

## Superior labral anterior posterior lesions of the shoulder: Current diagnostic and therapeutic standards

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### Abstract

Surgical treatment of superior labral anterior posterior (SLAP) lesion becomes more and more frequent which is the consequence of evolving progress in both, imaging and surgical technique as well as implants.

The first classification of SLAP lesions was described in 1990, a subdivision in four types existed. The rising comprehension of pathology and pathophysiology in SLAP lesions contributed to increase the types in SLAP classification to ten. Concerning the causative mechanism of SLAP lesions, acute trauma has to be differed from chronic degeneration. Overhead athletes tend to develop a glenohumeral internal rotation deficit which forms the basis for two controversial discussed potential mechanisms of pathophysiology in SLAP lesions: Internal impingement and peel-back mechanism. Clinical examination often remains unspecific whereas soft tissue imaging such as direct or indirect magnetic resonance arthrography has technically improved and is regarded to be indispensable in detection of SLAP lesions. Concomitant pathologies as Bankart lesions, rotator cuff tears or perilabral cysts should be taken into consideration when planning a personalized therapeutic strategy. In addition, normal variants such as sublabral recess, sublabral hole, Buford complex and other less common variants have to be distinguished. The most frequent SLAP type II needs a sophisticated approach when surgical treatment comes into consideration. While SLAP repair is considered to be the standard operative option, overhead athletes benefit from a biceps tenodesis because improved patient-reported satisfaction and higher rate of return to pre-injury level of sports has been reported.

**Key words:** Superior labral anterior posterior lesion; Tenodesis; Superior labral anterior posterior repair; Shoulder arthroscopy; Biceps tendon

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**Core tip:** Superior labral anterior posterior (SLAP) lesions often lead to painful shoulder impairment and especially in overhead athletes to restriction in sport specific activity. In the context of diagnostic examination, magnetic resonance arthrography is of particular importance, not only in detection of SLAP

lesions and concomitant pathologic findings but also in differentiation from normal anatomic variants. Therapeutic options include besides conservative treatment arthroscopic SLAP repair and biceps tendon tenodesis. Decision-making in SLAP lesions remains challenging and requires a distinct evaluation of individual patient history, accurate examination and detailed analysis of imaging to meet the requirements of a personalized treatment.

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## INTRODUCTION

Snyder *et al*<sup>[1]</sup> described four types of superior labral lesions anterior to posterior (SLAP) lesions which occur as single entity or associated to additional disorders of the shoulder. Progress in detection of SLAP lesions and development of modern suture anchor systems led to an increasing number of arthroscopic SLAP-repairs.

The highest incidence of SLAP lesions is observed in the 20 to 29 and 40 to 49 years age group<sup>[2]</sup>. Especially overhead athletes require a precise analysis of complaints and a differentiated evaluation of clinical and radiological findings to avoid postoperative persistent pain and an inability to return to previous level of activity.

## PATHOPHYSIOLOGY

### Anatomy

Vangness *et al*<sup>[3]</sup> described four types of attachment of the long head of the biceps tendon to the superior glenoid rim and to the superior labrum.

Numerous anatomic variants complicate clear discrimination between normal and pathologic findings.

A sublabral recess or sublabral sulcus is defined as a sulcus between superior glenoid cartilage and capsulolabral complex with smooth edges and is usually located at 10 to 3 o'clock position. Fealy *et al*<sup>[4]</sup> reported about the existence of sublabral recess in fetuses after 22<sup>nd</sup> week of pregnancy already. SLAP lesions may emerge from a sublabral recess by excessive stress.

In contrast, the sublabral hole or sublabral foramen is typically located at 12 to 2 o'clock position<sup>[5]</sup> and is a result of congenital fusion failure of the labrum which attaches to the glenoid with a smooth margin or a medial slip<sup>[6]</sup>.

The Buford complex is described as a congenitally absent of the antero-superior labrum along with a thickened cord-like middle gleno-humeral ligament<sup>[5]</sup>.

### Acute/traumatic SLAP lesions

Traumatic SLAP lesions are commonly caused by a fall

onto the outstretched arm or an unexpected pull on the arm, e.g., when losing grip of heavy objects or sudden traction (e.g., high bar exercises, hold off body weight in dropping rock climbers)<sup>[7-10]</sup>. Funk *et al*<sup>[11]</sup> reported a rate of 83% among professional rugby players with SLAP lesions following direct contact of the adducted shoulder with an opposing player or to the surface.

### Chronic/degenerative SLAP lesions

Degenerative SLAP lesions can naturally develop with advanced age as a sign of wear in maturity or by increased physical stress affecting particularly overhead workers or overhead athletes. Especially overhead athletes got into center of attention and investigations revealed basic informations about cause and effect of SLAP lesions, which will be described more detailed in the following.

### Glenohumeral rotation deficit

Alteration in rotational magnitude has been identified as a potential risk factor in developing shoulder injuries by changing normal glenohumeral kinematics<sup>[12]</sup>.

Overhead athletes frequently present asymmetrically decreased glenohumeral internal rotation on the dominant side which is considered to be part of positive adaptation to improved force development in conjunction with increased external rotation. The total rotational range of motion usually remains symmetric. Bony changes, capsuloligamentous factors and muscular components have been related to affect glenohumeral range of motion<sup>[13]</sup>.

When exceeding beyond certain dimensions, alterations in glenohumeral internal rotation and total rotational range of motion can obtain clinical relevance. Side-to-side asymmetries greater than 5° in total rotational range of motion are denoted total rotational range of motion deficit. Glenohumeral internal rotation deficit (GIRD) is defined as a side-to-side asymmetry in glenohumeral internal rotation greater than 18°<sup>[14]</sup>. Both findings are implicated in increased risk of shoulder injuries by modifying normal glenohumeral kinematics<sup>[15]</sup>.

