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Association of Arthroscopically-Assisted Latissimus Dorsi Tendon Transfer with Implantation of a Subacromial Balloon Spacer for Patients with Irreparable Posterosuperior Rotator Cuff Tears

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SUMMARY

Purpose. Massive irreparable posterosuperior rotator cuff tears in an active population, resulting in a pseudo-paralytic shoulder, pose a challenge for the orthopaedic surgeon. In an effort to avoid or delay arthroplasty surgery, other surgical strategies such as arthroscopically-assisted latissimus dorsi transfer (aLDT) or the implantation of a subacromial spacer (SAS) can be considered. The aim of the present study is to associate, for the first time, these two surgical procedures in order to demonstrate the surgical feasibility and the effectiveness of their synergistic biomechanical effect.

Methods. The study group consisted of patients who underwent aLDT for a massive irreparable posterosuperior rotator cuff tear with or without SAS placement. The study population consisted of 17 patients. Patients were assessed with the following outcomes scores: Constant and Murley Score (CMS), Disability of Arm, Shoulder and Hand (DASH), Oxford Shoulder Score (OSS), and Subjective Shoulder Value (SSV). Follow-up after surgery (T0) took place at the following time points: 40 days (T1), 3 months (T2), 9 months (T3), and 12 months (T4). Statistical analysis was performed by descriptive statistics, nonparametric ANOVA test, and a multivariate linear regression model. The effect of subscapularis repair on clinical outcomes was also examined with subgroup analysis.

Results. In the entire population, the mean change in scores between T0 and T4 was: +30.5 for CMS, -35.14 for DASH, +18.06 for OSS, +40.47 for SSV. A statistically significant increase in all scores for both aLDT alone and aLDT with concomitant SAS was detected starting as early as T2. The subscapularis repair group had the following results as compared with the subscapularis intact group: CMS -9.5580 ($p = 0.0164$), OSS -5.6873 ($p = 0.0378$), and DASH +21.0424 ($p = 0.0097$).

Conclusions. This study demonstrates, for the first time, the feasibility and efficacy of the arthroscopically-assisted latissimus dorsi transfer alone and with concomitant implantation of a subacromial spacer. Both surgeries demonstrate clinical efficacy as early as three months after surgery, with significant and progressive clinical improvements through 12 months postoperatively.

KEY WORDS

Shoulder; latissimus dorsi; tendon transfer; arthroscopy; rotator cuff; subacromial spacer.

INTRODUCTION

Irreparable massive rotator cuff tears represent one of the most significant challenges in shoulder surgery (1-4). Over the years, several surgeries, or combinations thereof, have been proposed (5-10). Among these, tendon transfers, initially studied for nerve injuries, are supported by biomechanical and clinical investigations describing their results in generally small to medium series (11-19). Transfer of the latissimus dorsi (LDT) on the greater tuberosity, at the level of the bicipital groove, transforms this muscle from an internal rotator to an external rotator (20, 21). Some studies support that the transferred LD is actively part of the recovered shoulder function (14, 22, 23). Otherwise, others limit its efficacy to a static tenodesis effect as a humeral depressor (24, 25). LDT was initially described by Gerber *et al*. (8) as an open surgery. Subsequently, Gervasi and colleagues (26) described the first arthroscopically-assisted technique (aLDT). Studies examining the outcomes of LDT consist of small patient populations with medium-term follow-up, and these series have found advantages to the arthroscopically-assisted technique (17-19).

Among other surgical techniques, some studies have demonstrated the effectiveness of implanting a subacromial spacer (SAS), however the degradation time of the device and its mechanism of action in the long term have not yet been definitively elucidated (27-30). SAS is biodegradable (6, 30), non-toxic, and resorbable within 12 months, although some studies report that only 50% of implanted devices are still present after 6 months (30-32). Placement of this device prevents superior migration of the humeral head, and according to a review by Johns *et al*. (30) this effect is quantifiable to an average inferior translation of 4.04 mm. Biomechanically, this results in restoration of humeral head position (33). Furthermore, a study by Chevalier demonstrated how this device allows for a reduction in both average and maximal subacromial pressure during shoulder range of motion (34). As a consequence, this study hypothesized a protective effect for any associated cuff repair. Thus, the biomechanical capabilities of the SAS may have a synergistic function with those of the LDT and a hypothetical protective function of the transfer implant site.

To date, the association between aLDT and SAS has never been proposed or studied. The purpose of this study is to demonstrate feasibility and efficacy of the combined procedure of aLDT and SAS implantation. The secondary objective is to compare the results of the proposed technique and with those of aLDT alone in the first 12 months after surgery. We hypothesized that both aLDT and SAS as well as aLDT alone would provide significant improvement in shoulder function.

