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Effects of type II SLAP lesion repair techniques on the vascular supply of the long head of the biceps tendon: a cadaveric injection study

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Background: One option for the treatment of type 2 superior labral anterior to posterior (SLAP) lesions is arthroscopic repair. However, the fact that the vascular supply of the proximal long head of the biceps tendon (LHBT) arises from the soft tissue near the SLAP repair site must also be considered. The aims of this study were to evaluate the vascular channel of the proximal long head biceps tendon and to compare potential damage to the vascular supply with alternative SLAP techniques.
Methods: Forty-five fresh cadaveric shoulders were divided into 3 groups: 9 shoulders each for the normal group and the created SLAP group, and 27 shoulders for the repaired SLAP group. SLAP group shoulders were repaired using one of 3 techniques: 2 anchors with simple sutures, 1 anchor with double sutures, or 1 anchor with a horizontal mattress suture. India ink was then injected into the acromial branch of the thoracoacromial artery. The proximal LHBT was resected for a histologic cross-sectional study. The intratendinous vascular distance was measured and compared among the groups.
Results: The vascular supply of the proximal LHBT arises from soft tissue lying anterior and dorsal to the tendon origin. In the normal shoulders, the average intratendinous vascular distance was 16.9 ± 1.5 mm (95% confidence interval: 15.8-18.1). A comparison of non-repaired SLAPs with each of the repair techniques found that using 2 anchors with simple sutures showed no significant difference in vascular distance ($P = .716$), whereas the other techniques showed a significant disruption of the blood supply. The differences in vascular distance among the 3 repair techniques were statistically significant ($P = .0001$).
Conclusions: The main vascular supply of the proximal LHBT comes from the anterior-dorsal direction. Some SLAP repair techniques can disrupt vascularization; however, the technique using 2 anchors with simple sutures, 1 anchor 3 mm anterior to the anterior border and 1 at the posterior border of the tendon, can preserve the vascularization of the LHBT.
Level of evidence: Anatomy Study; Cadaver Dissection

Keywords: SLAP; SLAP repair; long head biceps tendon; vascular supply; biceps tendon rupture

Approval for this study was received from the Research Ethics Committee of the Faculty of Medicine, Chiang Mai University (Study code: ORT-2558-03276).

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Superior labral tears from anterior to posterior (SLAP) lesions are a common pathology in overhead-throwing athletes.[2,11] The condition was first described by Andrews et al[2] in 1985 as an injury of the superior aspect of the glenoid labrum near the insertion of the long head of the biceps tendon (LHBT). Snyder et al[16] classified SLAP lesions into 4 types. Type II SLAP lesions are the most common and involve

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detachment of both the superior labrum and the biceps anchor from the glenoid, a clinically significant pathology in throwing athletes.[11] Arthroscopic assisted SLAP repair is one of the options for the treatment of this condition. Even though this procedure is declining in popularity,[5] in younger patients (<35 years), this procedure is still considered a good option.[17,18] Many SLAP repair techniques have been described, but there is no consensus regarding which technique represents the standard or the best method.[13,14] Many studies have been conducted on the biomechanics of SLAP repair,[6,7,12] but none have focused on the biology of the repair site.

The LHBT is one of the most frequently spontaneously ruptured tendons in the body, with a reported incidence ranging from 2% to 6% of all tendon rupture cases.[3,8] Hypotheses regarding the causes of this event include degenerative change, mechanical impingement, and insufficient vascular supply.[9,15,19] Many studies have included descriptions of the vascular supply of the LHBT.[1,4,9,10,15] Cheng et al[4] described how the thoracoacromial branch of the axillary artery runs across the osteotendinous junction and supplies 1.2-1.5 cm of the LHBT from its origin located near the SLAP repair site. We postulated that the SLAP repair process might affect the vascularization of the LHBT and could lead to pathology in the hypovascular area. The objectives of this study were to study the vascular supply of the LHBT and to evaluate the effect on the vascular supply of proximal LHBT resulting from different SLAP repair techniques. Our hypothesis was that the SLAP repair technique could affect the vascularity of the LHBT.

Materials and methods

This experimental study was conducted using shoulders from 45 fresh cadavers. Sample size estimation was performed using a comparison of 2 means sample size formula in a pilot study. Dye was injected into each shoulder, and the intratendinous vascular distance of the proximal part of the LHBT was measured during histologic examination.

