspinatus tendons with respect to the position of the rotator cable.

Methods Fifty-four tests were performed on 6 intact, human supraspinatus tendons, to assess the cutout strength of a simple suture configuration in different positions; medial to, lateral to, or within the rotator cable. Tendon thickness was measured and correlated for each positioned suture.

Results Suture positioning lateral to or in the rotator cable showed significantly lower suture retention properties compared with positioning the suture medial to the cable ($p = 0.002$). In all tested specimens, the central stitch in the row medial to the rotator cable provided the optimum retention properties (mean: 191 N; SD: ± 44 ; $p < 0.01$), even after correcting for tendon thickness.

Conclusion This study shows that it is desirable to identify the rotator cable and to pass sutures just medial to it, close to the middle of the tendon, which provided highest possible suture retention properties.

Keywords Rotator cuff repair · Suture cutout · Fixation strength · Rotator cable

Introduction

Despite important improvements in rotator cuff repair technique, the persistence or recurrence of defects of the repaired cuff remains too frequent [3, 4, 12, 14, 28]. The tendon quality is an important; however, predetermined factor and therefore the surgical technique might further be optimized.

The tendon quality is an important, however predetermined factor, and therefore it may be the surgical technique that needs to be further optimized to improve initial fixation and healing of the tendon to the bone. With the introduction of stronger anchors and modern polyblend suture materials, the suture–tendon interface has been identified as the weakest link of rotator cuff repair [2, 10]. Much research attention has been directed towards improving the biomechanical properties of different tendon grasping techniques [1, 2, 9, 11, 13, 16, 17, 20, 27]; however, there is a paucity of data in the current literature with regard to suture positioning within the tendon.

When sutures cut through a tendon, they tend to slip along the longitudinal orientation of the tendon fibres, analogous to a comb in a bundle of hair. The rotator cuff, however, is architecturally different from most other tendinous structures in the body: First identified by Clark et al. [7, 8] and later described and analysed as a loaded cable in the suspension bridge model by Burkhart and Burkhart et al. [5, 6], the rotator cable is now widely accepted as an independent anatomical structure of the glenohumeral capsulo-ligamentous joint complex. In terms of its origin, the superficial-medial layer arises from the superior facet of the lesser tuberosity and its deep lateral layer from the anterior facet of the greater tuberosity at the anterior edge of the SSP. Forming a semicircular arch, the cable runs perpendicular to the longitudinal axes of the SSP and ISP

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tendon, reaching the teres minor tendon on the posterior aspect of the greater tuberosity [15]. The rotator cable may be identified visually [7, 8, 15], arthroscopically [6], on MRI [23] or via ultrasonography [21]. Due to its perpendicular orientation, in relation to the fibres of the SSP and ISP tendons, the rotator cable may initially prevent further extension of a rotator cuff tear, which generally starts at the rotator crescent, a region of relative tendon weakness and hypovascularity lateral to the rotator cable [6].

The hypothesis of the present investigation was that the rotator cable, as a perpendicular structure to the tendon axis, could represent an important structural resistance against suture cutout, which could be exploited in cuff repair. This study was therefore designed to compare the cutout strength of a simple suture configuration in human supraspinatus tendons positioned medial, within, or lateral to the rotator cable.

Materials and methods

Two orthopaedic surgeons performed the dissections, preparations and repairs after thawing 10 fresh frozen (-20°) human shoulders for 24 h at room temperature. The specimens were stripped of all soft tissues except for the supraspinatus muscle and tendon. This tendon was sharply detached from its insertion site at the greater tuberosity of the humerus. Specimens were kept moist with 0.9 % saline during dissection, preparation, and mechanical testing. The scapula was set into a fixation device (Fig. 1). Four specimens had to be excluded due to partial or visible damage of the tendons and were used for preliminary testing. Fifty-four tests were performed on 6 (3 left and 3 right) shoulders, with no preexisting rotator cuff abnormalities on macroscopic examination.

The rotator cable was identified on the articular side of the supraspinatus tendon and stitch positioning was determined. Precise stitch positions are depicted in Fig. 2. First four lateral sutures were set 5 mm medial to the free lateral tendon margin. The most anterior suture was set in the anterior part of the rotator cable; the three following sutures were positioned lateral to the rotator cable (lateral row: antero-central, postero-central, and posterior). Simple stitches, piercing the width of the tendon using a braided nonabsorbable polyblend UHMWPE suture (USP No. 2) (FibreWire, Arthrex Inc., Naples, FL), were used to minimize variability in technique. Sutures were securely fixed to a 1,000 N load cell, forming a suture loop using 7 square knots. Following separate load to failure tests for every single suture starting from anterior to posterior, the tendon end was resected leaving 5 mm of the rotator cable and the second suture row was placed. Three sutures were positioned (anterior, central and posterior) exactly medial to the