MATERIALS AND METHODS

Between November 2019 and April 2021, 26 patients with an irreparable posterosuperior rotator tear were indicated to undergo an arthroscopically-assisted latissimus dorsi transfer. Patients were candidates for this surgery according to the inclusion criteria in **table I**. Specific exclusion criteria are listed in **table II**.

Clinical assessment of range of motion was performed with a goniometer. External rotation was assessed with the arm adducted and the elbow flexed to 90°. Anterior flexion and abduction were assessed with the elbow extended.

Outcomes scores were used to standardize the assessments, and these were completed by the surgeon and patient. These scores consisted of the Constant and Murley Score (CMS), Disability of Arm, Shoulder and Hand (DASH), Oxford Shoulder Score (OSS), and Subjective Shoulder Value (SSV). For the CMS, section D was not assessed. Demographic and medical history data were collected. The same clinical examination was performed preoperatively (T0) and repeated at each follow-up time-point. These follow-up assessments took place at 40 days (T1), 3 months (T2), 9 months (T3), and 12 months (T4) after surgery.

Table I. Inclusion criteria.

Inclusion Criteria
Active patient with an age of less than 75 years
Active ROM impairment in anterior flexion and external rotation
Irreparable tear of the posterosuperior rotator cuff (based on preoperative MRI evaluation): Goutallier grade 3 or higher of the infraspinatus Goutallier grade 3 or higher of the supraspinatus Goutallier grade 2 of infraspinatus and supraspinatus Patte grade 2 or higher Thomazeau grade 3 or higher Moderate or higher atrophy according to Werner's classification

Table II. Exclusion criteria.

Exclusion Criteria
Glenohumeral arthrosis (Hamada stage > 3)
Subscapularis insufficiency and injury (repairable tears of the superior tubular tendon were not excluded)
Deltoid insufficiency
Glenohumeral instability
Concurrent trapezius insufficiency and/or injury
Limitation in passive ROM (anterior flexion less than 60°)
Poor patient compliance
High BMI and uncontrolled diabetes or medical contraindications to performing surgery

Ethical approval

This study was approved by the Research Committee of the Giovanni XIII Hospital and was conducted in accordance with the ethical standards of the Declaration of Helsinki. Informed consent was obtained from all patients included in the study.

Imaging

High-field magnetic resonance imaging (MRI) and radiographic examinations were evaluated by a radiologist specialized in musculoskeletal pathology. Each MRI or x-ray examination was also re-evaluated by the authors. The MRI examinations guided the diagnosis and confirmed the surgical indication. Radiographic examinations, used to assess humeral-acromial distance, were performed in the true antero-posterior projection, with the patient in an upright position, preoperatively and on the first postoperative day.

Surgical technique and rehabilitation

The surgical technique involved the arthroscopically-assisted latissimus dorsi tendon transfer as described by Gervasi *et al*. (26).

The main steps are as follows. The patient is placed in lateral decubitus, with shoulder and elbow flexed at 90°. The anaesthesia is blended, general and brachial plexus block. A L-shaped 6-8 cm incision is made in the axilla, just anterior to the posterior axillary's pillar. This approach allows a direct exposure of the latissimus dorsi. Correct separation from the teres major and identification of the neuro-vascular peduncle (35) are mandatory. In the axilla, the radial nerve is ~2 cm distal off the latissimus humeral attachment, depending on the arm's position. The latissimus dorsi tendon is sharply detached from the humeral shaft while the arm is hold in internal rotation. At this point, holding and stretching the tendon, an accurate release of the muscle belly, reaching the inferior angle of the scapula, is always performed. Mobilization is completed when the end of the tendon, pulled over the acromion, crosses its posterior edge more than 2 cm. Open surgery ends with the placement of high-strength sutures on the tendon.

The arthroscopic procedure is standard. A wide release is performed and the associated lesions found are treated. Then, the posterior space between the teres minor and deltoid belly is opened with the arthroscope and the cautery, exiting at the axilla. With a dedicated device, the tendon sutures are retrieved out of the anterior portal and the tendon is transferred in the joint. Anchors are used as fixation method. The first anchor is usually inserted at the anterior aspect of the greater tuberosity, close to the articular cartilage and the long head of biceps groove. The tendon is then wrapped around the greater tuberosity and fixed with an additional lateral anchor. Sometimes two more proximal accessory sutures are added.

During the same surgical procedure and after tendon transfer, SAS implantation was performed according to the previously described technique (33-36). Patients were maintained in a shoulder brace at 15° abduction and 15° external rotation for 4 weeks. Pendulum movements and elbow and wrist mobilization were allowed several times a day starting on the first postoperative day. After the first week, if pain permitted, passive assisted mobilization was also allowed. Formal physiotherapy rehabilitation began with removal of the brace and recovery of passive range of motion. Active range of motion and stretching exercises followed. Exercises against resistance were allowed no sooner than 3 months after surgery. Physical therapy was recommended until at least 6 months postoperatively but was continued as long as the patient felt it was beneficial.