### Kinetic chain

Overhead action consists of a complex series of sequential coordinated motions to achieve appropriate body position and motion, and to develop required muscle activity. According to Kibler *et al*<sup>[14]</sup>, the kinetic chain meets the following requirements: linking multiple body segments into one functional segment<sup>[16]</sup>, providing a stable base for distal arm mobility, maximizing force development of the core and transferring it to the hand, interaction of distal joints to increase force and energy capability and decrease distal joint load<sup>[17]</sup>, and reduction of deceleration forces by producing torques<sup>[18]</sup>.

Deficits in kinetic chain components have been shown to be associated with shoulder injuries in baseball players and tennis players<sup>[19]</sup>. To maintain the same energy at ball impact in case of a 20% reduced provision of trunk kinetic energy, 33% more velocity or 70% more

mass in distal segments was necessary in mathematical calculations<sup>[20]</sup>.

Kinetic chain alterations become clinically significant by identifying components of non-shoulder deficits in shoulder injury pathogenesis, even though occurrence and mechanisms in the course of injury sequence remain unclear<sup>[14]</sup>.

### Scapula dyskinesia

The scapula occupies a central position in basic movement patterns of the shoulder and there is strong evidence of scapular kinematic alteration contributing to a variety of shoulder pathologies<sup>[21]</sup>. Scapula performance is essential to maintain functional interaction with the humerus for efficient motion, joint stabilisation, muscular capability and control<sup>[22]</sup>.

By definition, scapular dyskinesia characterizes the alteration of normal kinematics and reflects the loss of normal control of scapular motion<sup>[23]</sup>.

Subsequent internal rotation and anterior tilt can lead to increased tensile strain on the anterior ligaments, enhance the peel-back mechanism of the labro-bicipital complex and give rise to a pathologic internal impingement<sup>[24]</sup>.

The acronym scapular malposition/inferior medial border prominence/coracoid pain/dyskinesia of scapular movement (SICK) was used by Burkhart *et al.*<sup>[25]</sup> to characterize a pattern of scapular abnormality in the disabled overhead athlete shoulder. The excessive scapular protraction leads to glenohumeral hyperangulation in external rotation increasing strain to the undersurface of the posterior rotator cuff area and the anterior-inferior capsular structures, which can intensify the peel-back mechanism<sup>[25]</sup>.

### Internal impingement

Some clinical and cadaveric studies<sup>[26,27]</sup> demonstrated that contact occurs between the undersurface of the posterosuperior rotator cuff and the posterosuperior part of the glenoid in abduction and external rotation both in symptomatic and asymptomatic shoulders. In overhead athletes internal posterosuperior impingement sometimes gets pathologic and has been associated with partial-thickness articular surface tears of the deep side of the rotator cuff and lesions of the labro-bicipital complex resulting from repetitive microtrauma due to recurrent overhead motion under extreme loading conditions<sup>[28]</sup>. This leads to anterior microinstability caused by gradual stretching of anterior capsulolabral structures and consecutive aggravation of internal impingement<sup>[27]</sup>.

### Peel-back mechanism

Burkhart *et al.*<sup>[24]</sup> disagreed with the hypothesis of internal impingement provoking shoulder pathologies in the overhead athlete and presented a pathologic cascade leading to SLAP lesions with peel-back mechanism as an important factor.

The posteroinferior capsular contraction is assumed

to be the point of origin over the course of the above-mentioned cascade because glenohumeral rotation center migrates to a posterosuperior position with consecutive relaxation of the anteroinferior capsule. Now hyperexternal rotation is possible by reason of minimized cam effect of the proximal humerus and greater tuberosity clearance off the glenoid rim resulting in a magnified arc of external rotation before internal impingement appears.

The peel-back phenomenon<sup>[29]</sup> has its origin in a biceps vector change in the position of abduction and external rotation resulting in torsional forces to the labro-bicipital complex. Once fatigue failure of the posterior superior labrum is nascent, it will start to progressively rotate medially over the upper rim of the glenoid. In cocking position, peel-back forces are at a maximum and additional shearing forces arise during throwing cycle from core energy which is transmitted to the shoulder<sup>[24]</sup>.

## CLASSIFICATION

SLAP lesions were first described by Andrews *et al.*<sup>[30]</sup>. In 1990 Snyder *et al.*<sup>[1]</sup> published a classification including four types of lesion which has been extended with three additional types by Maffet *et al.*<sup>[31]</sup>. At present ten types of SLAP lesions have been defined, although it is controversial whether extensive labral tears such as type VIII or type IX should be classified as SLAP lesion.

The primal classification by Snyder is universally accepted and used. Figure 1 shows SLAP types I to IV.

Type I : Predominantly degenerative fraying of the superior labrum without involving the origin of the long head of the biceps tendon.

Type II : Most frequent type of lesion. Both superior labrum and biceps tendon are detached from the superior glenoidal rim leading to instability of the labro-bicipital complex (LBC). Morgan *et al.*<sup>[32]</sup> sub-divided SLAP- II lesions into three subcategories: anterior extension of labral tear (type II A), posterior extension of labral tear (type II B), anterior and posterior extension of labral tear (type II C).

Type III : Bucket-handle tear with potential displacement of the mobile labral fragment into the glenohumeral joint. The attachment of the long head of the biceps tendon remains intact.

