All-Suture Anchor Dynamic Anterior Stabilization Produced Successful Healing of the Biceps Tendon

A Report of 3 Cases

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Abstract

Cases: Three patients (age, 15-34 years) who had a history of chronic traumatic anteroinferior glenohumeral instability (2-10 dislocations) and preoperatively documented Bankart and Hill-Sachs lesions underwent all-arthroscopic trans-subscapular transposition of the long head of the biceps that was fixed on the anteroinferior glenoid using a novel double double-pulley all-suture anchor method that has not been reported previously.

Conclusion: Excellent 12-month clinical and imaging outcomes, with substantial improvements in the Western Ontario Shoulder Index and the Rowe score in the first consecutive patients who underwent this original technical variant of dynamic anterior stabilization and the surgical pearls and pitfalls are described in detail.

Dynamic anterior stabilization (DAS) is a new arthroscopic technique that fills a gap between bone block procedures and soft-tissue procedures in the treatment algorithm of patients with chronic traumatic glenohumeral anteroinferior instability without substantial bone damage of the glenoid and humeral head, but with poor quality of the

D

TABLE I Demographic and Clinical Characteristics*

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age at First Episode (y)</th>
<th>Age at Surgery (y)</th>
<th>Type of Trauma</th>
<th>No. of Shoulder Dislocation Episodes</th>
<th>FF (°)</th>
<th>Abd (°)</th>
<th>ER (°)</th>
<th>IR (°)</th>
<th>WOSI†</th>
<th>Rowe Score§</th>
<th>Shoulder Abduction Strength (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>15</td>
<td>Rugby</td>
<td>2</td>
<td>170</td>
<td>140</td>
<td>75</td>
<td>4</td>
<td>701</td>
<td>30</td>
<td>8.77</td>
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<tr>
<td>2</td>
<td>21</td>
<td>22</td>
<td>Bullfight</td>
<td>2</td>
<td>165</td>
<td>150</td>
<td>40</td>
<td>4</td>
<td>1,117</td>
<td>25</td>
<td>11.49</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
<td>34</td>
<td>Throwing</td>
<td>10</td>
<td>180</td>
<td>145</td>
<td>60</td>
<td>5</td>
<td>1,191</td>
<td>35</td>
<td>6.12</td>
</tr>
</tbody>
</table>

*Abd = active abduction, ER = active external rotation, FF = active forward flexion, IR = active internal rotation, and WOSI = Western Ontario Shoulder Index. †Measured as the highest vertebral body that the patient’s thumb could reach without pain: lateral thigh = 0, buttock = 1, sacrum = 2, lumbar = 3, T12 = 4, and T7 = 5. ‡0 to 2,100, consists of 21 items; the patient is asked to grade the function of a specific item on a horizontal visual analogue scale from 0 to 100; for every scale range provided, higher values represent a worse outcome. §0 to 100 points; for every scale range provided, higher values represent a better outcome.

C. de Campos Azevedo: consultant shoulder orthopaedic surgeon who conceived and designed the study, performed all surgical procedures, participated in the validation, data acquisition and formal analysis, investigation, resources, visualization, supervision, project administration, writing—original draft, review, editing and final manuscript approval. A. C. Ângelo: shoulder orthopaedic surgeon who participated in the surgical procedures and originally conceived of the double double-pulley shuttling technique for the procedures, participated in the investigation, conceived and executed the original digital artwork, critically revised, and approved the final manuscript.

Disclosure: The Disclosure of Potential Conflicts of Interest forms are provided with the online version of the article (http://links.lww.com/JBJS/C349).

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glenohumeral ligaments and labrum. One biomechanical cadaveric study and 2 technical notes have described different methods of transposing and fixing the long head of the biceps (LHB) tendon to the anteroinferior glenoid rim, but clinical studies on the outcomes of DAS are lacking. The proposed indication is anteroinferior glenohumeral instability with limited bone defects, associated with a superior labral tear from anterior to posterior (SLAP), or in overhead athletes and throwers. In the current study, a technical variation of DAS using an all-arthroscopic all-suture suture anchor fixation method is described and the preliminary clinical outcomes in 3 consecutive cases are reported.

The patients were informed that data concerning their cases would be submitted for publication, and they provided consent.

