

Postoperative Subscapularis Muscle Insufficiency After Primary and Revision Open Shoulder Stabilization

Markus Scheibel,^{*†} MD, Alexander Tsynman,[†] Petra Magosch,[‡] MD, Ralf Juergen Schroeder,[†] MD, and Peter Habermeyer,[‡] MD, PhD

From the [†]Center for Musculoskeletal Surgery and the Department of Radiology, Campus Virchow, Charité-Universitaetsmedizin Berlin, Berlin, Germany, and the [‡]Department of Shoulder and Elbow Surgery, ATOS-Clinic Heidelberg, Heidelberg, Germany

Background: Postoperative subscapularis muscle insufficiency after open shoulder stabilization procedures represents an unrecognized condition.

Hypothesis: Primary and revision open shoulder stabilization using the inverted L-shaped tenotomy approach impairs subscapularis muscle recovery and affects final clinical outcome.

Study Design: Cohort study; Level of evidence, 3.

Methods: Twenty-five patients who underwent primary (group 1: n = 13; mean age, 36.5 years; follow-up, 48 months) or revision (group 2: n = 12; mean age, 34.2 years; follow-up, 52 months) open shoulder stabilization procedures were followed up clinically (clinical subscapularis tests and signs, Constant score, and Rowe score) and by magnetic resonance imaging (tendon integrity, defined muscle diameters, and signal intensity analysis [ratio infraspinatus/upper subscapularis muscle and infraspinatus/lower subscapularis muscle]). A third group (group 0) of 12 healthy volunteers served as a control.

Results: Clinical signs for subscapularis muscle insufficiency were present in 53.8% of cases in group 1 and 91.6% of cases in group 2. There were no significant differences between groups with regard to Constant and Rowe scores ($P > .05$). On magnetic resonance imaging, no complete tendon ruptures were found. The mean vertical diameter of the subscapularis muscle and the mean transverse diameter of the upper subscapularis muscle portion were significantly greater in group 0 than in group 1 and greater in group 1 than in group 2 ($P < .05$). The mean transverse diameter of the lower subscapularis muscle was comparable in all groups ($P > .05$). The signal intensity analysis revealed the infraspinatus/upper subscapularis muscle ratio was greater in group 0 than in group 1 and greater in group 1 than in group 2 ($P < .05$). The infraspinatus/lower subscapularis muscle ratio was lower in group 0 than in groups 1 and 2 ($P < .05$).

Conclusion: Open shoulder stabilization using an inverted L-shaped tenotomy approach may lead to atrophy and fatty infiltration, particularly of the upper part of the subscapularis muscle, resulting in postoperative subscapularis muscle insufficiency. Revision procedures using the same approach may further compromise clinical subscapularis muscle function and structure. The lower portion of the subscapularis muscle seems to have a compensating effect that may, in addition to a meticulous capsulo-labral reconstruction, account for the uncompromised overall clinical outcome.

Keywords: shoulder instability; open shoulder stabilization; primary and revision procedure; subscapularis (SSC) insufficiency

Open shoulder stabilization procedures have been considered the gold standard for recurrent anterior shoulder instability, with success rates in the recently published literature

*Address correspondence to Markus Scheibel, MD, Center for Musculoskeletal Surgery, Campus Virchow, Charité-Universitaetsmedizin Berlin, Augustenburger Platz 1, 13353 Berlin, Germany (e-mail: markus.scheibel@charite.de).

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ranging from 86.6% to 97%.^{2,7,12,13,15,27,30} Different studies indicate that the surgical approach using an inverted L-shaped subscapularis (SSC) tenotomy may impair SSC recovery, resulting in postoperative SSC insufficiency.^{8,21,26,29} (Figure 1). The SSC muscle represents an important part of optimal shoulder function. It acts as an important internal rotator, shoulder abductor, humeral head depressor, and active anterior stabilizer of the glenohumeral joint.^{16-21,33,35} Postoperative SSC insufficiency may therefore affect and influence the final clinical outcome.