Data collection and final study sample

Two patients were excluded from the study because a partial arthroscopic tendon repair was associated with the procedure. In addition, although aLDT was performed, one patient with Personage Turner Syndrome (complete atrophy of supraspi-

natus and infraspinatus associated with partial atrophy of the teres minor) and 3 other patients in whom the procedure was performed due to neurological disorders were excluded from the study. In the remaining group of 20 patients, SAS implantation was performed randomly. During the study, one patient was lost to follow-up for unknown reasons. Due to the COVID-19 pandemic restrictions which coincided with the study period, 2 patients were excluded from the study for prolonged immobilization as a consequence of the disease course. Patients who were able to perform normal activities of daily living and/or physiotherapy sessions remotely were not excluded from the study. Ultimately, 17 patients were included in the study, with an equivalent number of surgeries performed. Because of the COVID-19 pandemic, follow-ups were performed in person or, when not possible, by video consultation. Each surgery was performed by the same surgeon (E.G.). The population of patients undergoing aLDT was defined as Surgery A (S.A.), and those undergoing aLDT associated with SAS as Surgery B (S.B.). Each clinical score was analyzed individually. Scores were compared, relative to T0, with each follow-up both for the entire patient population and separately for S.A. and S.B.

Statistical analysis

Data were collected in a database, including demographic information, patient history, clinical examination, and imaging findings. Statistical analysis was performed by descriptive statistics, nonparametric ANOVA test, and a multivariate linear regression model with the following factors: age over 65, dominant limb, subscapularis repair, teres minor atrophy, and previous surgery. A P-value < 0.05 was considered statistically significant.

All procedures followed were in accordance with the ethical standards.

RESULTS

A total of 17 patients were included in the study after applying inclusion and exclusion criteria. Of these, 10 underwent the aLDT procedure alone, while the remaining 7 patients underwent aLDT along with SAS implantation. The number of procedures corresponded to the number of patients, as surgery was always performed unilaterally.

The mean age of the patients was 59.9 years (47-71). Notably, when analysing age by sex, women (n = 6) had a mean age of 62.5 years (51-69), while men (n = 11) had a mean age of 58.5 years (47-71). The affected shoulder was the dominant side in 13 patients. There were 8 patients who had undergone previous surgery, of whom 4 patients had undergone mini-open surgery. 15 patients presented after an injury, with a rotator cuff tear of at least two tendons retracted to the glenoid and associated with hypotrophy/atrophy of at least one tendon. Only one patient presented with a single tendon tear: a supraspinatus tear, with severe retraction and stage IV atrophy according to Goutallier. Involvement of the teres minor was present in 4 patients in the form of mild to moderate (Goutallier ≤ 3) fatty infiltration of the muscle belly. At arthroscopic diagnostic evaluation, all patients in this study had an irreparable rotator cuff tendon tear. Tenotomy of the long head of the biceps was performed in the 6 patients whose tendon was still attached to the superior labrum. No significant acromioplasty was performed. Repair of the subscapularis tendon was performed in 5 patients. The duration of follow-up was 12 months for all patients.

Clinical evaluation of the entire study population

Analysing the whole study population, CMS increased from a mean score of 37.85 (24-57) preoperatively (T0) to a mean score of 68.35 (48.5-74) at T4. The mean increase in this score was 30.50. OSS analysis showed a mean score of 27.35 (range: 12-40) at T0 and a mean score of 45.41 (32-48) at T4. The mean increase in this score was 18.06. DASH decreased from a mean score of 45.09 (89.7-22.4) at T0 to a mean score of 9.95 (42.20-0) at T4. The mean decrease in this score was 35.14. SSV analysis demonstrated a mean score of 41.47% (25-65) at T0 and a mean score of 81.94% (45-99) at T4. The mean increase in this score was 40.47%.

The nonparametric ANOVA test (**table III**) found statistically significant clinical improvement based on data from all scores comparing timepoints T0 to T4. Moreover, there was already statistically significant improvement when comparing T0 to T2. The multivariate linear regression model showed the following estimates (T0-T4) for the subscapularis repair variable: CMS -9.5580 (p 0.0164), OSS -5.6873 (p 0.0378), and DASH 21.0424 (p 0.0097).

Preoperatively, the mean acromiohumeral distance was 6.9 mm (2.88-14.7). Postoperative analysis revealed a mean acromiohumeral distance of 10.5 mm (4.75-15.9). The mean increase in acromiohumeral distance from preoperatively to postoperatively was 3.6 mm.

Clinical evaluation of populations S.A. and S.B.

The nonparametric ANOVA test (Kruskal-Wallis and Dunn's multiple comparison tests) demonstrated statistically significant clinical improvement based on data from all scores between T0 and T4 (**appendix 1**). The nonparametric ANOVA tests conducted for each score on populations S.A and S.B. are represented in **figures 1-4**. The radiographic study showed an average increase in the acromiohumeral distance from preoperative to postoperative of 3.1 mm in the S.A. population and 4.2 mm in the S.B. population.