Fig. 1
Preoperative magnetic resonance images of patient 3 showing the glenoid and humeral bone loss. **Fig. 1-A** Measurement of the estimated glenoid bone loss according to the glenoid width method using the best-fit circle on the oblique sagittal proton density–weighted sequence \( \left( \frac{(R - r)}{2R} \right) \times 100\% = 20.24\% \), where \( R \) = estimated native glenoid radius, and **Fig. 1-B** Hill-Sachs lesion (white arrow) on the T2-weighted axial sequence, which measured 12.79 mm in length; the estimated intact native glenoid diameter (2R) was 22.00 mm and the glenoid defect (R – r) was 4.45 mm, thereby the glenoid track \( \left( 2R \times 0.83 \right) \) was 13.8 mm. The Hill-Sachs index was lower than the glenoid track which are findings that characterize an on-track lesion with low risk of engagement. Arthroscopically, before the dynamic anterior stabilization (DAS), the Hill-Sachs lesion engaged on the anteroinferior glenoid, whereas after the DAS it did not.

Fig. 2
Preoperative magnetic resonance images of patient 2 showing the glenoid and humeral bone loss. **Fig. 2-A** Measurement of the estimated glenoid bone loss according to the glenoid width method using the best-fit circle on the oblique sagittal proton density–weighted sequence \( \left( \frac{(R - r)}{2R} \right) \times 100\% = 17.29\% \), where \( R \) = estimated native glenoid radius, and **Fig. 2-B** 13.36 mm-long Hill-Sachs lesion on the T2-weighted axial sequence; the estimated intact native glenoid diameter (2R) was 33.48 mm and the glenoid defect (R – r) was 5.79 mm, thereby the glenoid track \( \left( 2R \times 0.83 \right) \) – [R – r]) was 22.00 mm. The Hill-Sachs index was lower than the glenoid track which are findings that characterize an on-track lesion with low risk of engagement. Arthroscopically, before the dynamic anterior stabilization (DAS), the Hill-Sachs lesion engaged on the anteroinferior glenoid, whereas after the DAS it did not.
Fig. 3
Arthroscopic images of the right shoulder of patients 1 and 2. **Fig. 3-A** Anterolateral portal view of patient 1 showing the switching stick (Sw), which is placed through the posterior portal and directed at the superior border of the lower third of the subscapularis tendon (SC), marking the level of the split where the radiofrequency ablator will be used to split the SC tendon from medial to lateral in a plane parallel to the direction of the fibers of the SC tendon (black arrow) and (**Fig. 3-B**) bellow the equator of the glenoid (a gauged probe points to the level of the equator of the glenoid); the long head of the biceps (LHB) will be transposed to the glenoid through the split to provide the sling effect. **Fig. 3-C** Posterior portal view of patient 2 showing the automated shaver (Sh) placed through the split of the SC and (**Fig. 3-D**) used to debride the fibrosis on the bony Bankart lesion to help improve the bone to tendon healing of the transposed LHB to the anterior glenoid rim. BB = bony Bankart, G = glenoid, HH = humeral head, and MGHIL = middle glenohumeral ligament.

Fig. 4
Representation of the posterior portal arthroscopic view of the trans-subscapular transposition of the long head of the biceps using the double pulley on a right shoulder in the beach chair position. **Fig. 4-A** Two knots of the double pulley are tied after all suture limbs were passed through the long head of the biceps (LHB) tendon; (**Fig. 4-B**) the remaining 4 opposing suture limbs are pulled and the LHB tendon reaches the anteroinferior glenoid rim after passing through the subscapularis tendon (SC) split; (**Fig. 4-C**) the dashed line represents the final course of the LHB tendon through and anteriorly to the subscapularis tendon. The opposing 4 suture limbs will each be used to obtain an additional 2 knots to reinforce the fixation of the LHB to the glenoid rim.
Case Report

Three otherwise healthy male patients were referred to our institution after 2 or more episodes of traumatic antero-inferior dislocation of the right dominant shoulder. These patients presented with pain and dysfunction that did not resolve after an adequate shoulder strengthening rehabilitation program. The demographic and clinical characteristics of each patient are presented in Table I. The magnetic resonance imaging (MRI) scans revealed a Bankart and a Hill-Sachs lesion in each patient: patient 1 had a soft-tissue Bankart associated