The goal of this study was to examine the integrity, structure, and clinical function of the SSC musculotendinous unit

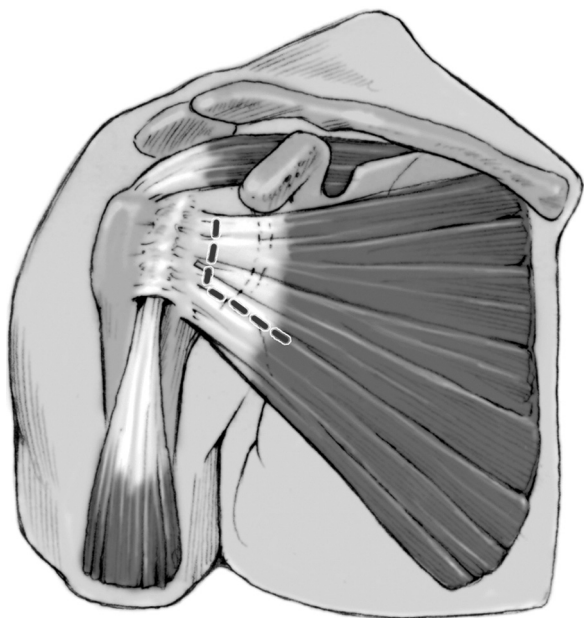


Figure 1. Standard approach for open instability repair: inverted L-shaped tenotomy of the subscapularis tendon.

in patients after primary and revision open shoulder stabilization using an inverted L-shaped tenotomy approach.

PATIENTS AND METHODS

Between January 1998 and December 2001, 360 open shoulder stabilization procedures using an inverted L-shaped tenotomy approach were performed at one institution. There were 256 patients who underwent primary repair and 62 patients who underwent revision open shoulder stabilization after a failed open instability repair. The remaining patients underwent open revision stabilization after a failed arthroscopic instability procedure.

Twenty-five patients (4 women and 21 men), with a mean age of 35.4 years (range, 21-56 years), were retrospectively included in this study. The patients were selected in a nonrandomized manner from the above-mentioned 256 primary and 62 revision cases. The recruitment of patients via telephone invitation was performed until at least 30 patients (15 of each group) agreed to participate in this study. Twenty-five were available for follow-up and were divided into 2 groups.

Group 1 (primary group) consisted of 13 patients who underwent primary open shoulder stabilization. The mean age of group 1 (3 women and 10 men) was 36.5 years (range, 22-56 years), and the follow-up averaged 48.1 months (range, 26-87 months). Group 2 (revision group) underwent revision open shoulder stabilization after a failed open instability repair. The 12 patients in group 2 (1 woman and 11 men) had a mean age of 34.2 years (range, 21-48 years) and a mean follow-up of 52.3 months (range, 24-75 months). A third group (group 0) of 12 healthy volunteers (4 women and 8 men) without any signs of shoulder injury served as a control

group. This group was recruited from a group of residents and physical therapists and had a mean age of 31.1 years (range, 26-33 years).

Group 1: Primary Group

All 13 patients in group 1 suffered from recurrent anteroinferior shoulder instability. Seven patients were classified as having an anteroinferior instability without signs of hyperlaxity and 6 as having instability with signs of hyperlaxity.

At the time of surgery, a diagnostic arthroscopy was performed, and a straight anterior approach was used for open instability repair. The upper two thirds of the SSC tendon was detached approximately 0.5 cm medial to the lesser tubercle (inverted L-shaped tenotomy), and the interval between the tendon and anterior capsule was identified. The SSC tendon was then stripped off the anterior capsule and armed with 3 to 4 sutures (Ethibond No. 2, Ethicon Inc, Johnson & Johnson, Somerville, NJ) using a modified Mason-Allen suture grasping technique for the later refixation and was retracted medially.⁶ A vertical capsular incision at the humeral insertion site was made, the capsule was armed with polydioxanone sutures and retracted medially, and a humeral head retractor was inserted into the joint to visualize the glenoid. In 8 cases, a Bankart repair using 2.4-mm titanium FASTak suture anchors with No. 2 braided sutures (Arthrex, Naples, Fla) and an additional anteroinferior capsular shift according to Matsen were performed to address associated inferior capsular redundancy or capsular laxity.²⁰ In 4 cases, an isolated Bankart repair was performed, and in 1 case, an isolated capsular shift was performed. The capsule was reattached with the polydioxanone sutures using simple stitches, and the SSC tendon was reattached anatomically using the Ethibond No. 2 sutures and the above-mentioned modified Mason-Allen technique with the arm in 30° of abduction and 20° of external rotation.

Group 2: Revision Group

All 12 patients in group 2 suffered from recurrent anteroinferior shoulder instability. In 9 cases, the index instability repair was performed elsewhere. Eight cases had an isolated Bankart repair using suture anchors, 3 cases had a Bankart repair with an additional capsular shift according to Matsen, and in 1 case an isolated capsular shift according to Neer via an inverted L-shaped tenotomy approach had been performed at the time of index surgery.²⁴ Four patients reported a history of major trauma after the index surgery. In the remaining patients, redislocation occurred without any significant trauma. Five patients had recurrent anteroinferior instability without signs of hyperlaxity and 7 with signs of hyperlaxity. At the revision procedure, all patients underwent diagnostic arthroscopy. The intra-articular portion of the SSC tendon was judged to be intact in all cases. The open revision procedure was performed as described above. In 4 cases, a Bankart repair using suture anchors was performed, and in 8 cases, a labral augmentation procedure as described by Harryman et al⁹ was performed. In all cases, an additional anteroinferior capsular shift according to Matsen was performed.

