A new arthroscopic classification of articular-sided supraspinatus footprint lesions: A prospective comparison with Snyder's and Ellman's classification

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The aim of this study was to find a descriptive rationale to quantify articular-sided supraspinatus tendon tears in the transverse and coronal planes, leading to a 2-dimensional description of the tear pattern. Fifty-six consecutive patients with articular-sided, symptomatic supraspinatus tendon tears diagnosed clinically and by magnetic resonance imaging underwent standardized diagnostic arthroscopy. Intra-articular findings of the rotator cuff were classified according to Ellman and Snyder. In addition, the longitudinal tear was assessed according to the length of the peeled-off bony footprint in the coronal plane. The sagittal tear extension was defined as a tear of the lateral reflection pulley on the medial border of the supraspinatus tendon and/or a tear in the area of the crescent zone. Statistically, we found a high correlation (r = 0.920, $P < .0001$*) between the classifications of Ellman and Snyder, and we found only a slight correlation between the classifications of Snyder and Ellman with this new classification. Neither the classification of Snyder nor that of Ellman reproduced the extension of the partial-thickness rotator cuff tear in the transverse and coronal planes related to its etiologic pathomorphology. (J Shoulder Elbow Surg 2008;17:909-913.)*

The incidence of partial-thickness tears ranges from 13% to 37%.[14] Reilly et al[19] reported an incidence of partial-thickness rotator cuff tears of 18.5% in 2553 cadaveric shoulders.

Tears on the articular surface are 2 to 3 times more common than bursal-side tears.[4,5] Most partial-thickness rotator cuff tears involve the supraspinatus tendon.[14]

The pathogenesis of degenerative rotator cuff tears is multifactorial. Articular-sided tears are more likely caused primarily by intrinsic factors, whereas both intrinsic and extrinsic factors may play roles in the development of bursal-sided tears.[25]

On the basis of a cadaveric study, Reilly et al[18] observed tear propagation from joint to bursal sides during abduction. Tendon failure with greater levels of degeneration occurred at the insertion site of the tendon.

In contrast, Nakajima et al[15] discussed an increased incidence of articular-side tears after a traumatic event, because the bursal side of the tendon was able to undergo greater deformation and had a greater tensile strength than the articular side.

The etiology of partial-thickness rotator cuff tears is not considered in most classification schemes. However, it may be important in terms of both prognosis and treatment selection. McConville and Iannotti[14] claim that a classification of partial-thickness rotator cuff tears should be descriptive in terms of the location (both the tendon involved and the surface affected), the size (depth) of the tear, and the cause.

In 1934, Codman[3] described the development of partial-thickness tears in the undersurface of the supraspinatus tendon at the point of attachment immediately adjacent to the articular surface of the humeral head. In 1983, Neer[16] classified rotator cuff disease into 3 stages within his progressive stages of impingement. Stage III includes partial- and full-thickness rotator cuff tears without further differentiation. In 1990, Ellman[4] divided Neer's stage III into a more detailed subclassification of partial- and full-thickness tears. Snyder[23] also differentiated articular-sided partial-thickness tears from bursal-sided partial-thickness tears.

Snyder[23] classified the size of the defect by its superficial extension. Grade I tears represent a synovial irritation or capsular fraying in a small localized area, usually less than 1 cm. A lesion with fraying and failure of some rotator cuff fibers, in addition to synovial, bursal, or capsular injury in an area smaller than 2 cm, is classified as a grade II lesion. More severe rotator cuff injury, including fragmentation of the tendon fibers usually in an area smaller than 3 cm, represents a grade III lesion, and a very severe partial rotator cuff tear that usually contains, in addition to fraying and fragmentation of the tendon, a sizable flap usually