Type IV : Bucket-handle tear with extension to the biceps tendon in a variable degree of affecting the tendon's cross-section dimension.

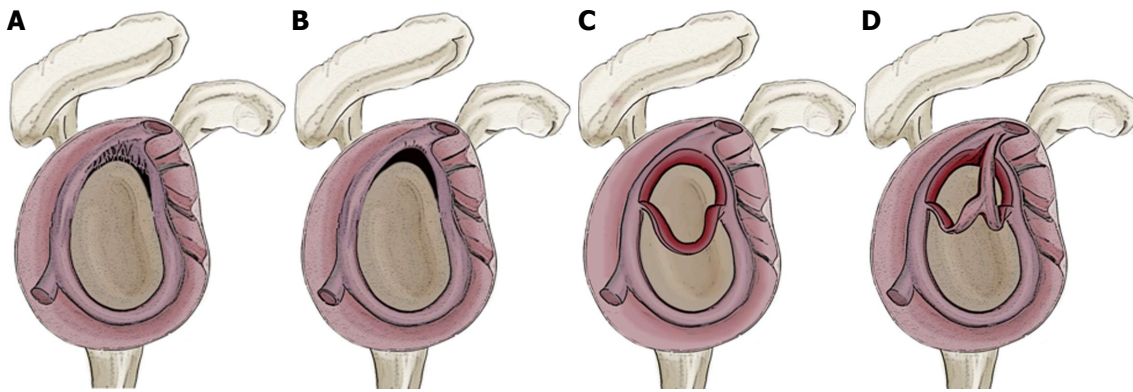
Type V : Anterior-inferior Bankart lesion in continuity with a type II SLAP lesion.

Type VI : Combination of a type II SLAP lesion and an unstable labral flap either anterior or posterior.

Type VII : Type II SLAP lesion with extension to the capsule and the middle glenohumeral ligament (MGHL).

Type VIII : Type II B SLAP lesion with posterior labral extension.

Type IX : Complete or almost complete circumferential detachment of the labrum from the glenoid.



**Figure 1 Superior labral anterior posterior classification.** A: SLAP I lesion: Degenerative fraying of the superior labrum; B: SLAP II lesion: Detached labro-bicipital complex; C: SLAP III lesion: Bucket-handle tear; D: SLAP III lesion: Bucket-handle tear with extension to the biceps tendon. SLAP: Superior labrum anterior posterior.

**Table 1 Superior labral anterior posterior classification, adapted from ref. [77]**

SLAP type	Location (o'clock)	Description	Comments
Snyder <i>et al</i> <sup>[31]</sup>			
I	11-1	Fraying with intact biceps tendon	More significant in young people with repetitive overhead motion or patients with degenerative change
II	11-1	Tear of BLC and biceps tendon stripping	Most common SLAP type, associated with repetitive overhead motion
III	11-1	Bucket-handle tear of superior labrum with biceps tendon intact	Associated with fall on outstretched hand
IV	11-1	Bucket-handle tear of superior labrum extension to biceps tendon	Associated with fall on outstretched hand
Morgan <i>et al</i> <sup>[32]</sup>			
II A	11-3	Tear of BLC with more anterior extension	
II B	9-11	Tear of BLC with more posterior extension	Associated infraspinatus tendon tear may be present
II C	9-3	Tear of BLC with anterior and posterior extension	Associated infraspinatus tendon tear may be present
Maffet <i>et al</i> <sup>[31]</sup>			
V	11-5	Bankart lesion in continuity with type II SLAP tear	Can result from anterior shoulder dislocation
VI	11-1	Anterior or posterior flap tear of the superior labrum with biceps tendon stripping	Probably represents a bucket-handle tear (SLAP III/IV) with tear of the handle
VII	11-3	Tear extends into MGHL	Can result from acute trauma with anterior dislocation
Powell <i>et al</i> <sup>[78]</sup>			
VIII	7-1	Superior labral tear with posteroinferior labral tear	Associated with posterior shoulder dislocation
IX	7-5	Superior labral tear with extensive anterior and posterior extension	Global labral abnormality, probably secondary to trauma
X	11-1	Superior labral tear with extension to the rotator interval	Involving the rotator interval structures including SGHL, long head biceps tendon and CHL

BLC: Bicipito-labral complex; MGHL: Middle glenohumeral ligament; SGHL: Superior glenohumeral ligament; CHL: Coraco-humeral ligament; SLAP: Superior labral anterior posterior.

Type X: Superior labral tear in combination with extension to the rotator cuff interval or the superior glenohumeral ligament or the coracohumeral ligament.

Table 1 gives a summary of SLAP types I to X.

## DIAGNOSIS

### Medical history and examination

A typical symptom especially in overhead athletes is a sudden or gradual deterioration of shoulder function and concomitant pain. In the majority of cases, the predominant arm is concerned. The term "dead arm syndrome" specifies the inability to execute sports specific movements at pre-injury velocity<sup>[33]</sup>. Other disorders are sensation of intermittent clicking or

popping during cocking phase and anterior shoulder pain. Non-specific history and medical conditions due to concomitant shoulder injuries like rotator cuff tears, capsular-labral lesions, biceps tendinopathy or internal impingement complicate any evaluation of a possible SLAP lesion<sup>[34]</sup>.

A huge number of clinical tests have been described in detection of SLAP lesions but currently no gold standard could be established with regard to sensitivity or specificity. Initial reports of specific SLAP tests appeared quite promising but mostly did not stand up to further surveys<sup>[35,36]</sup>.