Fig. 5
Arthroscopic images of the right shoulder of patient 3. Posterior portal view. **Fig. 5-A** Two double loaded all-suture anchors were implanted on the anteroinferior glenoid (G) rim; (**Fig. 5-B**) all the suture limbs were passed through the subscapularis tendon (SC) and through the long head of the biceps (LHB, black arrow); (**Fig. 5-C**) the ablator was used to perform the LHB tenotomy proximally to the most proximal suture fixation point on the LHB (black arrow); (**Fig. 5-D**) the transposed LHB was fixed to the anteroinferior glenoid rim; (**Fig. 5-E**) a suture passer is used to shuttle one suture limb of the all-suture anchor implanted superiorly to the transposed LHB tendon on the glenoid rim; (**Fig. 5-F**) the superior anchor knot is tied with the capsular remnants partially covering the transposed LHB tendon. HH = humeral head.
with a SLAP; patients 2 and 3 had a bony Bankart with less than 25% glenoid bone loss (GBL); each patient had a small-to-medium-sized Hill-Sachs lesion. The GBL was quantified in the sagittal proton density-weighed image using a best-fit circle method with the same equation of the arthroscopic bare spot technique, and the Hill-Sachs lesion was quantified in the axial T2-weighed image (Figs. 1 and 2). The measurements were determined by an experienced shoulder surgeon (C.d.C.A.). The concept of glenoid track in bipolar lesions was used to estimate the risk of engagement of the Hill-Sachs lesion.

After discussing the risks and benefits of isolated Bankart repair, Bankart repair with Hill-Sachs remplissage, Latarjet, and DAS in this setting, the patients opted for DAS and were enrolled in a single-arm prospective study on DAS designed by the authors and approved by the local institutional review board and ethics committee of Centro Hospitalar de Lisboa Ocidental (Approval Number: 08112018HSFX2, “Comissão de Ética para a Saúde do CHLO”), registered a priori and publicly accessible at the site of the US National Library of Medicine, ClinicalTrials.gov (ClinicalTrials.gov ID: NCT03693716, https://clinicaltrials.gov/ct2/show/NCT03693716?cond=NCT03693716&draw=2&rank=1).

**Surgical Technique**

Each patient underwent surgery by an experienced shoulder surgeon (C.d.C.A) in the beach-chair position under general anesthesia. The shoulder was surgically draped, and the fore-arm was placed in a mechanical arm positioner (AssistArm Surgical Limb Positioner; CONMED) with the shoulder at 70° of elevation and 10° of abduction and in neutral rotation. A posterior shoulder arthroscopic portal was established 2 cm medial and 2 cm inferior to the posterolateral corner of the acromion (soft spot) and a 4-mm and 30° arthroscope was placed through it. The type II SLAP in patient 1 was confirmed using a probe. The shoulder was placed at increased degrees of abduction and external rotation, and an engaging Hill-Sachs lesion was confirmed in patients 2 and 3. The
insufficiency of the anteroinferior glenoid labrum and capsule-ligamentous tissues in all patients was confirmed using a grasper. An anterolateral portal was established from outside-in, distal to the anterolateral aspect of the acromion, using the needle directed laterally to the transverse humeral ligament (THL), parallel and slightly distal to the superior border of the subscapularis. A 3.5 × 135-mm radiofrequency ablator probe (SERFAS Energy 90-S; Stryker) was introduced through the anterolateral portal and was used to cut the THL laterally to the LHB tendon, thereby completely releasing the LHB tendon from the bicipital groove. The subscapularis tendon split was performed using the radiofrequency ablator through the anterior portal after placing a switching stick through the posterior portal to mark the level of the split at the middle third and using the anterolateral portal as a viewing portal with the arthroscope through it (Figs. 3-A and 3-B). After debridement using a 4 × 125-mm automated shaver (Formula Aggressive Plus Cutter; Stryker) (Figs. 3-C and 3-D), two 1.8-mm all-

### TABLE II Stepwise Approach to Dynamic Anterior Stabilization After the First Posterior Viewing Portal Is Placed Through the Soft Spot*