Cadaveric grouping and preparation

Fresh cadaveric shoulders were used in this study, all from cadavers donated to the university hospital. Inclusion criteria included good soft tissue condition, no previous surgery around the shoulder or clavicle, and no pathologic condition, for example, a previous SLAP lesion, degeneration, or rupture of the LHBT. We excluded specimens with a torn rotator cuff, arthritis change, and previous operations. Forty-five shoulders (aged 50-90, average 74 years; 29 males and 16 females; 24 left and 21 right shoulders) were randomized into 3 groups (Fig. 1).

Group 1, consisting of 9 specimens, was used to study the normal blood supply of the proximal part of the LHBT. In group 2, also consisting of 9 specimens, a SLAP lesion was created using a surgical blade no. 15 to detach the superior labrum starting 5 mm from the anterior border of the LHBT to a point 5 mm posterior to the posterior border of the LHBT. SLAP lesions were created in the 27 specimens in group 3; then SLAP repair was performed using an anchor suture (Fastak 2.8 mm; Arthrex, Naples, FL, USA), all done by a single surgeon. Three different techniques were used for each of 9 shoulders (groups 3.1, 3.2, and 3.3) as follows (Fig. 2).

Group 3.1: Two single-loaded suture anchors with simple sutures. The first anchor was placed 3 mm anterior to the anterior border and the second at the posterior border of the LHBT.

Group 3.2: One double-loaded suture anchor with double simple sutures. The first stitch was at the anterior border of the LHBT, and the second was at the posterior border of the LHBT.

Group 3.3: One single-loaded suture anchor with a horizontal mattress suture. Both limbs of the suture were passed from the inferior surface to the superior surface of the labral lesion and were tied dorsally.

In the techniques used with groups 3.2 and 3.3, the anchor was located at the center of the root of the biceps.

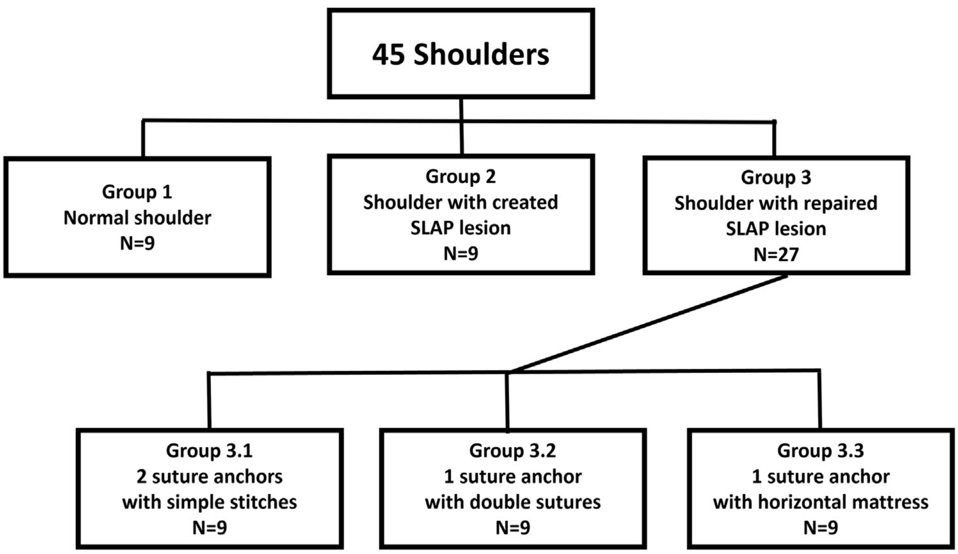

Figure 1 Diagram of cadaveric grouping. *SLAP*, superior labral anterior to posterior.