In order to determine utility of clinical tests in physical examination of the shoulder, Hegedus<sup>[37]</sup> presented a systematic review with meta-analysis. Among



**Table 2** Traditional superior labral anterior posterior tests, adapted from ref. [37]

SLAP test	Sensitivity (95%CI)	Specificity (95%CI)	PPV (95%CI)	NPV (95%CI)	OR (95%CI)
O'Brien	0.67 (0.51, 0.80)	0.37 (0.22, 0.54)	1.06 (0.90, 1.25)	0.89 (0.67, 1.20)	1.19 (0.76, 1.86)
Speed	0.20 (0.05, 0.53)	0.78 (0.58, 0.90)	0.90 (0.43, 1.90)	1.03 (0.86, 1.23)	0.87 (0.35, 2.55)
Anterior slide	0.17 (0.03, 0.55)	0.86 (0.81, 0.89)	1.20 (0.22, 6.51)	0.97 (0.96, 1.36)	1.24 (0.16, 9.47)
Crank	0.34 (0.19, 0.53)	0.75 (0.65, 0.83)	1.36 (0.84, 2.21)	0.88 (0.69, 1.12)	1.54 (0.75, 3.18)
Yergason	12.4 (6.60, 20.6)	95.3 (90.6, 98.1)	2.49 (0.97, 6.40)	0.91 (0.84, 0.99)	2.67 (0.99, 7.73)
Relocation	51.6 (41.2, 61.8)	52.4 (44.0, 60.6)	1.13 (0.88, 1.45)	0.93 (0.72, 1.20)	1.23 (0.72, 2.11)
Biceps palpation	38.6 (26.0, 52.4)	66.7 (52.9, 78.6)	1.06 (0.66, 1.68)	0.95 (0.74, 1.22)	1.13 (0.51, 2.50)
Compression rotation	24.5 (13.8, 38.3)	78.0 (72.9, 82.5)	2.81 (0.20, 39.70)	0.87 (0.66, 1.16)	3.39 (0.15, 74.78)

PPV: Positive predictive value; NPV: Negative predictive value; OR: Odds ratio; SLAP: Superior labral anterior posterior.

the traditional SLAP tests, relocation test showed best sensitivity; best specificity was found in Yergason's test. The compression-rotation test presented the best positive predictive value (Table 2).

More recent tests seem to be encouraging but warrant further investigation. The passive compression test<sup>[38]</sup> showed a sensitivity of 81.8% and a specificity of 85.7%. The positive predictive value was 87.1%, and the negative predictive value was 80.0%.

The modified dynamic labral shear demonstrated sensitivity of 72%, specificity of 98%, accuracy of 0.84, and a positive likelihood ratio of 31.57<sup>[39]</sup>. Combinations of clinical tests provide higher accuracy, in case of labral lesions, the best combination was identified to be the modified dynamic labral shear test and O'Brien's maneuver.

As clinical tests are a key element in diagnosing SLAP lesions, there is still a great need for further studies to improve the diagnostic conclusion and allow the shoulder surgeon to be more efficient in making a firm diagnosis.

### Imaging

The central element to confirm the diagnosis of a SLAP lesion is the implementation of magnetic resonance imaging (MRI) and magnetic resonance arthrography (MRA) or computed tomography arthrography (CTA).

Conventional arthrography and CTA are rarely used in detection of SLAP lesions. Specificity of CTA is in the order of 50% to 80%<sup>[40]</sup>. Investigations comparing conventional MRI to MRA demonstrated a significant improvement in sensitivity and accuracy with little or no reduction in specificity in favor to MRA<sup>[41-43]</sup>. MRA sensitivity is ranged from 82% to 100%, specificity from 71% to 98% and accuracy from 83% to 94%<sup>[41,42,44]</sup>. MRA can be realized as direct or indirect MRA. Direct or intraarticular MRA needs increased logistic effort, a contrast medium is applied directly to the glenohumeral joint space by puncture. Advantages are an improved outlining of intraarticular and synovial surfaces<sup>[45]</sup> by mild distension of the capsule. Potential disadvantages include sensation of pain, bleeding, extravasate into surrounding tissue and risk of infection due to the invasive nature of the procedure.

Indirect or intravenous MRA is non-invasive. Intra-

venous contrast medium is able to diffuse into the shoulder joint due to the lack of basement membrane<sup>[46]</sup>. Attention is demanded because of general enhancement of all vascularized structures which may lead to overestimation of pathologies<sup>[47]</sup>. Figures 2 and 3 give examples of SLAP lesions in MRI.

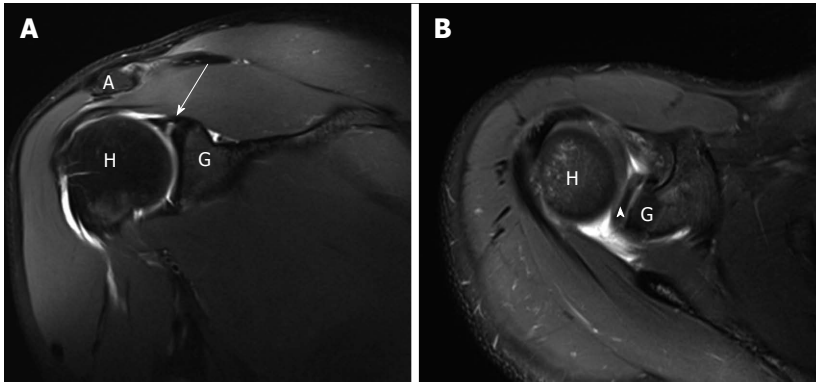
MRA has not been proven to reliably distinguish between ten types of SLAP lesions. Practically speaking, a detailed description of location, morphology, extend of abnormality and associated injuries is more valuable to the shoulder surgeon than a simple SLAP classification<sup>[40]</sup>.