Table III. Entire population nonparametric ANOVA test.

CMS					
	Estimate	**SE**	**df**	**t.ratio**	**P-value**
T0 – T1	-152.857	3.460.812	60	-0.44168	0.991908
T0 – T2	-23.75	3.460.812	60	-686.255	4.25E-08
T0 – T3	-444.143	3.460.812	60	-128.335	1.99E-11
T0 – T4	-498.429	3.460.812	60	-144.021	1.99E-11
T1 – T2	-222.214	3.460.812	60	-642.087	2.38E-07
T1 – T3	-428.857	3.460.812	60	-123.918	1.99E-11
T1 – T4	-483.143	3.460.812	60	-139.604	1.99E-11
T2 – T3	-206.643	3.460.812	60	-597.093	1.35E-06
T2 – T4	-260.929	3.460.812	60	-753.952	3.00E-09
T3 – T4	-542.857	3.460.812	60	-156.858	0.523022
OSS					
	Estimate	**SE**	**df**	**t.ratio**	**P-value**
T0 – T1	-11.5	3.644.751	60	-315.522	0.020382
T0 – T2	-314.786	3.644.751	60	-863.669	6.03E-11
T0 – T3	-476.071	3.644.751	60	-130.618	1.99E-11
T0 – T4	-527.929	3.644.751	60	-144.846	1.99E-11
T1 – T2	-199.786	3.644.751	60	-548.146	8.61E-06
T1 – T3	-361.071	3.644.751	60	-990.661	2.02E-11
T1 – T4	-412.929	3.644.751	60	-113.294	1.99E-11
T2 – T3	-161.286	3.644.751	60	-442.515	0.000387
T2 – T4	-213.143	3.644.751	60	-584.794	2.16E-06
T3 – T4	-518.571	3.644.751	60	-142.279	0.61564
DASH					
	Estimate	**SE**	**df**	**t.ratio**	**P-value**
T0 – T1	-0.38571	4.115.623	60	-0.09372	0.999982
T0 – T2	2.092.143	4.115.623	60	5.083.418	3.75E-05
T0 – T3	3.646.429	4.115.623	60	8.859.968	3.69E-11
T0 – T4	4.181.429	4.115.623	60	1.015.989	2,00E-11
T1 – T2	2.130.714	4.115.623	60	5.177.137	2.66E-05
T1 – T3	36.85	4.115.623	60	8.953.688	3.17E-11
T1 – T4	42.2	4.115.623	60	1.025.361	2,00E-11
T2 – T3	1.554.286	4.115.623	60	3.776.551	0.003265
T2 – T4	2.089.286	4.115.623	60	5.076.476	3.85E-05
T3 – T4	5.35	4.115.623	60	1.299.925	0.692264
SSV					
	Estimate	**SE**	**df**	**t.ratio**	**P-value**
T0 – T1	3.307.143	4.356.869	60	0.759064	0.9412
T0 – T2	-21.05	4.356.869	60	-483.145	9.31E-05
T0 – T3	-348.786	4.356.869	60	-800.542	4.97E-10
T0 – T4	-42.55	4.356.869	60	-976.619	2.05E-11

SSV					
T1 – T2	-243.571	4.356.869	60	-559.051	5.72E-06
T1 – T3	-381.857	4.356.869	60	-876.448	4.45E-11
T1 – T4	-458.571	4.356.869	60	-105.253	2,00E-11
T2 – T3	-138.286	4.356.869	60	-317.397	0.019357
T2 – T4	-21.5	4.356.869	60	-493.474	6.43E-05
T3 – T4	-767.143	4.356.869	60	-176.077	0.405721

Estimate: difference in median; SE: standard error; Df: degrees of freedom.

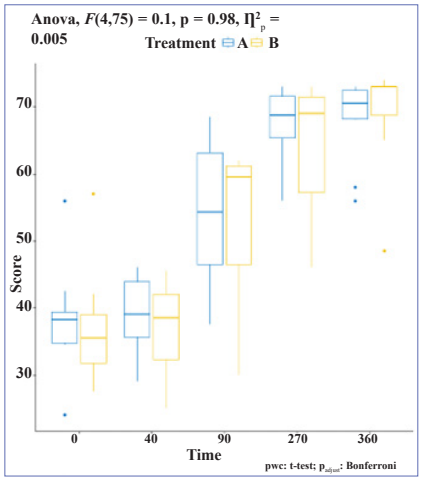

Figure 1. S.A. and S.B. population nonparametric ANOVA test: CMS.
Time: number of days.