Postoperative Management

Postoperatively, the shoulder was placed in a sling for the first 3 weeks. For the first 6 weeks, flexion and abduction were limited to 90°, and external rotation was limited to 0°. After 3 weeks, rehabilitation was advanced to assisted and then to active exercises. No active internal rotation was allowed for the first 6 weeks.

Clinical and Radiologic Evaluation

At the time of follow-up, all patients underwent a complete physical examination and MRI of both shoulders. The overall function of the shoulder was assessed by the Constant and Rowe scores.^{3,28} Clinical evaluation was performed by a single surgeon who was not the operating surgeon and was therefore blinded to each specific case.

On physical examination, special attention was paid to the integrity of the rotator cuff and any restriction of active or passive range of motion, in particular regarding internal rotation. Patients with any impairment of passive internal rotation were not included in this study. To assess the function of the SSC musculotendinous unit, the lift-off test, internal rotation lag sign (IRLS), modified belly-press test, and belly-off sign were performed.

The lift-off test was performed as described by Gerber and Krushell.⁵ The affected arm of the patient was internally rotated and extended, placing the hand on the lumbar region. The test has a positive result if the patient is unable to raise the arm posteriorly off the back. The presence of an IRLS, as described by Hertel et al,¹¹ is evaluated from the same starting position. The dorsum of the hand is passively lifted away from the body by the examiner until almost full internal rotation is reached. The patient is then asked to actively maintain this position. The IRLS was considered positive when a complete lag occurred and the hand dropped back to the lumbar region. It was judged as intermediate when lag occurred but the patient was able to keep the hand off the lumbar region. The belly-press test as described by Gerber et al⁴ was performed with slight modification. With the hand flat on the abdomen and the elbow close to the body, the patient was told to bring the elbow forward and straighten the wrist. The final flexion position of the wrist was then measured as described by Burkhart and Tehrani¹ for the Napoleon sign. Finally, the presence of the belly-off sign was evaluated.³¹ The affected arm of the patient was passively brought into flexion and maximum internal rotation with the elbow 90° flexed. The elbow of the patient is supported by one hand of the examiner while the other hand brings the arm into maximum internal rotation, placing the palm of the hand on the abdomen (Figure 2A). The patient is then asked to keep the wrist straight and actively maintain the position of internal rotation as the examiner releases the wrist while maintaining support at the elbow. If the patient cannot maintain this position, lag occurs and the hand lifts off the abdomen, resulting in the belly-off sign (Figure 2B).

Radiologic Evaluation

All patients and healthy subjects had MRI performed with a 0.2-T open system (E-Scan XQ, Esaote, Genoa, Italy). The