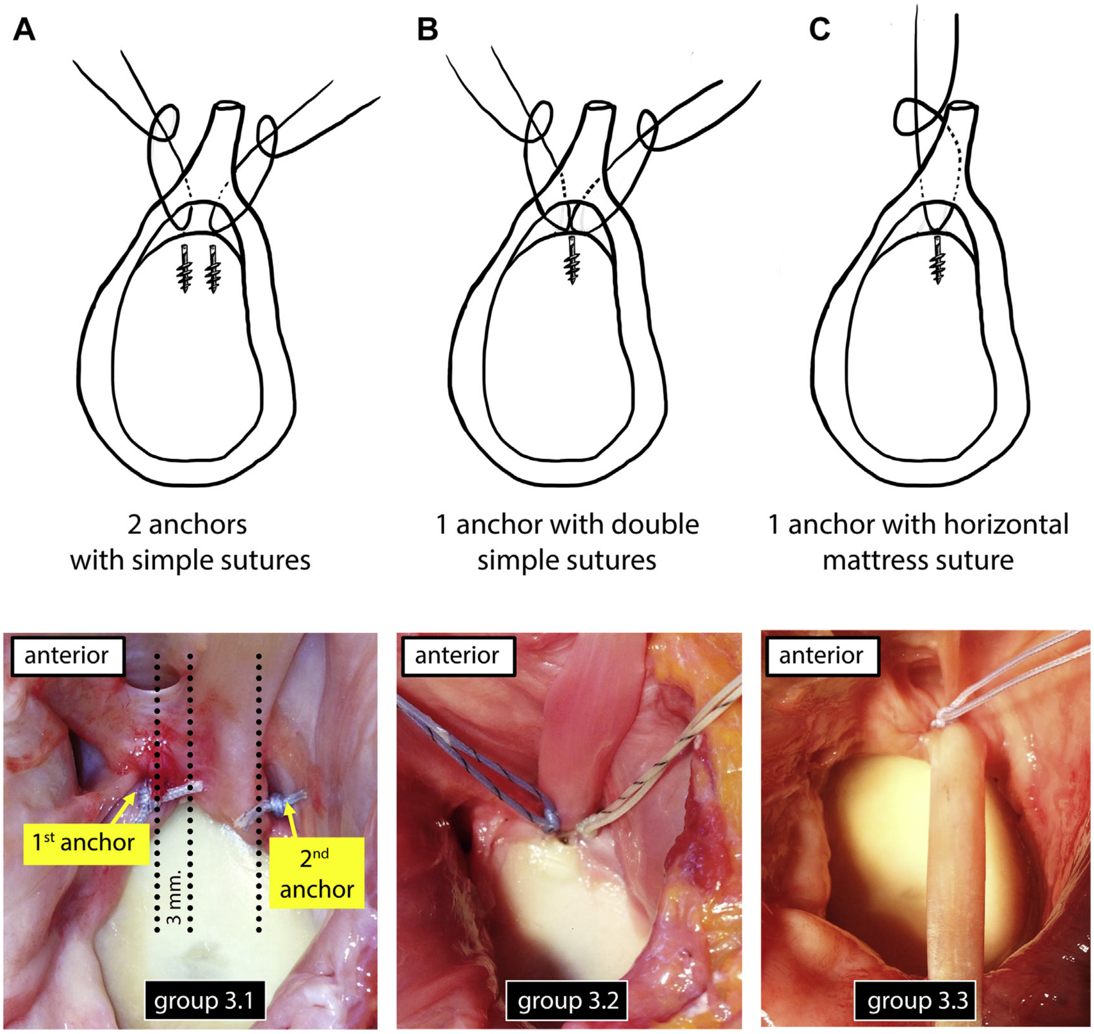

Figure 2 Three techniques of superior labral anterior to posterior repair using anchor sutures: (**A**) group 3.1: 3 anchors with simple sutures, (**B**) group 3.2: 1 anchor with double simple sutures, and (**C**) group 3.3: 1 anchor with a horizontal mattress suture.

Vascular injection technique

First, the acromial branch of the thoracoacromial artery was identified by dissection at the infraclavicular area. After ligation of the other branches of the thoracoacromial artery (pectoral, clavicular, and deltoid) and the distal axillary artery, 20 mL of 25% (V/V) green India ink solution (Kenton; Kenton Intertrade Co., Ltd.) was injected into the proximal axillary artery via an extension tube at a pressure of 120 mm Hg (Fig. 3). All cadaveric shoulders were warmed with a heated blanket for 1 hour before the injection.