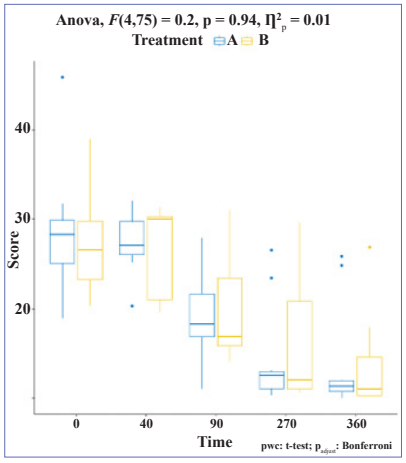

Figure 3. S.A. and S.B. population nonparametric ANOVA test: DASH.
Time: number of days.

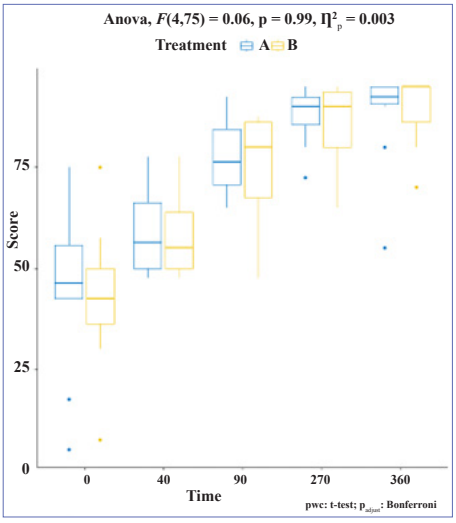

Figure 2. S.A. and S.B. population nonparametric ANOVA test: OSS.
Time: number of days.

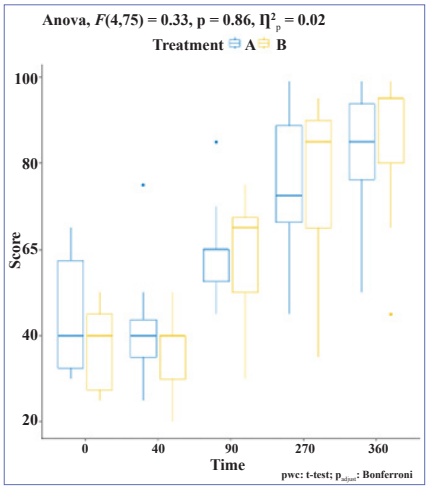

Figure 4. S.A. and S.B. population nonparametric ANOVA test: SSV.
Time: number of days.

Complications

No intra-operative complications were encountered. One patient received antibiotic therapy for a suspected surgical site infection of the incision in the axillary region, with no additional treatment required. One patient reported a sensory deficit in the fifth finger of the hand that resolved approximately 3 months after surgery. One patient developed a seroma in the axillary region. This patient underwent ultrasound-guided aspiration at 15 days postoperatively (60 cc aspirated) and 27 days postoperatively (30 cc aspirated) with subsequent seroma resolution.

DISCUSSION

This study demonstrates the efficacy and reliability of the first published technique of arthroscopically-assisted transfer of the latissimus dorsi associated with the implantation of a subacromial spacer for the treatment of irreparable massive rotator cuff tears. Moreover, in accordance with the literature (12, 14, 16, 19), the clinical results of the aLDT technique, in terms of functional outcome and pain resolution, are also confirmed. Statistical analysis shows, in fact, that both the entire population and the individual subgroups S.A. and S.B. had a statistically significant clinical improvement even at 3 months after surgery.

The results, as mentioned, are aligned with the literature, however it is critical that this comparison is strictly dependent on the surgical technique. The technique is not always clearly described or defined in its fundamental parts. The surgical technique described by Gervasi *et al.* (26) is based on a careful release of the latissimus dorsi, thus avoiding the use of a graft, and fixation of the transferred tendon lateral to the bicipital groove using anchors. This position and method of fixation allows for complete wrapping of the great tuberosity. In addition to maximizing the tendon-bone interface, this is, in our opinion, a key factor in achieving more optimal shoulder biomechanics and kinetics.

In the literature, focusing only on studies using the arthroscopically-assisted technique, the use of a graft is certainly relevant. This difference is of great impact on both the course of surgery and its outcomes. In 2019, Lim *et al.* (11) described a series of aLDT using a dermal patch, whereas, in 2016, Kanath and colleagues (16) used a fascia lata autograft. The technique described in this study is in agreement with Kany's 2014 study (22). In the Kany *et al.* investigation, the authors described how a correct and complete release of the latissimus dorsi grants this transfer a potential excursion of 33 cm, which is largely sufficient to be transferred without requiring any graft. Therefore, if an accurate LD release is performed, the use of an augment/graft is unnecessary.