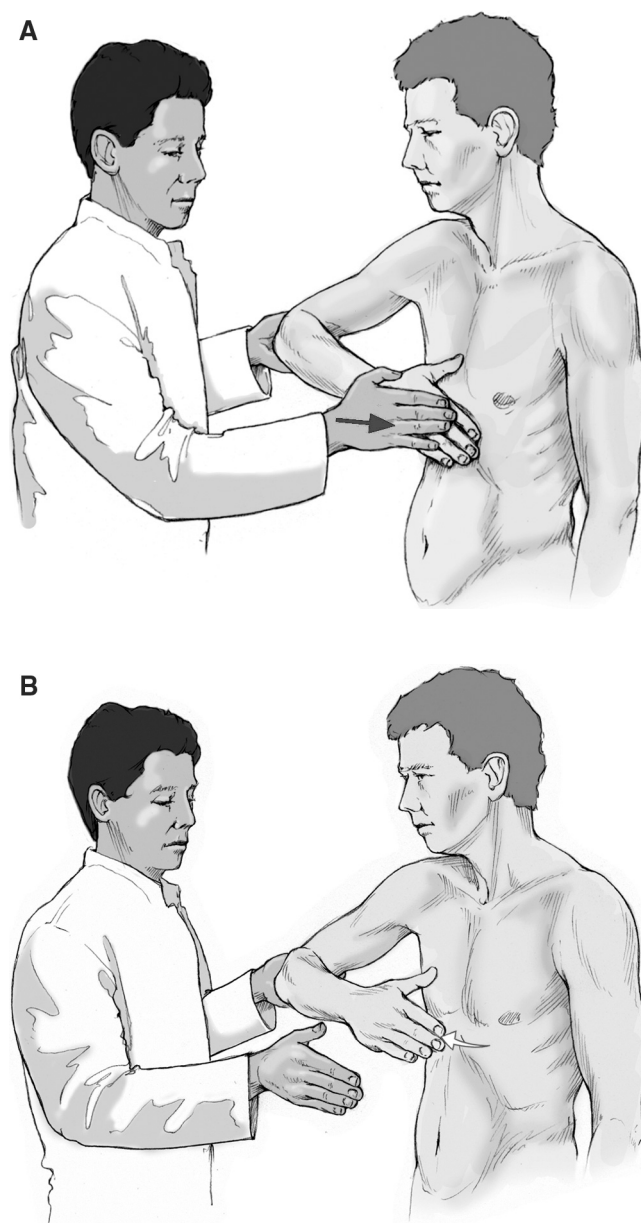


Figure 2. A, starting position for the evaluation of the belly-off sign. The affected arm of the patient is passively brought into flexion and maximum internal rotation with the elbow 90° flexed. The elbow of the patient is supported by one hand of the examiner while the other hand places the palm on the abdomen.³¹ B, the patient is then asked to keep the wrist straight and actively maintain the position of internal rotation as the examiner releases the wrist. If the patient cannot maintain this position, the hand lifts off the abdomen, resulting in the belly-off sign.³¹

patient was placed in the prone position with the arm in neutral position. A special shoulder coil (linear polarized doubled Helmholtz system) contributed to noise reduction and improved spatial resolution.

The following sequences were applied in transaxial, parasagittal (perpendicular to the scapula), and paracoronal

(parallel to the scapula) slice orientation: localizer sequence in all 3 directions of space, parasagittal T1-weighted spin echo sequence (repetition time [TR], 1010 milliseconds; echo time [TE], 24 milliseconds; turbo spin echo [TSE] factor, 2; flip angle, 90°; field of view, 200 × 200 mm; slice thickness, 4 mm; matrix, 256 × 192), paracoronal T1-weighted spin echo sequence (TR, 720 milliseconds; TE, 24 milliseconds; TSE factor, 2; flip angle, 90°; field of view, 200 × 200 mm; slice thickness, 4 mm; matrix, 256 × 192), and transaxial T1-weighted spin echo sequence (TR, 720 milliseconds; TE, 24 milliseconds; TSE factor, 2; flip angle, 90°; field of view, 200 × 200 mm; slice thickness, 4 mm; matrix, 256 × 192).

For all sequences, 2-dimensional acquisitions were used. The duration of each sequence ranged between 4.39 and 6.29 minutes. The phase codifying was done in anteroposterior orientation parallel to the y-axis.

The acquired data were saved as DICOM files on compact disc. For data analysis, the workstation Advantage Windows (General Electric, Milwaukee, Wis) and the software program Functool 2.5.24 (General Electric) were used.

Imaging criteria for detection of SSC tendon tears on axial images were fluid-equivalent signal in the way of a tendon, discontinuity, or retraction of a tendon. Circumscribed signal alteration of the tendon or caliber changes as described by Pfirrmann et al²⁵ were not used as diagnostic criteria because previous surgery had been performed.

On parasagittal images, using the most lateral image on which the spine of the scapula is in contact with the coracoid process (Y-shaped position), the vertical diameter of the SSC muscle and the transverse diameter of the upper and lower SSC muscle portion were measured. For the upper transverse diameter, a line perpendicular to the vertical diameter was drawn ending at the apex of the concavity of the SSC fossa. The lower transverse diameter was measured using a line perpendicular to the vertical diameter ending at the most inferior aspect of the body of the scapula (Figure 3).

The signal intensities of various parts of the SSC and the infraspinatus (ISP) muscle were measured using the T1-weighted parasagittal spin echo sequence. After definition of elliptic regions of interest (ROIs) of identical size (50 mm²), the signal intensity was measured using the integrated software. The analysis yielded the following parameters: minimal signal intensity, maximal signal intensity, mean signal intensity, and SD of the signal intensity.

All measurements were performed 3 times, and the mean value of these measurements was calculated. In all MRI examinations, the ROIs were strictly attended so as to be constant in position and size. Five ROIs were located in the following structures: upper part of SSC muscle, lower part of the SSC muscle, midportion of ISP muscle, and background noise (Figure 4).