Histologic examination

The proximal part of the LHBT was harvested 3 cm from the tendon origin for histologic examination. The tendon was embalmed in 10% buffered formalin for 24 hours. There were 2 steps in the preparation of the tendon cross-section (Fig. 4). First, the tendon was sectioned at 5-mm intervals, proximal to distal, after which dehydration and paraffinization into 6 paraffin blocks were performed. Hematoxylin and eosin (H&E) stain was applied to the tissue at the proximal surface of each paraffin block. In the second step, the distalmost block that was positive for India ink was used to perform 1-mm step sectioning and H&E staining again. Microscopic examination was conducted by 2 doctors who agreed on the most distal slide that was positive for India ink intravascularly.

Data analysis

The primary outcome measurement in this study was the intratendinous vascular distance that was calculated from the LHBT origin to the most distal millimeter of the H&E slide that was microscopically positive for intravascular India ink. Data analysis involved 3 separate comparisons.

Comparison I was done between groups 1 and 2 to demonstrate that our method of creating the SLAP lesion had not disturbed the vascular supply.

Comparison II was done between group 2 and each of the 3 group 3 subgroups to evaluate the effect of the different SLAP repair techniques by comparing the unrepaired SLAP lesions and the post-repair SLAP lesions.

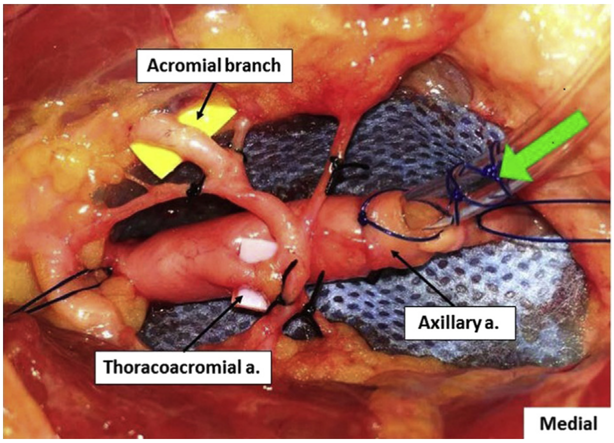

Figure 3 Example of the axillary artery with ligation of branches with the exception of the acromial branch of the thoracoacromial artery. Injection of India ink was done via an extension tube.

Comparison III involved comparison of the 3 SLAP repair techniques.

Student's *t*-test was used for comparisons I and II, and the Kruskal-Wallis *H* test for comparison III. Statistical significance was set at a *P* value of <.05. Sample size estimation was performed using a comparison of 2 means sample size formula in a pilot study.

Results

Macroscopic examination of the normal 9 shoulders (group 1) identified the intratendinous vascular supply of the proximal LHBT, which presented with the green India ink solution at the anterodorsal surface (Fig. 5). The vascular supply mainly originated from soft tissue lying anterior to the tendon origin. Short branches of the intratendinous vessels were observed at the dorsal surface of the tendon in 4 specimens; however, intratendinous vessels could not be seen clearly in some tendons.

Under microscopic examination, the intravascular dye could be seen in all 9 normal shoulders (100%) (Fig. 6). The mean intratendinous vascular distance in the normal LHBT shoulders was 16.9 ± 1.5 mm (95% confidence interval: 15.8-18.1).

In group 2 (the created SLAP shoulders), the average intratendinous vascular distance was 16.0 ± 4.0 mm (95% confidence interval: 12.9-19.0), which was not significantly different from the normal shoulders (*P* = .5030) (Table I).

In groups 3.1, 3.2, and 3.3, the experimental groups in which SLAP lesions were created and repaired using 3 different techniques, the average intratendinous vascular distances were 16.6 ± 3.4, 1.0 ± 2.1, 0.6 ± 1.7 mm, respectively. A comparison of the intratendinous vascular distance in the nonrepaired SLAP (group 2) and each of the repair techniques using intravascular India ink for measuring distance found that the technique using 2 anchors with simple sutures (group 3.1) showed no significant difference (*P* = .716), whereas groups 3.2 and 3.3 showed a significant difference in the intratendinous vascular distance (*P* = .0002) (Table I). During the histologic examination of the proximal LHBT, intravascular India ink was detected in all 9 shoulders in group 3.1 (100%) but was detected in only 2 of 9 shoulders in group 3.2 (22%) and in 1 of 9 shoulders in group 3.3 (11%). A comparison among the 3 techniques of SLAP repair found a significant difference in the intratendinous vascular distance (*P* = .0001) (Table II).