An additional variable in technique, which is certainly relevant, is the site of transfer implantation. De Casas *et al.* described how anchor placement, in the posterosuperior region of the great tuberosity, is performed prior to tendon harvesting (14). Grimberg (15), in 2015, and Goldstein (36), in 2013, performed a tubularization of the transfer by creating a tunnel from the posterosuperior portion of the great tuberosity. Kany, in 2010, compared two groups of patients where the transfer is placed in the posterosuperior or superior region of the great tuberosity (37). These choices also affect the method of fixation of the transfer. Tubularized tendons involve the creation of a tunnel and subsequent fixation with interference buttons or screws (14, 15, 36). The studies that thoroughly and accurately described their technique and are comparable to this study are the series of Castricini (12), Henseler (23), and Wantespull (19).

Regarding the fixation technique, in 2011 Diop *et al.* performed a biomechanical study comparing anchor and interference screw fixation after transfer tubularization (38). They concluded that the risk of graft loosening after cyclic loading is decreased with the use of interference screws, while no difference was detected at "load to failure." The surgical technique in the present study involves the use of anchors, which we believe enables shorter surgical times and decreases the well-known risk of intra-operative tuberosity fractures (38).

The subscapularis is thought to be critical for successful surgery (13, 39, 40). The number of subjects in the present case series limits the ability to provide a definitive conclusion with respect to the effect of the subscapularis. However, statistical analysis showed that concomitant repair of a subscapularis tendon tear was correlated with poorer clinical scores. Interestingly, this score reduction did not seem to have a relevant effect on the global outcome of the transfer, as reported in the literature (17-19).

A similar analysis can be made for the involvement of the teres minor. In the present investigation, mild/moderate fatty atrophy of this muscle (4 patients) did not appear to have a major effect on clinical outcome. This finding is in agreement with the 2015 work of Grimberg *et al.* (15). We believe, however, that a complete impairment of the teres minor could lead to inferior clinical outcomes, in agreement with what has been described by Costouros (13) in 2007, Novè-Josserand (41) in 2009, and Gerber (42) in 2013.

The outcomes of latissimus dorsi transfer when performed as primary *versus* revision surgery is debated in the literature. Some studies describe better outcomes, in terms of satisfaction, function, and failures, when this surgery is performed as a primary procedure (12), while others find no significant

differences (25, 43). In the present study, perhaps because of the sample size, a valid statistical finding was not found.
The last clinical evaluation concerns strength. This aspect is probably the most important limitation of this surgery, especially when, in a very young population, there is a high functional demand. In this study, in order not to alter the results with nonhomogeneous measurements, the specific D section of the CMS was not calculated. In the literature, Castricini *et al*. report that up to 80% of strength can be recovered in women and 50% in men (12). Grimberg *et al*. report that good strength, quantified as sufficient to return to doing heavy manual labour, is not achievable with this procedure and the patient should be counselled regarding this limitation (15). Weening *et al*., in 2009, described an increase in strength, however the authors specifically found that in activities above the scapular level this strength improvement remains very modest (39). In our study, patient feedback and some scores confirm what has been described in the literature.
Analyzing only comparable surgical techniques, the postoperative rehabilitation proposed in the present study is in accordance with that described by Castricini (12). In contrast, Wantespull (19) and Henseler (23) described the use of a 45° abduction and 30°-45° external rotation brace for 6 weeks.
Despite the different follow-up lengths, we believe that early mobilization, as described in this study, is important to achieve a good functional outcome as early as 3 months. Nevertheless, it is important to remember how a brace with significant abduction and external rotation may result in significant patient discomfort and is perhaps unnecessary.
There are no studies in the literature that have associated the implantation of a SAS with an aLDT. Regarding the implantation of a subacromial spacer, Chevalier's cadaver study (34) describes a reduction in maximum and mean pressure between the acromion and the underlying supraspinatus tendon. He also concluded by hypothesizing a potential protective effect of the spacer on a tendon repair. The rationale to conduct the present study is based on the hypothesis that the protective effect may also apply to the tendon transfer. Our study results do not show a relevant variation from aLDT alone. However, a long-term follow-up will be necessary to evaluate whether transfer survival will be increased in patients who also underwent balloon implantation.
The literature is discordant on the longevity of SAS. Haim Zada *et al*. report how device failure varies between 83 and 98 days (44). The review by Johns (30) indicates survival up to 12 months (50% at 6 months) although clinical benefits are described up to 5 years. Beyond controversial long-term efficacy, which is not the subject of this study, we believe that the purpose of the association of SBS and aLDT is the protective effect on the transfer in the first months of maximum fragility. This results in both protection of the tendon-bone interface during the healing period and limitation of stretching of the newly transferred latissimus dorsi.
The radiographic investigation shows an increase in acromiohumeral distance, which can be associated with a re-centering of the humeral head in those cases of significant superior migration. Zafra *et al*. report an average humeral head lowering of 3.2 mm after performing a latissimus dorsi transfer (45). Johns' review of subacromial spacers describes a reduction in mean humeral head superior translation of 4.04 mm (30). In the present investigation, the mean acromiohumeral space increase was 3.6 mm (S.A. 3.1 mm and S.B. 4.2 mm). We believe that this analysis, although performed in the most accurate and standardized method possible, is easily biased. However, the results of this study are in agreement with the existing literature.
Regarding surgical time, the literature indicates about 10 minutes as the average time to implant a SAS (30). Although this parameter was not evaluated in the study, it is believed that, since no further preparation of the surgical field is required, the implantation time of SAS combined with aLDT is less than 5-7 minutes.
In the follow-up period, no patient underwent surgery for revision or treatment for any complication. The only complication noted in this study was seroma in the axillary region which resolved after two aspirations. The literature suggests that hematoma formation occurs in 3.8% and 14.3% of patients undergoing latissimus dorsi transfer (22). During the follow-up period, no SAS implant-related complications occurred. The literature reports minimal risks of complications due to the implantation of this device (30).
Finally, regarding the scores chosen for this study, they are all widely used in the literature, as there is no dedicated score for this surgery. However, in particular, Wantelspull *et al*. define the CMS as unsuitable and poorly correlated to real patient satisfaction (19). Grimberg *et al*., in a 2014 review, emphasized how CMS can never reach satisfactory levels, relative to the patient's true perception, because of the strength ratings (section D of the CMS) (22). However, throughout the literature, only one score or at most the association of two scores is typically used. No study has compared four different scores on the same patient population in this type of surgery.
The present study has few limitations. The small sample size represents one of the major limitations of this study.
Furthermore, we consider the proper functioning of the subscapularis to be fundamental. Therefore, in the smallness of the sample, the limited population of subscapularis