The signal intensity of the background noise—the disturbing inhomogeneous overlapping signals received by the MRI that cannot be eliminated completely—was determined using the method of Hendrick et al.¹⁰ An ROI of 50 mm² was set into a part of the background where no tissue signal, movement, or pulsation artifacts were detectable. The above-described software yielded the quantitative signal intensity with SD of the background.

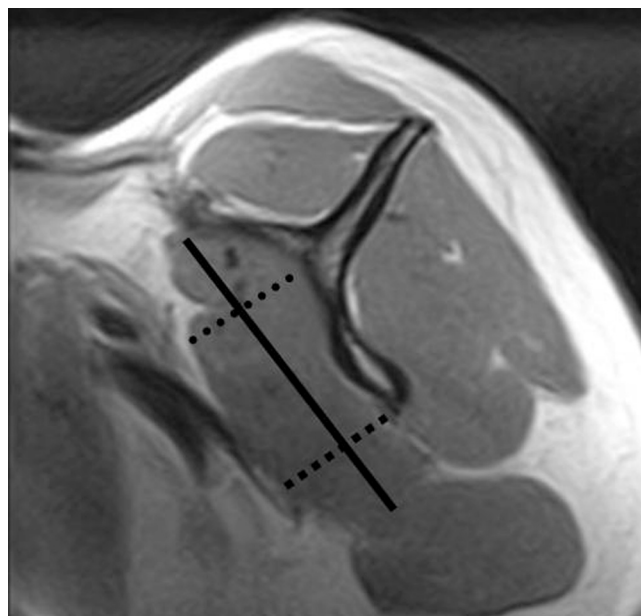


Figure 3. Measurements of vertical subscapularis muscle diameter and the transverse diameter of upper and lower subscapularis muscle portions on parasagittal T1-weighted images using the most lateral image on which the spine of the scapula is in contact with the coracoid process (Y-shaped position).

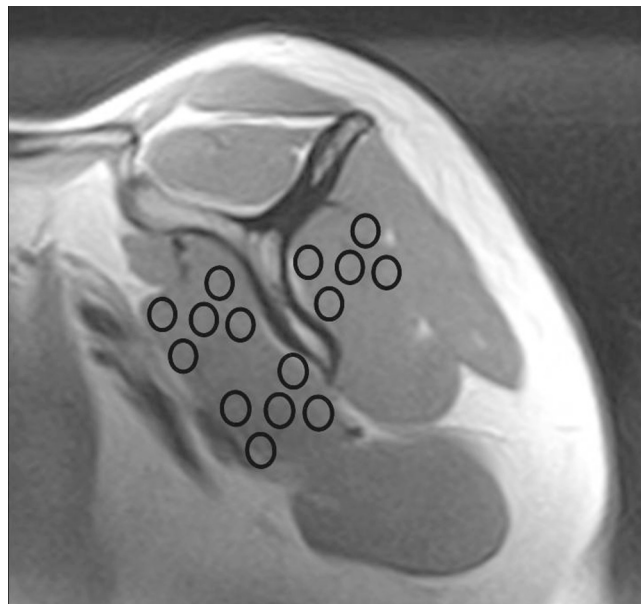


Figure 4. Placement of regions of interest in the upper and lower muscle portion of the subscapularis muscle and midportion of the infraspinatus muscle on parasagittal T1-weighted images using the most lateral image on which the spine of the scapula is in contact with the coracoid process (Y-shaped position).

The calculation of the signal-to-noise ratio (SNR) allows comparison of different MRI examinations with respect to the measured signal intensity. Thus, quantitative analysis

is possible. For calculation, the formula of Hendrick et al¹⁰ was used:

$$\text{SNR} = (\text{SI}_{\text{Str}} - \text{SI}_{\text{BG}}) / \text{SD}_{\text{BG}}$$

where SI_{Str} is the mean signal intensity within an ROI set into a tissue structure, SI_{BG} is the mean signal intensity within an ROI set into the background, and SD_{BG} is the SD of SI_{BG} .

Statistical Methods

Univariate analyses of the Constant score, Rowe score, belly-press test, MRI vertical diameter and transverse diameter, as well as the signal intensity parameters were performed using the Mann-Whitney *U* test. For analyzing differences of lift-off test, IRLS, and belly-off sign between the groups, the 2-sample Kolmogorov-Smirnov test was carried out. All statistical analyses were performed with SPSS for Windows, version 13.0 (SPSS Science Inc, Chicago, Ill).