Discussion

This study of the LHBT demonstrated that the hypovascular zone starts from 1.2 to 3 cm from the tendon origin. In the first group of cadaveric specimens, we were able to show that a constant blood supply of the LHBT came through the anterodorsal surface of the LHBT to within 3 mm of the anterior border of the tendon and extended approximately 16 mm; it was the main blood supply of the proximal part of the tendon. Although there is no consensus on the treatment of SLAP lesions, the preservation of the biology of the surrounding tissue is key for successful surgery. In this study, we raised a concern regarding whether the vascular supply of the tendon might be affected by the specific surgical procedure. Biceps

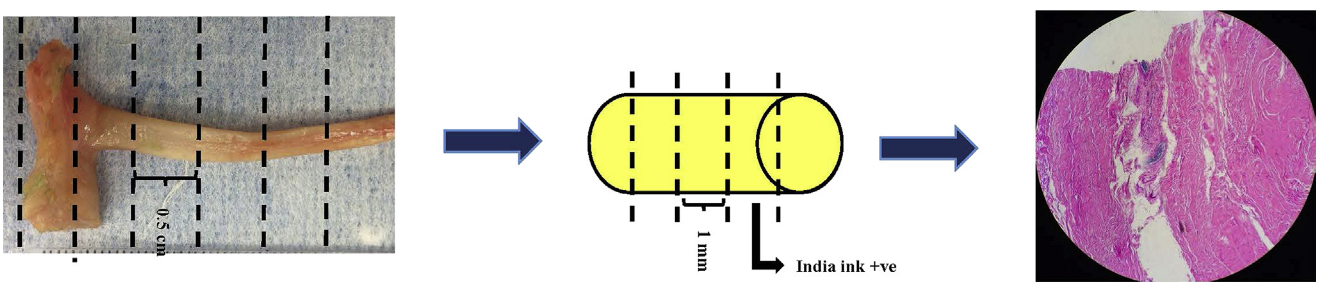

Figure 4 Diagram of 2-step technique of creating tendon cross-sections. Thirty millimeters of the labral-biceps tendon was harvested and then cut into 5-mm lengths. The most distal section (*yellow*) that contained dye was identified and then cut into 1-mm sections. Histologic study was performed using hematoxylin and eosin stain.

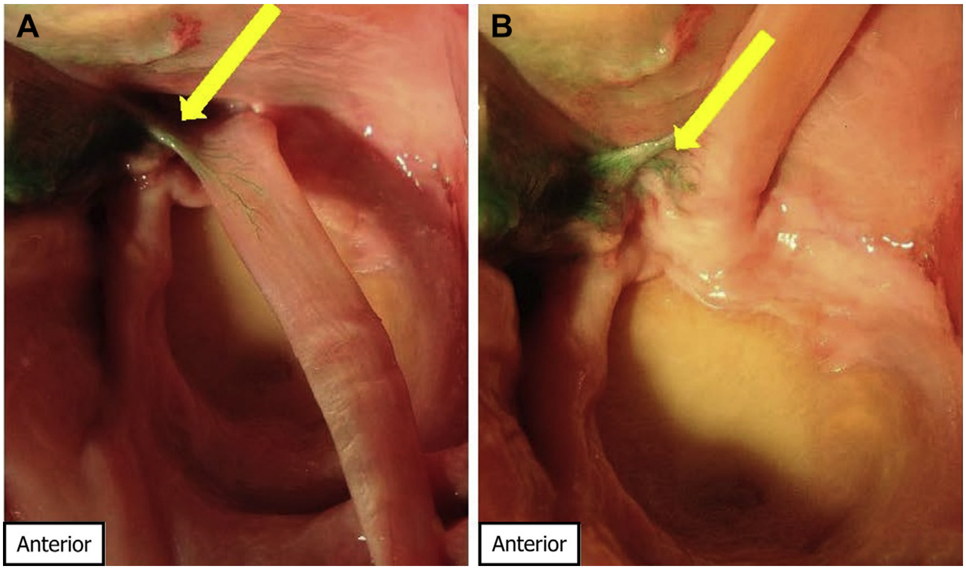

Figure 5 The vascular supply of the proximal long head of the biceps tendon of the left shoulder presented with the *green* India ink solution seen macroscopically at the anterodorsal surface.