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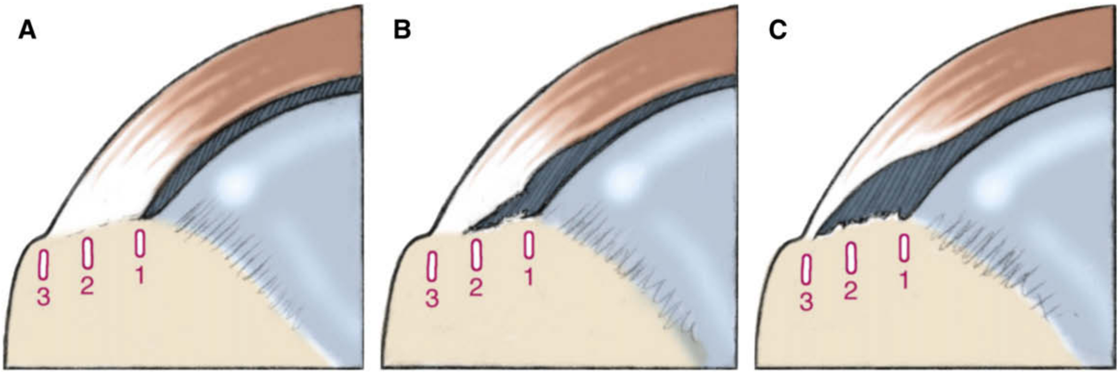

Figure 1 Longitudinal extension of articular-sided supraspinatus tendon tear in coronal plane. **A**, Type 1 tear: small tear within transition zone from cartilage to bone. **B**, Type 2 tear: extension of tear up to center of footprint. **C**, Type 3 tear: extension of tear up to greater tuberosity.

larger in size than 3 cm, involving more than a single tendon, is assessed as a grade IV lesion. The PASTA lesion (partial articular supraspinatus tendon avulsion) is described as a special form of a type A III or A IV tear with a traumatic etiology, which established a relationship to a tear at the tendon insertion without taking the extension of the tear, as well as the exact location of the partial-thickness tear, into account.

On the basis of a multicenter study, using standardized arthroscopic videos of different rotator cuff tears, Kuhn et al[13] found high interobserver agreement among experienced surgeons in distinguishing between full-thickness and partial-thickness tears and high agreement on the side of involvement of partial tears but no agreement when classifying the depth of the partial-thickness tear.

The aim of this study was to find a descriptive rationale to quantify articular-sided rotator cuff tears in the transverse and coronal planes.

MATERIAL AND METHODS

From October 2002 to May 2004, 56 consecutive patients (26 men and 30 women) with a mean age of 54 years (range, 27-71 years) who had an articular-sided anterosuperior rotator cuff tear, diagnosed clinically and by magnetic resonance imaging, underwent standardized diagnostic arthroscopy and were prospectively documented by use of an intraoperative documentation sheet.

Of the patients, 26 (46.4%) reported a traumatic history, and the mean duration of symptoms was 24.6 months (range, 1 week to 25 years). Overhead sports activity was performed by 29% (16 patients). Clinically, 59% showed a positive full-can test and 63% had a positive empty-can test.[11,12] Only 14% had a positive painful arc between 60° and 120° of abduction, and 6% had a positive liftoff test.[6] During clinical examination of the long head of the biceps (LHB) tendon, 81% of the patients had a positive O'Brien test[17] and 59% had a positive palm-up test. Of the patients, 58% had a positive impingement sign according to Hawkins and Kennedy[9] and 45% had a positive impingement sign according to Neer.[16] None of the patients had a positive drop-arm sign, and all patients showed a free range of active movement in all planes.

Exclusion criteria were bursal-sided tears, full-thickness tears, concomitant glenohumeral osteoarthritis, and previous surgery.

Intraoperatively, the partial-thickness rotator cuff tears were classified according to Ellman[4] and Snyder.[23] In addition, the longitudinal extension of the tear (Figure 1) was assessed by the length of the peeled-off bony footprint in the coronal plane.

A type 1 tear is a small tear within the transition zone from cartilage to bone. A type 2 tear is defined as a tear up to the center of the footprint, and a type 3 tear extends up to the greater tuberosity.

Sagittal tear extension (Figure 2) in the transverse plane is defined as a tear of the lateral reflection pulley on the medial border of the supraspinatus tendon and/or a tear in the area of the crescent zone. A tear of the lateral portion of the coracohumeral ligament continuing into the medial border of the supraspinatus tendon is defined as a type A tear. An isolated partial-thickness tear of the supraspinatus tendon within the crescent zone is a type B tear, and a tear extending from the lateral portion of the coracohumeral ligament and continuing into the medial border of the supraspinatus tendon up to the crescent zone is defined as a type C tear.