RESULTS

Clinical Results

The mean Constant score in group 1 was 85.9 points (range, 70.8-95.5 points), and the mean Rowe score was 85 points (range, 25-100 points). One patient in this group had a redislocation (redislocation rate of 7.7%). The mean Constant score in group 2 was 86.4 points (range, 79.5-93.8 points); the Rowe score averaged 90.4 points (range, 75-100 points). One patient in this group had a redislocation (redislocation rate of 8.3%). There was no statistically significant difference between the groups with regard to the above-mentioned scores ($P < .05$).

At least 1 clinical sign for SSC insufficiency was present in 53.8% of cases in group 1 (7/13 patients had a positive belly-off sign) and in 91.6% of cases in group 2 (11/12 patients had a positive belly-off sign). The test results are summarized in Table 1.

Statistical evaluation revealed no significant changes for the results of the lift-off test between the 3 groups ($P > .05$). However, the measured flexion position of the wrist achieved during the performance of the belly-press test was lower in group 0 than in group 1 and lower in group 1 than in group 2 ($P < .05$). In addition, group 1 and group 2 had significantly worse clinical results with regard to SSC dysfunction demonstrated by the modified belly-press test and the belly-off sign ($P < .05$).

Radiologic Results

On the axial views, no signs of complete tendon rupture were detected in any group. The remaining radiologic results are summarized in Table 2. Statistical evaluation revealed the mean vertical diameter of the SSC muscle and the mean transverse diameter of the upper SSC

muscle portion were higher in group 0 than in group 1 and higher in group 1 than in group 2 ($P < .05$). The mean transverse diameter of the lower SSC muscle was comparable in all groups ($P > .05$). The signal intensity analysis revealed that the ISP/upper SSC ratio was higher in group 0 than in group 1 and higher in group 1 than in group 2 ($P < .05$). The ISP/lower SSC ratio was lower in group 0 than in groups 1 and 2 ($P < .05$).

DISCUSSION

Among the many open surgical techniques described for the treatment of anterior instability of the shoulder, the inverted L-shaped tenotomy of the SSC tendon is widely used to approach the glenohumeral joint. Only a few clinical studies have focused on the negative effects of this approach to the SSC musculotendinous unit. Greis et al⁸ reported on 4 patients with acute postoperative SSC tendon disruption after open Bankart reconstruction. All patients had a traumatic event during the postoperative rehabilitation period and experienced recurrent instability, weakness in internal rotation, increased external rotation, and abnormal lift-off test results. The authors recommended prompt reexploration and repair of the SSC tendon to achieve adequate stability and SSC function. In contrast to acute postoperative tendon disruption, chronic SSC insufficiency appears to be a different problem. In a retrospective study, Picard et al²⁶ evaluated the effects of subtotal vertical section of the SSC tendon in 40 patients who underwent open shoulder stabilization using the Latarjet procedure. The SSC muscle was assessed by measuring strength for internal rotation and the distance from hand to back during the lift-off test. The structure of the SSC muscle was assessed by CT scan. Four years after the surgical procedure, the authors found a 50% loss of SSC muscle strength and significant fatty degeneration of the muscle in 41% of patients.

Maynou et al²¹ evaluated the clinical function and structure of the SSC muscle after the Latarjet-Patte procedure with an inverted L-shaped tenotomy approach versus a lengthwise incision. The SSC function was evaluated by measuring distance and strength using the lift-off test. Fatty degeneration and atrophy were also analyzed using CT scan. The authors found that distance and strength were significantly reduced and fatty degeneration significantly increased in the inverted L-shaped tenotomy group. According to the Duplay score, patients in this group had less satisfying overall clinical results.³⁶ The authors concluded that the inverted L-shaped tenotomy results in loss of strength, fatty degeneration, and atrophy of the muscle belly and recommended the SSC split for the Latarjet-Patte procedure.

Recently, Sachs et al²⁹ evaluated 30 patients after primary open Bankart repair. The authors divided their patients into 2 groups. Twenty-three patients (77%) were thought to have a competent SSC (negative lift-off test result), and 7 patients (23%) were thought to have an incompetent SSC demonstrated by a positive lift-off test result. The authors found no difference in the Constant scores and the American Shoulder and Elbow Surgeons scoring system between

TABLE 1
Results of Lift-Off Test, Internal Rotation Lag Sign, Modified Belly-Press Test, and Belly-Off Sign for Detecting Subscapularis Insufficiency After Primary and Revision Open Stabilization Procedure

Test	Number			P		
	Control Group: Group 0	Primary Group: Group 1	Revision Group: Group 2	Group 0 vs Group 1	Group 0 vs Group 2	Group 1 vs Group 2
Lift-off test				1	.99	1
Positive	0	1	2			
Negative	12	12	10			
Internal rotation lag sign				.894	.034	.42
Positive	0	1	2			
Intermediate	0	2	5			
Negative	12	9	5			
Modified belly-press test (range), deg	-3.8 (-20 to 0)	7.3 (0 to 30)	24.6 (0 to 50)	.002	<.0001	.003
Belly-off sign				.045	<.0001	.334
Positive	0	7	11			
Negative	12	6	1			