repairs must also be considered. This factor could be relevant in highlighting the fundamental importance of this structure.
Another limitation of the study is that no postoperative imaging investigation was performed to confirm the integrity of the tendon transfer or the subacromial spacer.
This study poses at least two future goals. The first will be to evaluate in the long term whether the hypothetical initial reduction in stress on the transfer, provided by SAS, may actually increase its survival. The second will be to perform an EMG evaluation to compare the patterns of activation of the latissimus dorsi between the S.A. and S.B. patient populations.

CONCLUSIONS

This study demonstrates, for the first time, the feasibility and efficacy of the surgical technique involving the association of a subacromial spacer with an arthroscopically-assisted latissimus dorsi transfer for the treatment of irreparable posterosuperior cuff tears. This surgery, as well as performing aLDT alone, allows a significant increase in shoulder function. This surgery provides significant improvement in clinical outcomes, including all four outcomes scores tested, by three months after surgery, with further clinical improvements evident up to 12 months postoperatively.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

EG: conceptualization, first surgeon. EG, GEV: methodology. GEV, AT, GS, FF: assistant surgeon. GEV: investigation. GEV, PV: data curation. GEV: writing - original draft preparation. PV: writing - review and editing. EG, LC: supervision. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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SUPPLEMENTS

Appendix 1. The nonparametric ANOVA test based on the data of all scores between follow-ups.

Treatment	**Surgery A**			*Treatment*	**Surgery A**		
Score	**Constant**			*Score*	**DASH**		
Kruskal-Wallis test				*Kruskal-Wallis test*			
P-value	< 0.0001			P value	< 0.0001		
Exact or approximate P-value?	Approximate			Exact or approximate P-value?	Approximate		
P-value summary	****			P-value summary	****		
Do the medians vary signif. (p < 0.05)	Yes			Do the medians vary signif. (p < 0.05)	Yes		
Number of groups	5			Number of groups	5		
Kruskal-Wallis statistic	36,56			Kruskal-Wallis statistic	28.77		
Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary	*Dunn's multiple comparisons test*	Mean rank diff,	Significant?	Summary
T0 vs T40	-1.2	No	ns	*T0 vs T40*	-0.3	No	ns
T0 vs T90	-14.75	No	ns	*T0 vs T90*	13.95	No	ns
T0 vs T270	-27.25	Yes	***	*T0 vs T270*	23	Yes	**
T0 vs T360	-29.55	Yes	****	*T0 vs T360*	25.85	Yes	***
T40 vs T90	-13.55	No	ns	*T40 vs T90*	14.25	No	ns
T40 vs T270	-26.05	Yes	***	*T40 vs T270*	23.3	Yes	**
T40 vs T360	-28.35	Yes	***	*T40 vs T360*	26.15	Yes	***
T90 vs T270	-12.5	No	ns	*T90 vs T270*	9.05	No	ns
T90 vs T360	-14.8	No	ns	*T90 vs T360*	11.9	No	ns
T270 vs T360	-2.3	No	ns	*T270 vs T360*	2.85	No	ns