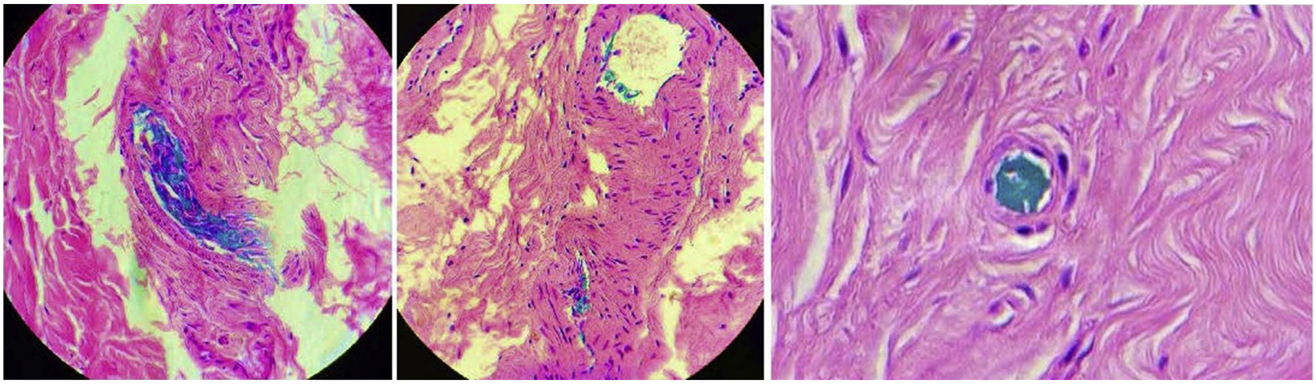

Figure 6 Tissue retrieved from the long head of the biceps tendon (LHBT). Microscopic examination of the LHBT showing intravascular dye, indicating the continuity of the vascular supply of the tendon.

tendon pathology can be the result of several factors. Insufficient vascular supply is one of the most frequently mentioned theories.[9,10,15] For that reason, in any shoulder surgery procedure, we recommend preserving the soft tissue in this area to avoid the destruction of vascular channels of the LHBT.

In the group 2 shoulders by using a controlled operation to create a SLAP lesion and conducting a vascular injection study, we demonstrated that the way the SLAP lesion was created did not disturb the vascular channel. This result was

Table I Comparison of the intratendinous vascular distance between normal shoulders (group 1), created SLAP shoulders (group 2), and repaired SLAP shoulders (groups 3.1-3.3) using Student's *t*-test

Intratendinous vascular distance	Mean ± SD (mm)	*P* value
Group 1	16.9 ± 1.5	.5030
Group 2	16.0 ± 4.0	
Group 3.1	16.6 ± 3.4	.7162*
Group 3.2	1.0 ± 2.1	.0002*
Group 3.3	0.6 ± 1.7	.0002*

SLAP, superior labral anterior to posterior; *SD*, standard deviation.
* Compared with group 2.

Table II Comparison of repair techniques (groups 3.1, 3.2, and 3.3) using the Kruskal-Wallis *H* test

Intratendinous vascular distance	Mean ± SD (mm)	*P* value
Group 3.1	16.6 ± 3.4	.0001
Group 3.2	1.0 ± 2.1	
Group 3.3	0.6 ± 1.7	

SD, standard deviation.

then used to compare different surgical techniques to study the effect of repairs on vascularity. This study did not, however, investigate the vascular condition in a real SLAP type II patient. To the best of our knowledge, there have been no published studies on the vascular system of a SLAP patient.

Differences in the effect of alternative repair techniques on the vascular system were the main focus of this study. In group 3.1, we used 2 single-loaded suture anchors. We put the anchors in separately, one more than 3 mm in front of the biceps root and the second behind the biceps root; then we sutured using a simple stitch. In this group, the vascularity of the LHBT was preserved as there was no significant difference when compared with group 2, indicating that the repair technique did not disturb the vascular channel. This result is supported by the anatomic findings in our group 1 study, which showed that the vessel comes from the anterodorsal part of the LHBT.