TABLE 2
Results for Vertical Diameter of the Subscapularis (SSC) Muscle, the Transverse Diameter of the Upper and Lower SSC Muscle Portion, and the Signal-to-Signal Ratios of Infraspinatus (ISP)/Upper SSC and ISP/Lower SSC Muscles Measured on MRI

Test	Control Group: Group 0		Primary Group: Group 1		Revision Group: Group 2		P		
	Mean	Range	Mean	Range	Mean	Range	Group 0 vs Group 1	Group 0 vs Group 2	Group 1 vs Group 2
Vertical diameter of SSC muscle, mm	92.7	78.9-100.4	85.7	76.1-90.7	79.1	71.4-90.5	.034	<.0001	.032
Transverse diameter of upper SSC muscle, mm	28.8	22.7-37.4	23.4	16.4-35.8	18.5	9.3-24.7	.007	<.0001	.019
Transverse diameter of lower SSC muscle, mm	29.6	22.8-39.9	29.3	19.5-35.2	29.1	23.5-37.2	.98	.69	.69
Signal-to-signal ratio									
ISP/upper SSC	1.44	1.2-1.7	1.23	1.0-1.7	1.07	0.8-1.4	.02	<.0001	.04
ISP/lower SSC	1.68	1.4-2.0	2.15	1.6-2.5	1.99	1.6-2.3	.003	.012	.1

groups. However, patients with a competent SSC had higher subjective satisfaction rates and higher values on the Western Ontario Shoulder Instability Index.

To our knowledge, this is the first study that compares the integrity, structure, and clinical function of the SSC musculotendinous unit in patients after primary and revision open shoulder stabilization. Our study confirms previous observations that an inverted L-shaped surgical approach for open instability repair impairs SSC recovery, resulting in postoperative SSC insufficiency, including atrophy and fatty infiltration, particularly in the upper part of the SSC muscle (Figure 5). Many patients in group 1 (53.8%) and most of the patients in group 2 (91.6%) demonstrated clinical signs of upper SSC insufficiency.

In particular, the modified belly-press test/Napoleon sign and the belly-off sign appeared to be the most reliable signs to detect upper SSC insufficiency. Tokish et al³⁴ found the belly-press test to be superior to the lift-off test for activating the upper SSC muscle. These electromyographic data may explain the findings that the belly-press test as well as the belly-off sign were more reliable in detecting insufficiency of the upper part of the SSC muscle than were the IRLS and the lift-off test. Patients in group 2 had significantly worse clinical results with regard to SSC dysfunction, demonstrated in particular by the IRLS, modified belly-press test, and belly-off sign.

The mean vertical diameter of the SSC muscle and the mean transverse diameter of the upper SSC muscle portion