## MANAGEMENT

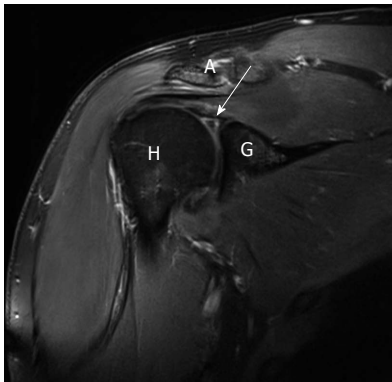
A distinct evaluation of individual patient history, accurate examination and detailed analysis of imaging should be the basis for decision-making in therapy of SLAP lesions. Global algorithms of treatment by means of SLAP classification do not exist and do not meet requirements of a personalized treatment.

### Non operative treatment

In selected cases non-operative treatment can be successful. SLAP I lesions predispose to a conservative treatment in absence of other intra-articular pathologies. Non-operative treatment for SLAP tears in overhead athletes has been suggested by Edwards *et al.*<sup>[48]</sup> who showed a 66% of throwers being able to return to play at the same or better level than before. When presenting a GIRD, further progression of external rotation gain and posterior-superior shift of the humeral head can be stopped by conservative treatment with the objective to eliminate posterior-inferior capsular tightness due to shortened inferior glenohumeral ligament. Various exercises are utilized like the "sleeper stretch" in which the patient lies on his side, flexing both the elbow and shoulder to 90° while the shoulder is passively internally rotated<sup>[24]</sup>, shoulder cross-body adduction with forward elevation<sup>[49]</sup>, capsular mobilization<sup>[50]</sup> or towel/racquet stretches<sup>[51]</sup>. Additionally performed exercises include strengthening programs for rotator cuff and, especially in the setting of SICK scapula, scapular stabilizers. Closed chain exercises are initially executed in order to address protraction, retraction, elevation/depression



**Figure 2 Superior labral anterior posterior II lesion: Findings in direct magnetic resonance arthrography.** A: The coronal oblique fat saturated image (cor pd tse fs) shows the detached labro-bicipital complex from the upper rim of the glenoid. The tear is marked by the arrow; B: The transverse fat saturated magnetic resonance arthrography-image (tra pd tse fs) reveals the slight runnel of contrast agent between superior labrum (arrowhead) and glenoid. A: Acromion; H: Humeral head; G: Glenoid.



**Figure 3 Superior labral anterior posterior III lesion: Findings in direct magnetic resonance arthrography.** The coronal T1-weighted (cor t1 tse fs) fat-saturated image shows the separated triangle (arrow) of the bucket-handle without instability of the labro-bicipital complex. A: Acromion; H: Humeral head; G: Glenoid.

and retraction, internal rotation and elevation, and external rotation and depression<sup>[25]</sup> followed by open chain exercises in the course. Exercises have to be individualized based on the mechanism of injury, functional demand and activity level<sup>[33]</sup>.

In case of apparent SLAP lesions, overhead athletes often require operative treatment to return to a high level of function, whereas in patients without sportive demands conservative treatment may be sufficient and definitive.

### Operative treatment

Operative treatment becomes more and more frequent since arthroscopic techniques and implants have advanced. Individual variety has been shown in operative technique, patient positioning and arthroscopic access.

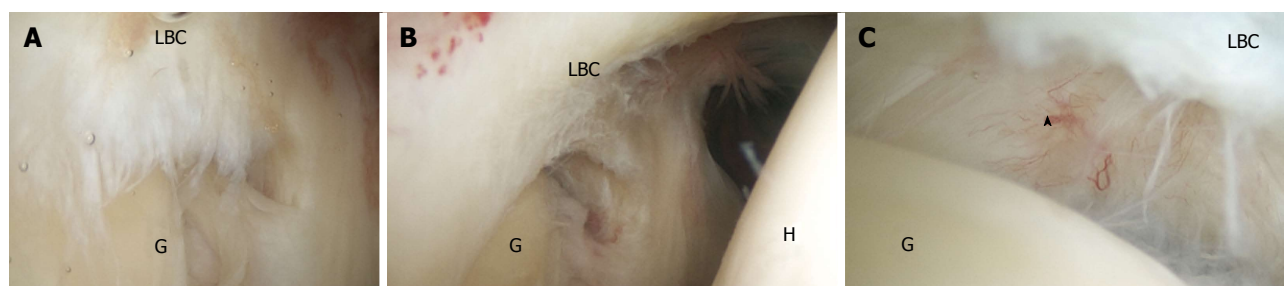
Several operative concepts coexist in SLAP lesions: Simple arthroscopic debridement, arthroscopic SLAP repair/refixation, arthroscopic tenotomy of the long head of the biceps tendon, arthroscopic tenodesis or open/mini-open tenodesis of the long head of the biceps tendon.

Patient positioning can either be in beach chair position or lateral decubitus position. Two or three portal techniques exist (standard posterior viewing portal, anterior portal superior to the upper border of the subscapularis tendon and optional anterosuperior rotator interval portal approximately 1 cm off the anterolateral tip of the acromion)<sup>[52]</sup>.