In the other 2 subgroups, groups 3.2 and 3.3, significant disruption of the blood supply to the LHBT was found. That disruption was not caused by the number of suture anchors but rather by the location of the sutures, that is, at the biceps root. When we closed the SLAP lesion, the sutures were put in near the biceps root. That resulted in vascular strangulation of the biceps as demonstrated by the fact that no dye could be detected more than a few millimeters beyond the biceps root. On the basis of these findings, we concluded that different SLAP repair techniques can have a negative effect on vascularity. Thus, the occurrence of ligament rupturing might be explained by the devascularization of the tendon. Choosing an appropriate technique can help preserve the blood supply of the LHBT. The location of the placement of the anchor and the suture configuration are very important. Usually, a SLAP lesion extends posterior, in which case devascularization should not be a concern. Occasionally, however, a SLAP lesion will extend anteriorly. In that event, the potential impact of repair on the vascular channel becomes very important. Anecdotally, we had a patient who had a ruptured long head of the biceps tendon after a SLAP repair. The method of repair was similar to the configuration in group 3.3.

Recommendations to avoid the devascularization of the LHBT while repairing SLAP lesions are as follows:

- First, try to avoid creating any iatrogenic injury to the dorsal or the anterior soft tissue where the blood supply enters the LHBT.
- Second, position anchors appropriately (Fig. 7).
  - Anterior lesion: The anterior anchor should be placed at least 3 mm anterior to the anterior border of the tendon.
  - Posterior lesion: The posterior anchor can be safely placed at any location posterior to the border of the tendon.

A limitation of this study is that it was performed using cadaveric specimens, which might not reflect the situation in a living patient. Thus, it is not possible to conclude definitively that some repair techniques can cause a rupture of the LHBT, but only that the specific repair technique used can influence vascularity. Further study in living patients should be conducted to determine the effect of different techniques on clinical outcomes.

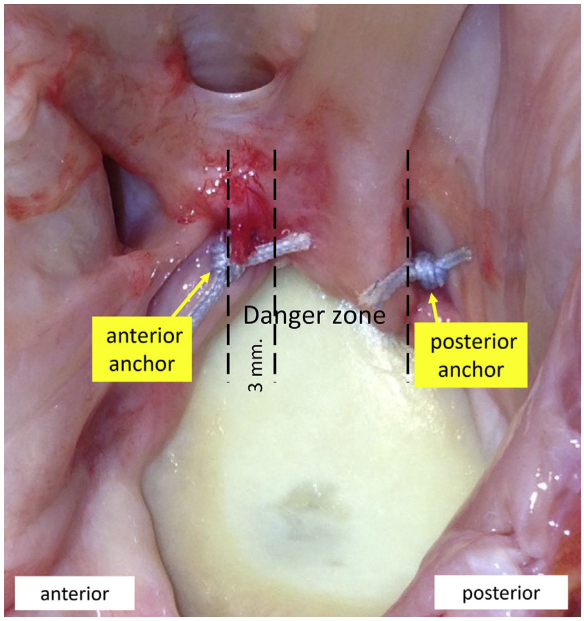

Figure 7 The "Danger zone"—avoid placing anchor sutures here.

Conclusions

Blood supply of the proximal part of the LHBT comes from the anterodorsal surface of the tendon and supplies approximately 1.6 cm of the proximal part of the tendon. To avoid the devascularization of the proximal part of the LHBT, repairs of a SLAP lesion should avoid placing anchors and tying knots on the vascular channel. Posterior anchors can be placed starting just behind the LHBT insertion. If an anterior anchor is required, it should be placed at least 3 mm away from the anterior border of the LHBT.