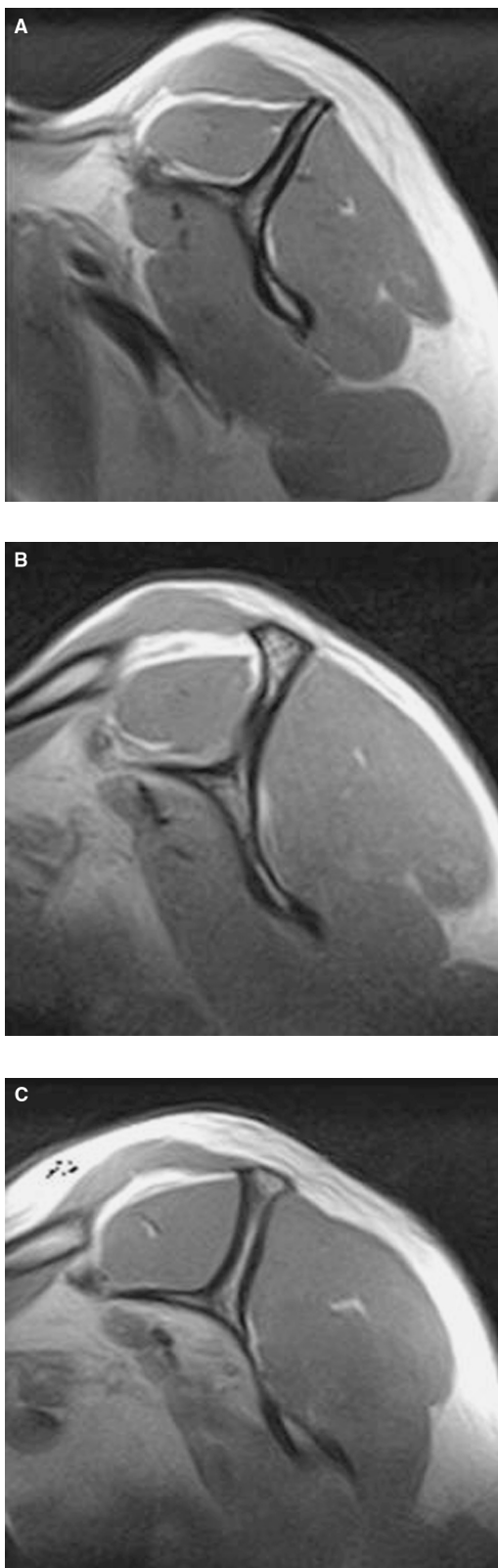


Figure 5. Parasagittal T1-weighted images showing an intact subscapularis muscle (A) and the subscapularis muscle after primary (B) and revision (C) open shoulder stabilization using an L-inverted tenotomy approach. The upper subscapularis muscle portion shows progressive atrophy and fatty infiltration.

measured on the Y-shaped position were significantly higher in group 0 than in group 1 and higher in group 1 than in group 2, suggesting a progression of muscular atrophy. In addition, the signal intensity analysis revealed the ISP/upper SSC ratio was higher in group 0 than in group 1 and higher in group 1 than in group 2, suggesting a progression of fatty degeneration with multiple detachments of the SSC tendon. However, the ISP/lower SSC ratio was significantly lower in group 0 than in groups 1 and 2. The reason for the increase is unclear. However, it seems that the lower SSC muscle portion undergoes adaptive changes that may be explained by a compensating effect.

We did not find a statistically significant difference in the Constant and Rowe scores between groups. There may be different reasons for these findings. We believe that the Constant and Rowe scores, representing well-established scores for overall shoulder function, may not be sensitive enough to detect the amount of upper SSC dysfunction found by specific clinical tests and MRI. In addition, it seems that a meticulous reconstruction of the static stabilizers of the glenohumeral joint and addressing the underlying pathologic changes causing the instability are sufficient to achieve a stable glenohumeral joint, despite the presence of atrophy and fatty infiltration of the upper SSC muscle. Clinical, cadaveric, and electromyographic studies have shown the SSC muscle to have at least 2 separate innervations and functions.^{1,14,19,22,32,34} Liu et al¹⁹ suggested that the superior portions may play an important role in generating abduction torque, and the inferior portions may enhance stability. These facts may also account for the uncompromised overall clinical outcome in terms of stability.

The reason for the degeneration of the SSC muscle remains unclear. Picard et al²⁶ assumed that a secondary partial or total rupture of the SSC tendon after refixation can be a possible explanation. Our study did not reveal any significant tears of the SSC tendon on axial MRI. However, failures in continuity suggesting an intact tendon or missed partial tears that could not be detected by MRI cannot be ruled out. Miller et al²³ suggested the possibility of denervation during release of the musculotendinous unit. Electromyography and nerve conduction studies may add in clarifying the pathogenesis.

The results of our study suggest that with regard to deterioration of the clinical function and structure of the SSC muscle, an SSC split or even an arthroscopic approach may potentially cause less violation of the integrity of the musculotendinous unit. However, prospective studies are needed for further clarification.

Our study has certain limitations. First, it is retrospective in nature. However, all patients had been documented prospectively before the index or revision surgical procedure. Second, although patients in group 1 had been operated on by 1 surgeon, 8 patients in the revision group had their index surgeries performed elsewhere. However, all patients were treated initially with the inverted L-shaped tenotomy approach described previously. A third limitation is that our study does not include any data concerning intraobserver or interobserver reliability, particularly with regard to the clinical evaluation. However, the physical examination was performed by a blinded single surgeon, who was not the

operating surgeon, using defined criteria. Finally, the patients in both groups were not selected at random. Therefore, the prevalence of SSC compromise in our subgroups might not reflect the true prevalence in larger populations.

In summary, our study confirms previous observations that an inverted L-shaped surgical approach for open instability repair impairs SSC recovery, resulting in postoperative SSC insufficiency including atrophy and fatty infiltration, particularly of the upper part of the SSC muscle. Revision procedures using the same approach may further compromise clinical SSC function and structure. The lower portion of the SSC seems to have a compensating effect that may, in addition to a meticulous capsulolabral reconstruction, account for the uncompromised overall clinical outcome.

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