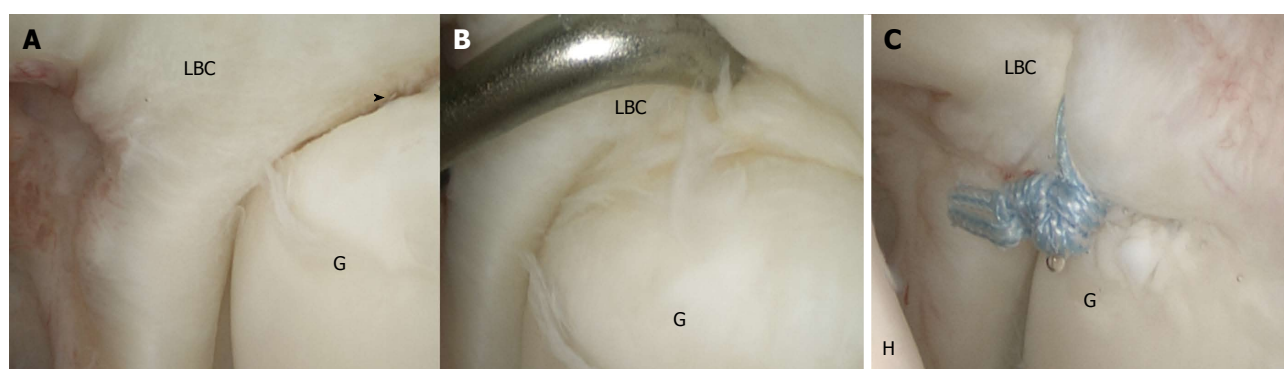
Isolated arthroscopic labral debridement in unstable SLAP tears demonstrated short-term improvement inside first studies in the 90s, but outcome declined over time<sup>[53-55]</sup>.

Actually, arthroscopic debridement is recommended in type I SLAP lesions. An example of a type I lesion and concomitant sublabral recess ist shown in Figure 4.

Controversial debates about surgical treatment in case of type II SLAP lesions are still in progress. Surgical reattachment of the LBC at its origin with the use of transosseous sutures, staples, metal screws, bioabsorbable tacks and bioabsorbable anchors are performed. The use of bioabsorbable tacks has been abandoned due to complications with this fixation type. Persistent postoperative pain and disability<sup>[56]</sup> as well as dislocation and broken tacks with chondral damage have been reported. Further complications following the use of polyglycolide lactic acid tacks include foreign body synovitis and full-thickness humeral head chondral injury<sup>[57]</sup>. Sileo *et al*<sup>[58]</sup> demonstrated decreased bio-mechanical strength of knotless suture anchors vs standard suture anchors even though pullout strength was noted to be higher in certain knotless anchor systems<sup>[59]</sup>. Dines *et al*<sup>[60]</sup> suspect the bulky suture knot of standard anchors to be the source of postoperative pain in throwers due to the limited glenohumeral joint space. Positioning of the anchors is supposed to be ideal at the most superior portion of the glenoid rim because glenoid bone stock is most solid there<sup>[61]</sup>. The anchor should be placed at a 45° angle to the osseous surface at the articular margin. Some authors warn against anchor placement anterior to the biceps tendon to avoid undesired tightening of the MGHL or closure of a sublabral foramen, which may lead to a restricted external rotation<sup>[62]</sup>.



**Figure 4 Superior labral anterior posterior I lesion: Intraoperative findings in shoulder arthroscopy (posterior-anterior view from the posterior portal of a right shoulder).** A: A degenerative fraying of the superior labrum could be detected by diagnostic arthroscopy; B: After debridement of the superior labrum, a sublabral recess appears. The presence of a type II SLAP lesion should be excluded; C: A more detailed demonstration of the sublabral recess (arrowhead) with smooth lining without instability of the labro-bicipital complex. LBC: Labro-bicipital complex; H: Humeral head; G: Glenoid; SLAP: Superior labrum anterior posterior.



**Figure 5 Superior labral anterior posterior II lesion: Intraoperative findings in shoulder arthroscopy (posterior-anterior view from the posterior portal of a left shoulder).** A: Intraoperative aspect of a non-displaced SLAP II lesion (arrowhead); B: Verification by inserting a probe; C: SLAP repair by a single stitch posterior to the biceps tendon. LBC: Labro-bicipital complex; H: Humeral head; G: Glenoid; SLAP: Superior labrum anterior posterior.

Numerous biomechanical investigations exist about suture anchor location and configuration. The results are inconsistent; some consider simple sutures to be superior to mattress type configuration<sup>[63]</sup>, while others demonstrated an advantage of mattress sutures compared to simple sutures with one- and two-point fixation<sup>[64]</sup>. Morgan *et al*<sup>[65]</sup> found parity between one anterior and one posterior simple suture and two posterior simple sutures in resisting “peel-back” forces. No significant differences in functional scores between vertical knot technique and horizontal mattress technique could be found by Yang *et al*<sup>[66]</sup> even though last mentioned technique seemed to be favorable with regard to pain and internal rotation at abduction. Castagna *et al*<sup>[67]</sup> described a combined technique with one mattress stitch posterior and medial to the biceps tendon and one simple stitch anterior, which was characterized as an anatomic repair technique. Finally, most surgeons prefer simple translabral sutures with a variety of arthroscopic knots<sup>[52]</sup>. Figure 5 demonstrates an arthroscopic SLAP repair.

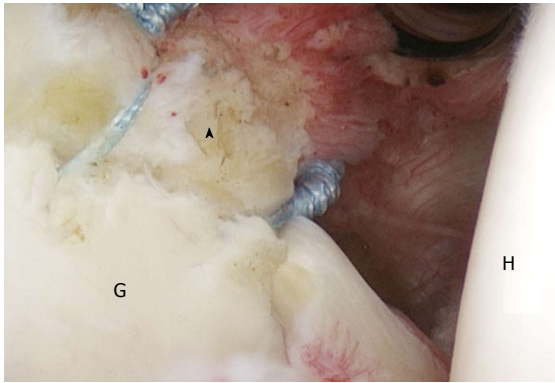
Due to discouraging results in overhead athletes after arthroscopic SLAP repair, with inconsistent return to their previous level of sports participation and inconsistent subjective patient satisfaction, biceps tenodesis became more and more important<sup>[68]</sup>. Arthroscopic tenotomy can be performed in patients without esthetic demand and high work load or sporting activities.