Treatment	**Surgery A**			*Treatment*	**Surgery A**		
Score	**OXFORD**			*Score*	**SSV**		
Kruskal-Wallis test				*Kruskal-Wallis test*			
P-value	< 0.0001			P-value	< 0.0001		
Exact or approximate P-value?	Approximate			Exact or approximate P-value?	Approximate		
P-value summary	****			P-value summary	****		
Do the medians vary signif. (p < 0.05)	Yes			Do the medians vary signif. (p < 0.05)	Yes		
Number of groups	5			Number of groups	5		
Kruskal-Wallis statistic	34.45			Kruskal-Wallis statistic	26.99		
Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary	*Dunn's multiple comparisons test*	Mean rank diff,	Significant?	Summary
T0 vs T40	-5.85	No	ns	*T0 vs T40*	2.65	No	ns
T0 vs T90	-19.05	Yes	*	*T0 vs T90*	-11.8	No	ns
T0 vs T270	-28.3	Yes	***	*T0 vs T270*	-20.65	Yes	*
T0 vs T360	-30.55	Yes	****	*T0 vs T360*	-23.95	Yes	**
T40 vs T90	-13.2	No	ns	*T40 vs T90*	-14.45	No	ns
T40 vs T270	-22.45	Yes	**	*T40 vs T270*	-23.3	Yes	**
T40 vs T360	-24.7	Yes	**	*T40 vs T360*	-26.6	Yes	***
T90 vs T270	-9.25	No	ns	*T90 vs T270*	-8.85	No	ns
T90 vs T360	-11.5	No	ns	*T90 vs T360*	-12.15	No	ns
T270 vs T360	-2.25	No	ns	*T270 vs T360*	-3.3	No	ns

Treatment	**Surgery B**			*Treatment*	**Surgery B**			*Treatment*
Score	**Constant**			*Score*	**DASH**			*Score*
Kruskal-Wallis test				*Kruskal-Wallis test*				*Kruskal-Wallis test*
P-value	0.0001			P-value	0.0035			P-value
Exact or approximate P-value?	Approximate			Exact or approximate P-value?	Approximate			Exact or approximate P-value?
P-value summary	***			P-value summary	**			P-value summary
Do the medians vary signif. ($p < 0.05$)	Yes			Do the medians vary signif. ($P < 0.05$)	Yes			Do the medians vary signif. ($p < 0.05$)
Number of groups	5			Number of groups	5			Number of groups
Kruskal-Wallis statistic	23			Kruskal-Wallis statistic	15.66			Kruskal-Wallis statistic
Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary	*Dunn's multiple comparisons test*	Mean rank diff,	Significant?	Summary	*Dunn's multiple comparisons test*
T0 vs T40	-0.07143	No	ns	*T0 vs T40*	-0.6429	No	ns	*T0 vs T40*
T0 vs T90	-8.929	No	ns	*T0 vs T90*	7.643	No	ns	*T0 vs T90*
T0 vs T270	-16.29	Yes	*	*T0 vs T270*	12.71	No	ns	*T0 vs T270*
T0 vs T360	-20.43	Yes	**	*T0 vs T360*	16.71	Yes	*	*T0 vs T360*
T40 vs T90	-8.857	No	ns	*T40 vs T90*	8.286	No	ns	*T40 vs T90*
T40 vs T270	-16.21	Yes	*	*T40 vs T270*	13.36	No	ns	*T40 vs T270*
T40 vs T360	-20.36	Yes	**	*T40 vs T360*	17.36	Yes	*	*T40 vs T360*
T90 vs T270	-7.357	No	ns	*T90 vs T270*	5.071	No	ns	*T90 vs T270*
T90 vs T360	-11.5	No	ns	*T90 vs T360*	9.071	No	ns	*T90 vs T360*
T270 vs T360	-4.143	No	ns	*T270 vs T360*	4	No	ns	*T270 vs T360*

Surgery B			*Treatment*	**Surgery B**		
OXFORD			*Score*	**SSV**		
			Kruskal-Wallis test			
0.0002			P-value	0.0007		
Approximate			Exact or approximate P-value?	Approximate		
***			P-value summary	***		
Yes			Do the medians vary signif. ($p < 0.05$)	Yes		
5			Number of groups	5		
22.19			Kruskal-Wallis statistic	19.39		
Mean rank diff,	Significant?	Summary	*Dunn's multiple comparisons test*	Mean rank diff,	Significant?	Summary
-5.214	No	ns	*T0 vs T40*	0.7143	No	ns
-12.43	No	ns	*T0 vs T90*	-8.643	No	ns
-18.93	Yes	**	*T0 vs T270*	-13.71	No	ns
-21.64	Yes	***	*T0 vs T360*	-18.71	Yes	**
-7.214	No	ns	*T40 vs T90*	-9.357	No	ns
-13.71	No	ns	*T40 vs T270*	-14.43	No	ns
-16.43	Yes	*	*T40 vs T360*	-19.43	Yes	**
-6.5	No	ns	*T90 vs T270*	-5.071	No	ns
-9.214	No	ns	*T90 vs T360*	-10.07	No	ns
-2.714	No	ns	*T270 vs T360*	-5	No	ns