Fig. 1 Biomechanical test setting: The prepared scapula was set into a fixation device. Each suture was set 5 mm medial to the free lateral tendon margin. Sutures were securely fixed to a 1,000-N load cell of the material testing machine (Zwick-Roell, Ulm, Germany), forming a suture loop using 7 square knots. Ultimate load to failure test was performed at a rate of 1 mm/s

rotator cable (5 mm medial to the free lateral tendon margin). Analogous tests were performed. After repeated resection of tendon, one anterior and one posterior stitch were set medial to the musculotendinous junction again exactly 5 mm away from resection line and the same test protocol was performed. The thickness of the tendon (mm) and the distance to the myotendinous junction (mm) was measured for every positioned suture with a caliper.

The investigations were performed using a material testing machine (Zwick-Roell, Ulm, Germany), which recorded the data with the dedicated software (testExpert 10, Zwick-Roell, Ulm, Germany) and evaluated the data regarding load (N) and displacement (mm), which were digitally recorded and the deformation curve and the mode of failure was documented. After preloading the system with 5 N, an ultimate load to failure test was performed at a rate of 1 mm/s. Failure of the suture–tendon complex was defined as suture cutout through the remaining 5 mm tendon substance.

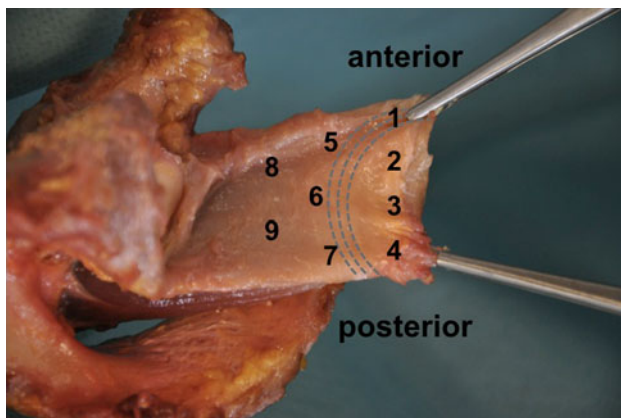


Fig. 2 Articular side of a supraspinatus tendon with illustration of suture placement in relation to the rotator cable. Sutures pierced the tendon and were placed in three rows 5 mm medial to the resected free tendon margin: Antero-lateral in the cable (1). Lateral to the cable: antero-central (2), postero-central (3), and posterior (4). Medial to the cable: anterior (5), central (6), and posterior (7). Medial to musculotendinous junction: anterior (8) and posterior (9)

Statistical analysis

Statistic analysis was performed with a commercial software package (PRISM, Version 4 for Macintosh, Graphpad Software Inc.) A two-way ANOVA for repeated measure with post hoc Dunnett's multiple comparison was performed to evaluate strength of the different suture positions. Correlation between tendon thicknesses to strength was calculated using Spearman's rank correlation. Level of significance was set at $p < 0.05$.

Results

The mode of failure was suture cutout of the tendon in all specimens. Scapula fracture, muscle rupture, knot slippage, or suture breakage were not observed. The mean force to failure, standard deviations, and the lowest value as well as

mean tendon thickness are presented in Table 1. In all specimens, the central stitch in the row just medial to the rotator cable provided highest suture retention properties (mean: 191 N; SD: ± 44 ; $p < 0.01$) (Fig. 3a).

Suture positioning lateral to or in the rotator cable showed significantly lower suture retention values compared to suture positioning medial to the cable ($p = 0.002$). Suture positioning medial to the myotendinous junction provided almost equal properties as lateral tendon stitches.

Mean distance to the myotendinous junction decreased continuously from anteriorly to posteriorly and measured 21 and 15 mm for the lateral and middle suture row, respectively.

Thickness of the tendon revealed a correlation to suture retention properties ($p < 0.001$; $r = 0.63$). Therefore, tendon thickness was correlated as a confounding factor for every stitch of the lateral and middle row. Although the thickness has a confounding influence, it did not change the results with respect to the superior pullout strength of a medial suture position. The differences between medial and lateral suture positioning decreased slightly in this analysis; however, the difference between suture positioning antero-lateral in the cable and medial to cable became even more pronounced (Fig. 3b).