Intraoperatively, intra-articular findings, such as the presence or absence of a cable sign and the state of the superior glenohumeral ligament, the subscapularis tendon, the LHB, the anchor of the LHB (SLAP [superior labrum anterior-posterior] lesions, classified according to Snyder[23]), the labrum, and the middle glenohumeral ligament were documented. In the subacromial space, the undersurface of the acromion, the acromioclavicular joint, and the state of the subacromial bursa were assessed.

Statistical analysis

Univariate analyses of an association between the longitudinal tear extension as well as the sagittal tear extension and the classification of partial-thickness rotator cuff tears according to Ellman[4] and Snyder[23] were carried out by use of the Spearman rank correlation coefficient. All statistical analyses were performed with SPSS for Windows, version 13.0 (SPSS, Chicago, IL).

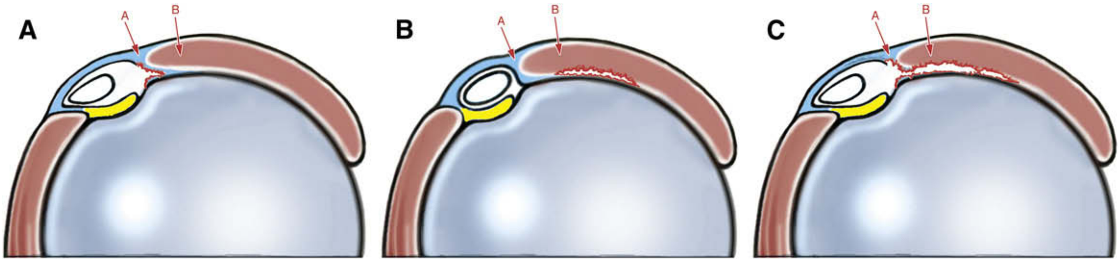

Figure 2 Sagittal extension of articular-sided supraspinatus tendon tear in transverse plane. **A**, Type A tear: tear of coracohumeral ligament continuing into medial border of supraspinatus tendon. **B**, Type B tear: isolated tear within crescent zone. **C**, Type C tear: tear extending from lateral border of pulley system over medial border of supraspinatus tendon up to area of crescent zone.

RESULTS

In 56 patients, an articular-sided partial-thickness rotator cuff tear was confirmed arthroscopically. Of these 56, 16 (28.6%) had a combined articular-sided supraspinatus and subscapularis tendon tear.

A positive cable sign was found in 62.5% (35 patients).

When the partial-thickness supraspinatus tendon tears were classified according to Ellman,[4] 26 patients (46.4%) had an A 1 tear, 13 (23.2%) had an A 2 tear, and 17 (30.4%) had an A 3 tear.

When the articular-sided supraspinatus tendon tears were assessed according to Snyder,[23] 17 patients (30.4%) had a type A I tear, 18 (32.1%) had a type A II tear, 20 (35.7%) had a type A III tear, and 1 (1.8%) was classified as having a PASTA lesion. Statistically, we observed a high correlation ($r = 0.920$, $P < .0001$) between the classifications of Ellman[4] and Snyder.

In the transverse plane, we observed that, in 26.8% of the patients (15 cases) with an articular-sided supraspinatus tear (sagittal extension of the tear), there was a tear of the coracohumeral ligament continuing into the supraspinatus tendon, which we classified as a type A lesion. In 23% (13 cases) of these patients, an articular-sided supraspinatus tendon tear in the area of the crescent zone with an intact rotator interval (type B) was seen. In 50% (28 cases) of the patients, a partial articular-sided supraspinatus tendon tear was found that extended from the lateral pulley system adjacent to the medial border of the supraspinatus tendon up to the area of the crescent zone (type C).

Assessing the longitudinal extension of the partial tear in the coronal plane, we observed an extension of the tear up to the transition zone from cartilage to bone (type 1) in 48.2% of patients (27 cases) with an articular-sided supraspinatus tear, extension of the tear up to the center of the footprint (type 2) in 37.5% (21 cases), and extension of the tear up to the greater tuberosity (type 3) in 14.3% (8 cases).