<table>
<thead>
<tr>
<th>Order</th>
<th>Surgical step</th>
<th>Rationale</th>
<th>Pearl</th>
<th>Pitfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anterior portal at the superior border of the lower third of the SC</td>
<td>Working portal, used to place the switching stick to help split the SC, and to place the drilling guide for the glenoid anchors</td>
<td>Correct level of placement helps ensure that the transposed LHB tendon will be fixed at the ideal level, below the equator of the glenoid</td>
<td>Placing this portal too high risks either placing the anchors above the equator or kinking the suture limbs during the shuttling the LHB tendon through the SC split</td>
</tr>
<tr>
<td>2</td>
<td>Cleaning the rotator interval</td>
<td>To ensure adequate visibility to perform the cutting of the THL, SC split, and LHB tendon shuttling steps</td>
<td>Enables an extraarticular view of the THL while the shoulder is in forward flexion, and enables changing the arthroscopic view of the subscapularis tendon from the posterior to the anterolateral portal afterwards, to have a perfect view both of the THL and of the SC split while the switching stick is placed through the posterior portal to help with the split</td>
<td>Inadequate cleaning may lead to poor visibility during the THL cutting and SC split steps and leads to difficult suture management during the shuttling step and to an increased risk of damage of the SC insertion and axillary nerve</td>
</tr>
<tr>
<td>3</td>
<td>Anterolateral portal distal to the level of the superior border of the SC</td>
<td>Working portal used during the THL cutting step, and viewing portal used during the SC split step</td>
<td>Ensures adequate distal access to the THL and visibility during the SC split and LHB tendon shuttling steps</td>
<td>Placing this portal too high risks either not adequately releasing the THL or poor visibility during the SC split</td>
</tr>
<tr>
<td>4</td>
<td>Cutting the THL lateral to the LHB tendon</td>
<td>To completely release the LHB tendon from the bicipital groove</td>
<td>After the LHB tendon subluxates medially, it becomes easier to pass the sutures from the anterior portal using the suture passer; complete release avoids kinking or catching of the LHB tendon at the bicipital groove after the transposition through the SC is performed</td>
<td>Cutting the THL medially risks damage to the SC insertion; incomplete LHB release may cause painful kinking</td>
</tr>
<tr>
<td>5</td>
<td>Passing the sutures through the LHB tendon using a low-profile suture passer and tying 2 double-pulley knots</td>
<td>To ensure the LHB tendon is fixed securely to the anteroinferior glenoid</td>
<td>The nitinol needle of the suture passer is not aggressive to the LHB tendon; suture management is easier if the LHB is intra-articularly shuttled while pulling the opposing sutures limbs and pushing each double-pulley knot simultaneously</td>
<td>Avoid using bulky suture piercers to pass sutures through the LHB because the LHB may be damaged and tear longitudinally</td>
</tr>
</tbody>
</table>

*LHB = long head of the biceps, SC = subscapularis tendon, and THL = transverse humeral ligament.*
### TABLE III Clinical Results*

<table>
<thead>
<tr>
<th>Patient</th>
<th>6 mo Postoperative</th>
<th>12 mo Postoperative</th>
<th>Shoulder Abduction Strength (kg)</th>
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<tbody>
<tr>
<td></td>
<td>FF (°)</td>
<td>Abd (°)</td>
<td>ER (°)</td>
</tr>
<tr>
<td>1</td>
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<td>2</td>
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<td>3</td>
<td>175</td>
<td>170</td>
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*Abd = active abduction, ER = active external rotation, FF = active forward flexion, IR = active internal rotation, and WOSI = Western Ontario Shoulder Index. †Measured as the highest vertebral body that the patient’s thumb could reach without pain: lateral thigh = 0, buttock = 1, sacrum = 2, lumbar = 3, T12 = 4, and T7 = 5. ‡0 to 2,100, consists of 21 items; the patient is asked to grade the function of a specific item on a horizontal visual analogue scale from 0 to 100; for every scale range provided, higher values represent a worse outcome. §0 to 100 points; for every scale range provided, higher values represent a better outcome.