Discussion

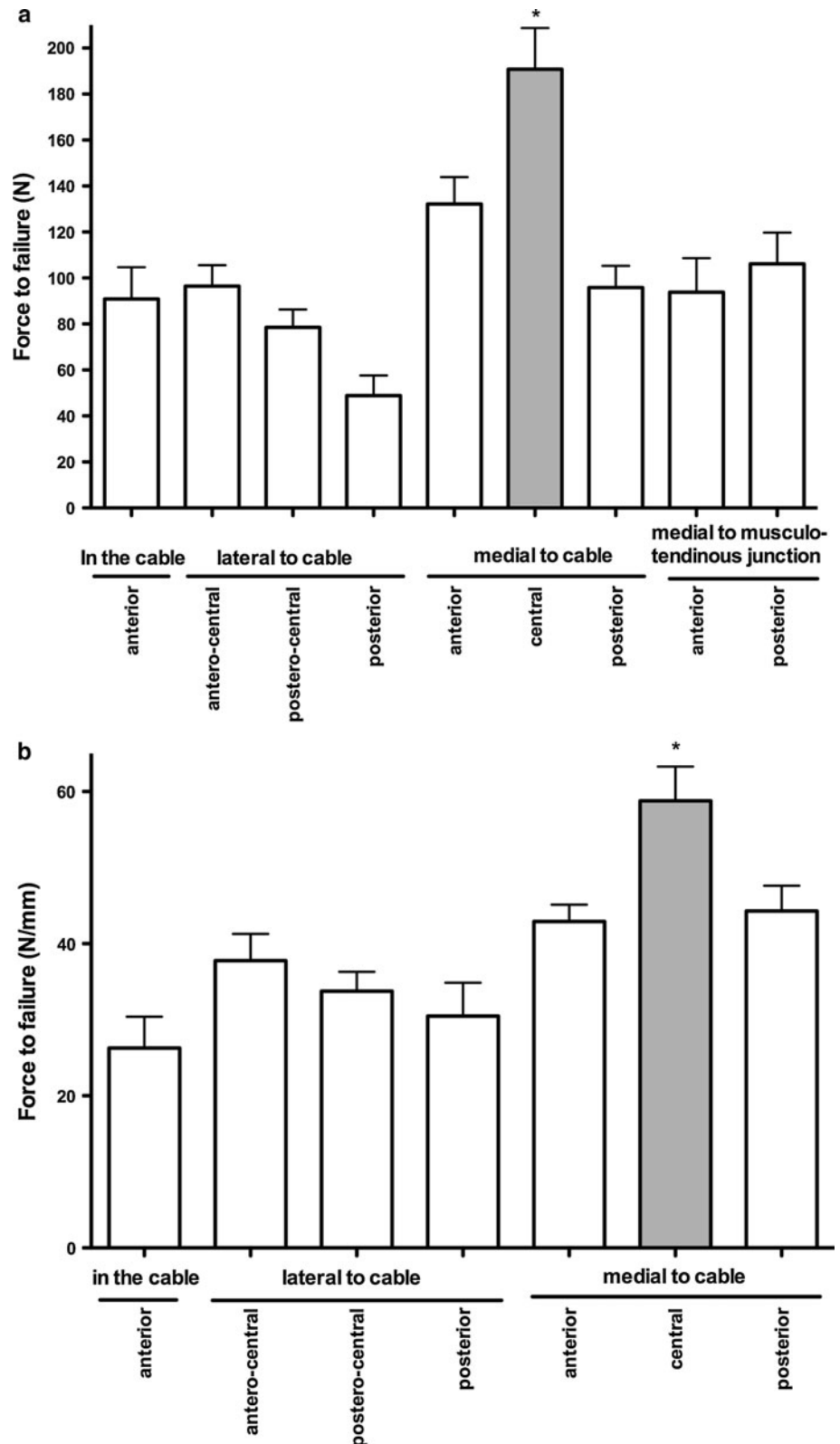
The most important finding of this study was that in all tested specimens, suture positioning medial to the rotator cable provided the best retention properties, even after correcting for tendon thickness. This article was intended to aid surgeons in determining optimal stitch positioning in arthroscopic rotator cuff repair. It shows that it is desirable to identify the rotator cable and to pass sutures just medial to it, close to the middle of the tendon to provide highest possible suture retention properties for initial fixation of a

Table 1 Forces to failure and tendon thickness

	In the cable			Lateral to the cable			Medial to the cable			Medial to musculotendinous junction	
	Anterior	Antero-central	Postero-central	Posterior	Anterior	Central	Posterior	Anterior	Posterior		
Force to failure (N)											
Mean	91	97	79	49	132	191	96	94	106		
SD	34	22	19	22	29	44	23	36	33		
Range	54–138	70–121	62–112	20–72	98–170	148–263	63–130	35–135	70–150		
Tendon thickness (mm)											
Mean	3.5	2.6	2.3	1.6	3.1	3.3	2.2				
SD	0.8	0.4	0.4	0.4	0.6	0.4	0.4				

The mean force to failure, the standard deviation, the lowest value of each suture position, as well as the mean tendon thickness and the corresponding standard deviation are shown

Fig. 3 Suture retention properties without (a) and with correlation of tendon thickness (b). Intermuscular stitches were not correlated for thickness. In all specimens, the central stitch in the row just medial to the rotator cable provided highest suture retention properties, compared to all other stitches ($p < 0.01$). After correction for tendon thickness, the differences in suture retention were less pronounced. Still significant differences were found with the best retention properties for the central stitch medial to the rotator cable



supraspinatus tendon repair. Suture positioning lateral to or in the rotator cable showed significantly lower suture retention properties compared with positioning the suture medial to the cable.