The 2-dimensional longitudinal and sagittal tear extension is shown in a coordinate system (Table I), which shows 9 possible subdivisions of this 2-dimensional classification. Most of the partial tears in our patients were classified as type 1 C or type 2 C.

Table I Frequencies of 2-dimensional sagittal and longitudinal extension of articular-sided supraspinatus tendon tear

	Sagittal tear		
Longitudinal tear	**Type A**	**Type B**	**Type C**
Type 1	8	6	13
Type 2	5	5	11
Type 3	2	2	4

The distribution of classifications of relative frequencies (percentages) of supraspinatus tears is shown in Table II.

Only a slight correlation was observed between patients with an extension of the supraspinatus partial tear up to the transition zone and the classification of Ellman ($r = 0.376$, $P = .003$),[4] as well as the classification of Snyder[23] ($r = 0.324$, $P = .007$). In addition, a slight correlation was also found between the extension of the supraspinatus partial tear up to the center of the footprint and the classification of Ellman ($r = 0.380$, $P = .003$) and the classification of Snyder ($r = 0.326$, $P = .011$). The extension of the tear up to the greater tuberosity also showed a slight correlation with the classification of Ellman ($r = 0.380$, $P = .003$), as well as the classification of Snyder ($r = 0.326$, $P = .011$).

In 42.9% of the cases (24 patients), pathology of the superior glenohumeral ligament was noted; 13 patients had a partially torn ligament, and in 11, a complete tear was seen.

Concomitant pathologic changes of the LHB were observed in 64.3% of the patients (36 cases), as represented by synovitic changes in 16, a partial tear of the LHB in 37, a complete tear of the LHB in 1, subluxation of the LHB in 13, and dislocation of the LHB out of the bicipital groove in 1. Overall, 20 patients showed a combination of pathologic changes of the superior glenohumeral ligament and the LHB tendon.

Table II Distribution of relative frequencies of longitudinal extension of partial-thickness supraspinatus tendon tear related to classifications of Snyder[23] and Ellman[4]

Longitudinal tear extension	Classification according to Snyder				Classification according to Ellman			
	A 0	A I	A II	A III	0	I	II	III
Type 1: SSP tear at transition zone from cartilage to bone	18%	32%	32%	18%	18%	50%	14%	18%
Type 2: SSP tear up to center of footprint	17%	17%	17%	44%	17%	17%	33%	33%
Type 3: SSP tear at greater tuberosity	0%	13%	13%	75%	0%	13%	13%	75%

SSP, Supraspinatus.

In 26 patients (46.4%), the SLAP complex had a normal appearance. A SLAP I lesion was seen in 19 patients; 7 had a SLAP II lesion; and in 2 cases each, a SLAP III lesion and a SLAP IV lesion were seen.

In addition, we found 5 cases with a partial tear of the middle glenohumeral ligament, and in 2, the ligament was torn.

Fraying of the anterosuperior labrum and fraying of the posterosuperior labrum were found in 29 patients (51.8%) each.

We found 46 patients (82.1%) with fraying of the undersurface of the acromion, and spur formation of the acromion was found in 30 cases (53.6%). Of the patients, 52 (92.9%) had subacromial bursitis, and in 17 patients, osteophytes of the acromioclavicular joint were detected.

DISCUSSION

We describe a 2-dimensional classification of articular-sided supraspinatus tendon tears in the coronal plane as well as the sagittal plane, with regard to the origin of articular-sided partial tears at the tendon insertion. Within the entire patient group, we did not observe any articular-sided partial tear starting in the middle of the tendon without regard to the tendon insertion. Nearly 60% of our patients had a nontraumatic history.

Degenerative rotator cuff tears develop predominantly at their insertion.[18] Sano et al[22] observed a high stress distribution at the tendon insertion in an intact tendon with the arm in 60° of abduction, which increased in the presence of a partial-thickness rotator cuff tear and can eventually lead to a full-thickness tear at the critical zone.