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References

1. Alashkham A, Alraddadi A, Felts P, Soames R. Blood supply and vascularity of the glenoid labrum: its clinical implications. J Orthop Surg (Hong Kong) 2017;25:2309499017731632. https://doi.org/10.1177/2309499017731632
2. Andrews JR, Carson WG Jr, McLeod WD. Glenoid labrum tears related to the long head of the biceps. Am J Sports Med 1985;13:337-41.
3. Chen CH, Hsu KY, Chen WJ, Shih CH. Incidence and severity of biceps long head tendon lesion in patients with complete rotator cuff tears. J Trauma 2005;58:1189-93. https://doi.org/10.1097/01.ta.0000170052.84544.34
4. Cheng NM, Pan WR, Vally F, Le Roux CM, Richardson MD. The arterial supply of the long head of biceps tendon: anatomical study with implications for tendon rupture. Clin Anat 2010;23:683-92. https://doi.org/10.1002/ca.20992
5. Cvetanovich GL, Gowd AK, Frantz TL, Erickson BJ, Romeo AA. Superior labral anterior posterior repair and biceps tenodesis surgery: trends of the American board of orthopaedic surgery database. Am J Sports Med 2020;48:1583-9. https://doi.org/10.1177/0363546520913538
6. DiRaimondo CA, Alexander JW, Noble PC, Lowe WR, Lintner DM. A biomechanical comparison of repair techniques for type II SLAP lesions. Am J Sports Med 2004;32:727-33. https://doi.org/10.1177/0095399703258751
7. Domb BG, Ehteshami JR, Shindle MK, Gulotta L, Zoghi-Moghadam M, MacGillivray JD, et al. Biomechanical comparison of 3 suture anchor configurations for repair of type II SLAP lesions. Arthroscopy 2007;23:135-40. https://doi.org/10.1016/j.arthro.2006.10.018
8. Habermeyer P, Magosch P, Pritsch M, Scheibel MT, Lichtenberg S. Anterosuperior impingement of the shoulder as a result of pulley lesions: a prospective arthroscopic study. J Shoulder Elbow Surg 2004;13:5-12. https://doi.org/10.1016/j.jse.2003.09.013
9. Hermann B, Steiner D. Arterial supply of the human long biceps tendon. Acta Anat 1990;137:129-31.
10. Kolts I, Tillmann B, Liillmann-Rauch R. The structure and vascularization of the biceps brachii long head tendon. Ann Anat 1994;176:75-80.
11. Morgan CD, Burkhart SS, Palmeri M, Gillespie M. Type II SLAP lesions: three subtypes and their relationships to superior instability and rotator cuff tears. Arthroscopy 1998;14:553-65.
12. Panossian VR, Mihata T, Tibone JE, Fitzpatrick MJ, McGarry MH, Lee TQ. Biomechanical analysis of isolated type II SLAP lesions and repair. J Shoulder Elbow Surg 2005;14:529-34. https://doi.org/10.1016/j.jse.2004.11.002
13. Parnes N, Ciani M, Carr B, Carey P. The double-pulley anatomic technique for type II SLAP lesion repair. Arthrosc Tech 2015;4:e545-50. https://doi.org/10.1016/j.eats.2015.05.009
14. Prodromos CC, Finkle S, Dawes A, Baik JY. Treatment of type two slap lesion with anatomic suture anchor repair without biceps tenotomy or tenodesis. Open Orthop J 2018;12:324-30. https://doi.org/10.2174/1874325001812010324
15. Refior H, Sowa D. Long tendon of the biceps brachii: sites of predilection for degenerative lesions. J Shoulder Elbow Surg 1995;4:436-40.
16. Snyder SJ, Karzel RP, Del Pizzo W, Ferkel RD, Friedman MJ. SLAP lesions of the shoulder. Arthroscopy 1990;6:274-9.
17. Sullivan S, Hutchinson ID, Curry EJ, Marinko L, Li X. Surgical management of type II superior labrum anterior posterior (SLAP) lesions: a review of outcomes and prognostic indicators. Phys Sportsmed 2019;47:375-86. https://doi.org/10.1080/00913847.2019.1607601
18. Wang KK, Yalizis M, Hoy GA, Ek ET. Current trends in the evaluation and treatment of SLAP lesions: analysis of a survey of specialist shoulder surgeons. JSES Open Access 2018;2:48-53. https://doi.org/10.1016/j.jses.2017.12.002
19. Wilk KE, Reinold MM, Dugas JR, Arrigo CA, Moser MW, Andrews JR. Current concepts in the recognition and treatment of superior labral (SLAP) lesions. J Orthop Sports Phys Ther 2005;35:273-91. https://doi.org/10.2519/jospt.2005.35.5.273