It is not uncommon to observe sutures pull through a tendon along the length of its fibres with relatively little resistance. The hypothesis that suture placement into or medial to the rotator cable provides better suture retention

properties can be confirmed in part. In all tested specimens, the central stitch in the intermediate row, medial to the rotator cable, provided the best suture retention properties, before and after correction for tendon thickness, which is a recognized confounding factor. Interestingly, suture retention decreased rapidly with a more posterior suture position, consistent with the reduced tendon thickness in this posterior region, where one of the five tendon layers is missing [7]. Although we found a good correlation for tendon thickness and suture retention, the thickest region of the tendon in the antero-lateral aspect did show unexpectedly low values until suture cutout occurred. This might be a consequence of the semicircular course of the cable, which anteriorly bends into a more parallel course with the main tendon fibres. However, in the middle portion of the tendon, the perpendicular course of the cable fibres provides the best resistance against the cutting sutures.

In the case of a massive rotator cuff tear, where the tear extends beyond the rotator cable, a more medial suture position may be the only alternative for suture placement. However, rarely used in clinical situations, due to the fact that such medial suture position will lead to a very tight or even over tensioned rotator cuff repair, we tested the properties of such an intramuscular suture position and found decreased initial fixation strength of almost 50 %, comparable to the best intratendinous suture positions.

To our best knowledge, there is only one article available in current orthopaedic literature, which focused on the regional differences with respect to suture retention properties in human supraspinatus tendons [26]. In this biomechanical investigation, sutures were placed either medial at the myotendinous junction or lateral, close to the free SSP tendon margin. In intact specimens, no difference in load to failure could be detected between medial and lateral suture positioning. As medial suture positioning was independent of cuff integrity, among torn tendons load to failure was significantly lower in the lateral region compared to the medial region. However, in this study, they did not analyse the anatomical relationship of suture positioning and the rotator cable.

Other anatomical studies stated that the anterior SSP tendon, which is more cord like, narrow and longer than the posterior portion [22, 25], might play a more important functional role in rotator cuff repairs because of its superior tensile properties and smaller amount of gapping compared to the posterior tendon following tendon repair [19, 24]. This could be confirmed with our study at least in part, as the anterior stitches in the lateral and intermediate (medial to the rotator cable) row showed higher suture retention properties compared to the posterior ones. However, by far the strongest suture position was in the central part of the tendon exactly medial to the rotator cable, which we

believe provides the best restraint against suture cutout following rotator cuff repair.

This study has some limitations. We used healthy tendons and did therefore not consider possible changes to the tendon quality with tears and possible loss of tendon substance and integrity, which may be subject of future studies. Although the rotator cable was impressively well identified in the laboratory setting, we are aware of the fact that this might not always be possible during arthroscopic rotator cuff repair. Furthermore, we did not correlate our results for specimen age, which might not only influence quality of the SSP tendon itself but also limit the structural integrity of the rotator cable. While we did reach statistically significant results with a relatively limited number of tests, we did only investigate ultimate load to failure and not the response to cyclic loading. This might not represent the cyclic loading conditions experienced in vivo but represents as a comparable method of repeated measurements in a single tendon. Nevertheless, these results demonstrate that the position of the suture influences initial fixation strength of a supraspinatus repair, which is in contradistinction to the currently accepted ovine or bovine laboratory models of rotator cuff testing [1, 2, 9, 11, 13, 17, 20].

Further research in this topic should address whether a similar zone of resistance exists in the subscapularis tendon, for instance the so-called “comma sign”, which is created by retraction of the superior subscapularis and the anterior supraspinatus tendon [18], and the resistance of the rotator cable against gap formation under cyclic loading conditions. Furthermore, it will be interesting to study the alterations in the anatomical position and condition of the rotator cable in the case of chronic and retracted tendon tears, as this might impair the possibility of proper suture passage medial to the rotator cable.

Conclusion

This study shows that it is desirable to identify the rotator cable and to pass sutures just medial to it, close to the middle of the tendon, which provides a potentially strong suture position for initial fixation of a supraspinatus tendon repair.

Conflict of interest The authors have no potential conflict of interest.

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