Tenotomy can be done without need of extraneous material for fixation but down-slippage of the long head of the biceps tendon has to be kept in mind.

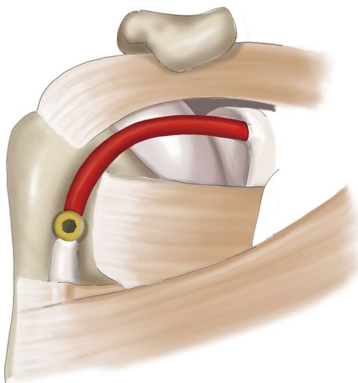
During arthroscopic tenodesis, the tendon is fixed at the top of the bicipital groove with bioabsorbable interference screws or bioresorbable anchors. Alternatively a mini-open tenodesis after arthroscopic tenotomy of the long head of the biceps tendon has been described recently. The extraarticular tenodesis is located either subpectoral to preserve length and shape of the tendon and to avoid groove tenderness<sup>[69]</sup> or above the upper rim of the major pectoral tendon<sup>[9]</sup> which is assumed to be more favourable in justification of the biceps tendon’s tension. The intraarticular remaining superior labrum should be reattached to prevent articular entrapment. Figures 6 and 7 demonstrate the principle technique of mini-open tenodesis.

Type III SLAP lesions require the resection of the unstable bucket-handle fragment, usually no further stabilisation of the biceps anchor is necessary. If the lesion is causative from an acute trauma and located within the “red-red zone”, refixation of the torn flap analogous to meniscal tears has been recommended by some authors<sup>[8]</sup>.

Type IV lesion repair depends on biceps tendon stability after resection of the torn flap. At least half of the tendon’s calibre should be intact to preserve stability of the LBC. In case of instable biceps tendon,



**Figure 6 Superior labral anterior posterior II lesion: Intraoperative findings in shoulder arthroscopy (posterior-anterior view from the posterior portal of a right shoulder).** First step in mini-open tenodesis is an arthroscopic tenotomy of the biceps tendon (arrowhead) and reattachment of the superior labrum. H: Humeral head; G: Glenoid.



**Figure 7 Mini-open biceps tenodesis: The red tagged part of the biceps tendon is resected.** An extra-anatomical fixation is performed above the upper border of the tendon of the great pectoral muscle.

degenerative appearance and substantial loss of more than 50% of calibre, a tenotomy or tenodesis is performed.

Types V to X include more extended SLAP lesions and require additional treatment of concomitant pathologies.

## OUTCOME

### SLAP lesion and SLAP repair

Morgan *et al.*<sup>[32]</sup> presented excellent short-term results after SLAP repair with 87% excellent results overall and 84% return to sports at previous level at 1 year follow-up. In 2010, Friel *et al.*<sup>[70]</sup> could not observe differences in outcome between overhead athletes, non-overhead athletes, recreational overhead athletes and collegiate overhead athletes after SLAP repair. The conclusion drawn by the authors was that SLAP repair is successful regardless of occupation or athletics. Funk *et al.*<sup>[11]</sup> analyzed the outcome in professional rugby players with isolated SLAP lesions in a retrospective cohort study. By 6 mo post-operative 89% were satisfied and 95% were able to return to pre-injury level of play. A retrospective

study published by Enad *et al.*<sup>[71]</sup> described efficiency of SLAP repair in military (competitive recreational sports level). Seventy-six point nine percent reached an activity level equal or higher than pre-operative and 96.2% were able to stay in full active duty at final follow-up 30.5 mo after surgery.

Several investigations focused upon SLAP repair in overhead athletes. Among athletes Sayde *et al.*<sup>[72]</sup> had 83% good to excellent results after SLAP repair and 73% return to previous level of play, but only 63% of overhead athletes could regain the pre-injury level of play. They took the higher incidence of concomitant shoulder pathologies (e.g., shoulder instability, rotator cuff injury) in overhead athletes as a reason for worse outcome. O'Brien *et al.*<sup>[73]</sup> used a trans-rotator cuff approach for SLAP repair with only 16 of 31 patients succeeding to return to their previous level of sports, 11 returned to limited activity and two remained inactive at an average follow-up of 3.7 years. In 41 patients treated by arthroscopic type II SLAP lesion repair, only 71% were satisfied, 41% had continued night pain and merely 14 of 29 athletes were able to return to their previous level of sports<sup>[74]</sup>. Kim *et al.*<sup>[75]</sup> could prove, that in 34 patients (30 involved in athletic activities, 18 overhead athletes) after arthroscopic SLAP repair, overhead athletes had significantly lower shoulder scores and lower percentage of return to preoperative shoulder function than non-overhead athletes.

Overall, reported results after SLAP repair are non-homogeneous and uniform recommendations can not be imposed as a general rule for specific surgical treatment, resulting in variable rates of return to preinjury level. This might be based on multiple confounding variables not consistently accounted for including differences between studies in population demographics, surgical details related to surgical technique, surgeon experience, hardware used, and post-surgical rehabilitation parameters.