Previously, Sano et al[22] observed that the width of the transition zone correlated positively with the regressive changes of the supraspinatus tendon. They considered the width of the transition zone as an indicator of the integrity and the tensile strength of the tendon.[21]

Ide et al,[10] in 43 Japanese cadaveric shoulders, found that the mean width of the supraspinatus insertion (medial to lateral) was 9.6 mm (range, 7-13 mm) and the distance between the articular cartilage edge and the tendon insertion was 0.3 mm (range, 0-2 mm). They postulated that partial tears of more than 6 mm of the supraspinatus tendon thickness involved more than 50% of the tendon thickness in most of their patients.

On the basis of a cadaveric study of 17 shoulders without rotator cuff pathology in cadavers with a mean age of 70 years, Ruotolo et al[20] measured the dimension of the supraspinatus footprint. The mean superior-to-inferior tendon thickness was 11.6 mm at the rotator interval, 12.1 mm at the midtendon, and 12 mm at the posterior edge of the tendon. The distance from the articular cartilage margin to the bony tendon insertion was 1.5 to 1.9 mm, with a mean of 1.7 mm. From these results, articular partial-thickness tears with more than 7 mm of exposed bone lateral to the articular margin should be considered significant tears, approximating 50% of the tendon substance. Therefore, arthroscopic measurement of the exposed bone between the articular margin and the supraspinatus tendon insertion (footprint) represents an accurate way to estimate tear depth and provide a rational, reproducible guideline for treatment. We recommend determining the amount of tendon involvement, and to assess an articular-sided partial-thickness cuff tear for debridement or repair properly, the diseased and frayed tendon should be debrided.

In our study, we found only a slight correlation between the assessment of the tear extension in the coronal plane at the tendon insertion and the classifications of Ellman[4] and Snyder,[23] because these classifications do not take the origin of the articular-sided partial-thickness tear into account. On the other hand, we found a high correlation between the classifications of Ellman and Snyder because the depth of the tear represents the severity of the injury of the rotator cuff.

Several concomitant lesions were described in the literature with pathologic changes of the rotator cuff. Walch et al[24] described subluxation and dislocation of the biceps tendon out of the bicipital groove, which were always associated with rotator cuff tearing in their patients. Subluxation of the LHB was associated with partial rupture of the subscapularis tendon, and the ligamentous pulley was always torn in cases of subluxation in their patients. Habermeyer et al[8] reported a high association of pathologic changes of the LHB, with 89.9% of patients having lesions of the pulley system and anterosuperior articular-sided partial-thickness rotator cuff tears.

Bennett[1] reported that only 10% of all tears of the supraspinatus tendon involved the coracohumeral ligament. In contrast, we observed involvement of the coracohumeral ligament in 73% of articular-sided supraspinatus tendon tears. A high association of lesions of the pulley system with articular-sided anterosuperior rotator cuff tears and pathologic changes of the LHB is well known[7,8] and is confirmed by our study.

Superior labral lesions in association with articular-sided partial-thickness cuff tears were observed by Budoff et al[2] in 73.3% of patients, which occurred very frequently in those who did not routinely engage in overhead athletics.

Gerber and Sebesta[7] and Habermeyer et al[8] reported an association of superior labral fraying in terms of anterosuperior impingement with pulley lesions and anterosuperior articular-sided rotator cuff tears in 62.5% and 43.8% of their cases, respectively.

We observed concomitant fraying of the superior labrum in 57.1% of patients (32 cases). Of these patients, 3 had fraying of the posterosuperior labrum, 16 had fraying of the anterosuperior labrum, and 13 had fraying of the labrum from anterior to posterior.

The weakness of the classifications of partial-thickness rotator cuff tears by Snyder[23] and Ellman[4] is the absence of anatomic landmarks with reference to the localization of the tear at the insertion of the tendon, especially at the border of the tendon insertion, at the rotator cable, or within the crescent zone. The assessment of the depth of the tear with a probe depends strongly on the area where the measurement is performed, which is sometimes not necessarily the deepest point of the tear. In addition, it is difficult to assess the relationship between the depth of the tear and the complete thickness of the tendon, which always varies.

In conclusion, neither the classification of Snyder[23] nor that of Ellman[4] reproduces the extension of the partial-thickness rotator cuff tear in the transverse and coronal planes related to its etiology and pathomorphology.

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