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Magnetic resonance images of the 3 patients at the final follow-up showing the successfully healed transposed long head of the biceps tendon. Course of the long head of the biceps tendon (white arrows) through the subscapularis tendon on the axial and coronal proton-density or T2-weighted slices of (Fig. 7-A) patient 1, (Fig. 7-B) patient 2, and (Fig. 7-C) patient 3.
suture double-loaded anchors (Y-Knot Flex; CONMED) were implanted on the anteroinferior glenoid rim, through the subscapularis split, one at the 4 o’clock and the other at the 5 o’clock position (right shoulder) approximately 5-mm apart. All limbs of the sutures from the glenoid anchors were passed through the LHB tendon with the suture passer (Spectrum; CONMED) according to the following sequence: first, 2 limbs of the sutures from the superior glenoid anchor were passed distal to the bicipital anchor on the labrum and a surgeon’s knot and 2 half-stitches were tied to be used as the first double-pulley knot; second, approximately 5-mm distal to this knot, 2 limbs of the sutures from the inferior glenoid anchor were passed, and the second double-pulley knot was tied (Fig. 4). Using the ablator, the LHB was tenotomised distally to the bicipital anchor on the superior labrum and proximally to the first double-pulley knot. The opposing limbs of the sutures from the glenoid anchors were pulled while the 2 double-pulley knots were used to push the tenotomised LHB through the subscapularis tendon split. The suture limbs were tied once the LHB reached the anteroinferior glenoid rim (Fig. 5). One 1.3-mm all-suture single-loaded anchor (Y-Knot Flex; CONMED) was implanted between the 4 and 5 o’clock positions, adjacent to the superior half of the transposed LHB tendon on the glenoid rim, and a simple knot was tied to plicate the remaining anteroinferior labrum or capsular tissue onto the glenoid rim. In addition, one 1.3-mm all-suture single-loaded anchor (Y-Knot Flex; CONMED) was implanted on the superior glenoid rim and a mattress suture technique was used to repair the SLAP in patient 1 (Fig. 6). The average operative time was 87 minutes (101, 81, and 79 minutes, respectively). A stepwise approach to DAS and the pearls and pitfalls of the procedure are summarized in Table II.

Rehabilitation
For the first 3 weeks, the patients wore a sling and were instructed to remove it several times a day to perform active assisted shoulder elevation, external and internal rotation, and active-assisted elbow flexion exercises. Use of the sling was subsequently diminished, and all patients underwent the same shoulder rehabilitation protocol with progressive passive and active range of motion exercises. Until 6 weeks postoperatively, active resistant elbow exercises were not allowed. Until 3 months postoperatively, active-resistant elbow flexion exercises were restricted to 2 kg. After 6 months, a return to full sports activity was progressively allowed.

Clinical and MRI Outcomes
As shown in Table III, there was a mean improvement of 840.3 in the Western Ontario Shoulder Instability Index (WOSI) and of 68.3 in the Rowe score at 12 months postoperative. The MRI scans at the 6- and 12-month follow-ups revealed that the transposed LHB tendon had successfully healed to the anteroinferior glenoid rim (Fig. 7). There were no postoperative complications. All patients returned to their recreational level of sporting activity, had no apprehension or instability, and were very satisfied with the procedure at the 12-month follow-up.

Discussion
The main findings of this case report are that DAS using the all-arthroscopic double-pulley, and all-suture anchor fixation method produced substantial improvements in the WOSI and Rowe score from the preoperative to the 12-month postoperative follow-up in each of the 3 patients, with successful healing of the transposed LHB. The improvement in the Rowe score reported for each patient is considered clinically important considering the minimal clinically important difference (MCID), defined as the smallest change in an outcome measurement that signifies an important improvement in a symptom after arthroscopic repair of anterior shoulder instability: 9.7 for the Rowe score. The improvement in the WOSI in each patient was substantially higher than the MCID determined for the WOSI by the distribution-based and the effect size-based methods, which are 60.7 and 151.9, respectively. These excellent clinical and imaging results suggest that the technical modification of DAS described in this case report may be a safe and reliable treatment option for chronic anteroinferior glenohumeral instability with Bankart and Hill-Sachs lesions with limited (≤13.5%) or subcritical (≥13.5%) GBL, and types I-III SLAP lesions but may be contraindicated in patients with critical (≥25%) GBL or LHB tears.

References