### SLAP lesion and tenodesis

A prospective cohort study has been published by Boileau *et al.*<sup>[68]</sup> dividing overhead athletes with SLAP lesion in arthroscopic SLAP repair group (10 patients) and arthroscopic biceps tendon tenodesis group (15 patients). After arthroscopic SLAP repair, only 40% were satisfied and only 20% could return to their pre-injury level of sports. As for athletes treated by arthroscopic biceps tenodesis, 93% were satisfied and 87% were able to return to their previous level of sport. As a source of failure in SLAP repair, the authors stated that the rigid reattachment of the labro-bicipital complex to the upper rim of the glenoid disables the physiological medial rolling of the biceps tendon anchor during abduction and external rotation. Due to traction to the LBC which is innervated by a dense network of sensory sympathetic fibres<sup>[76]</sup>, persistent shoulder pain is a result. Study validity is lessened by a relatively small sample size and the nonrandomized design.

Schöffl *et al.*<sup>[9]</sup> registered excellent results in high-



**Table 3** Outcomes after repair of superior labral anterior posterior tears, adapted from ref. [77]

Ref.	Study design	No. of patients	Repair techniques	Outcome summary
Morgan <i>et al</i> <sup>[32]</sup>	Retrospective	102	Type II repair, suture anchor	83% excellent overall; 87% excellent results in 53 overhead athletes
Friel <i>et al</i> <sup>[70]</sup>	Prospective cohort	48	Suture anchor fixation	54% returns to previous level of sport
Sayde <i>et al</i> <sup>[72]</sup>	Systematic review	506	Suture anchor, bioabsorbable tacks, staples	63% return to previous level of play
Snyder <i>et al</i> <sup>[53]</sup>	Retrospective	140	Type I : debridement, 56% type II : debridement, 44% suture fixation	N/A
Cohen <i>et al</i> <sup>[74]</sup>	Retrospective	39	Biodegradable tacks	27/39 G-E results; 14/29 return to play at preinjury level at 3.7 yr follow-up
Funk <i>et al</i> <sup>[11]</sup>	Retrospective	18	Suture anchor fixation	89% satisfaction rate; 95% return to play at preinjury level
Enad <i>et al</i> <sup>[71]</sup>	Retrospective	27	Suture anchor fixation	24/27 G-E results
Coleman <i>et al</i> <sup>[79]</sup>	Retrospective	± 50 acromioplasties	Biodegradable tacks	65% G-E results at 3.4 yr follow-up
Brockmeier <i>et al</i> <sup>[80]</sup>	Prospective cohort	47	Suture anchor fixation	41/47 G-E results at 2.7 yr follow-up
O'Brien <i>et al</i> <sup>[73]</sup>	Retrospective	31	Biodegradable tacks	22/31 G-E results at 3.9 yr follow-up
Kim <i>et al</i> <sup>[75]</sup>	Retrospective	34	Suture anchor fixation	31/34 return to play at preinjury level
Boileau <i>et al</i> <sup>[68]</sup>	Prospective cohort	25 (2 groups)	Suture anchor fixation (SLAP repair) vs interference screw (biceps tenodesis)	4/10 satisfied in SLAP repair group; 13/15 satisfied in tenodesis group
Schöffl <i>et al</i> <sup>[9]</sup>	Prospective cohort	6 (rock climbers only)	Mini-open biceps tenodesis	96.8% satisfaction, 100% return to preinjury level of climbing
Voos <i>et al</i> <sup>[81]</sup>	Retrospective	34 SLAP + RCR; 28 RCR alone	Suture anchor fixation for RCR ± SLAP	90% G-E results, 77% return to play at preinjury level
Youm <i>et al</i> <sup>[82]</sup>	Retrospective	10 SLAP + spinoglenoid cyst	SLAP repair, no cyst treatment	8/10 resolution of cyst and labral healing in MRI

G-E: Good to excellent; RCR: Rotator cuff repair; SLAP: Superior labral anterior posterior; N/A: Not available; MRI: Magnetic resonance imaging.

level rock climbers following mini-open tenodesis in a prospective cohort study. At a follow-up of 6 mo self-perception of shoulder function and climbing ability was at 96.8%.

Table 3 gives an overview of outcomes after repair of SLAP lesions.

## CONCLUSION

Diagnosis and therapy of SLAP lesions remain a challenge despite improvement in imaging and surgical techniques and implants. In face of a various number of clinical SLAP tests, no one could bear up under the aspect of acceptable sensitivity or specificity. Interpretation of MRI requires a high degree of specialized knowledge about both pathologic findings and normal variants like sublabral recess or sublabral hole. Decision-making in SLAP lesions, may it be conservative or surgical, has to be based on multiple factors: Patient's history (acute trauma or chronic degeneration), age, level of physical activity, patient's expectations and functional demands. SLAP repair represents the standard treatment for the most common SLAP type II with excellent results especially in case of traumatic SLAP lesions. In overhead athletes poor results after SLAP repair have been reported in more focused studies with persistent shoulder pain and long-term inability to return to previous level of sports. A constant pull at the origin of the long head of the biceps tendon, degeneration of the LBC as a consequence of repetitive microtrauma and reduced blood flow are accused to be causative for poor healing tendency. In this cases tenodesis of the biceps tendon may be an appropriate alternative with proven benefit to

the patient. Concerns about humeral head migration or anterior instability after removal of the intraarticular part of the long head of the biceps tendon were disproved<sup>[68]</sup>. As the authors deal with a statly number of overhead athletes (especially rock climbers), a mini-open tenodesis above the upper border of the great pectoral tendon is an alternative in cases with absent signs of fresh injury<sup>[77]</sup>.

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