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Original Article

Bi-Cortical transhumeral drilling for biceps tenodesis — Is it safe?

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A R T I C L E I N F O

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A B S T R A C T

Background: Biceps tenodesis is an effective procedure performed to treat shoulder pain originating from the long head biceps tendon. In arthroscopic biceps tenodesis unicortical drilling of the humerus is more commonly practiced as it is considered safe to the vital structures lying posterior to the proximal humerus. Many surgeons are wary of the bi-cortical approach as it poses a risk to these vital structures. The aim of this study was to establish whether bi-cortical drilling in proximal humerus is safe or not. Our second purpose was to find a safe zone (if any) for bi-cortical drilling if bi-cortical drilling is safe.
Methods: This study is a descriptive study conducted on cadaveric shoulders. Bilateral shoulders and arms of ten fresh-frozen cadavers (mean age 77.7 y) were dissected. Four landmarks in the dissected humerus were identified. They were superior margin of the bicipital groove, center of the bicipital groove, upper and lower border of pectoralis major insertion. Bi-cortical trans-humeral pinning was done in the humerus at all these points so that the pin exited through the posterior cortex of the humerus. The shortest distance between the pin and the nearest vital structure namely axillary nerve, radial nerve, articular surface of the humeral head, and cephalic vein was calculated from each fixed landmark.
Results: We established that bi-cortical drilling in proximal humerus was safe. The safe zone established for bi-cortical biceps tenodesis is at the middle of bicipital groove, which is 18.00 ± 4.02 mm inferior to the groove's upper border. The boundaries of the safe zone lie 9.39 mm superiorly and 9.40 mm inferiorly to the middle of the bicipital groove.
Conclusion: The center of the established safe zone for bi-cortical trans-humeral pinning was 18 mm inferior to the bicipital groove's upper border.

1. Introduction

Lesions in the long head biceps tendon are common causes of shoulder pain. Arthroscopic biceps tenodesis is an accepted procedure to treat such conditions. Currently, different methods of biceps tenodesis are used, depending on the surgeon's preference. Most surgeons prefer the unicortical approach, while others prefer bicortical drilling method. Both these techniques have their own advantages and drawbacks.

Unicortical approach is more widely used because of safety concerns to the posterior vital structures. However, there are reports on incidences of post-operative humeral fractures after unicortical drilling.[1,2] This is because in the unicortical approach the surgeon needs to drill a larger hole (≈8 mm) diameter in the humerus. On the other hand, in bicortical approach, a smaller hole (≈5 mm) diameter is drilled in the humerus.[3] Thus the risk of the complication of fracture of the proximal humerus is reduced in bicortical drilling technique. Moreover, the bi-cortical technique allows the surgeon to attain the required tension of the biceps tendon. Once the end of the biceps tendon is passed through the humerus, the surgeon can modify its tension until it is deemed optimal. Hence, the biceps tendon in its new placement would be more firm and stable, which is also reported by a biomechanical strength study.[4] Nonetheless, the main drawback of the bi-cortical technique is that it may injure structures located posterior to the proximal humerus. Moreover, there is no consensus in terms of site of tenodesis in the humerus. In this study, we propose to evaluate the posterior structures at risk in bi-cortical *trans*-humeral drilling and establish a safe zone for biceps tenodesis, if any.

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2. Materials and methods

2.1. Study design

A descriptive study on the anatomy of ten cadaveric shoulders was conducted. The calculated sample size was 10 by using the formula for quantitative variable.

$$\text{Sample Size} = \frac{{Z_{1-\alpha/2}}^2 SD^2}{d^2} = \frac{2.58^2(3.5)^2}{3^2} = 9.0601 \approx 10$$

Hence, a sample size of 10 is appropriate for evaluating the distance from a vital structure to the nearest pin at 1% of type 1 error and precision of 3 mm from the average and the standard deviation, based on a similar study,[5] is 3.5 mm. The inclusion criteria were fresh cadavers. The sampling method used was purposive sampling, which involved selecting the ten fresh-frozen cadavers who had informed consent documents for medical research at our hospital. The exclusion criteria were cadaver who underwent major surgery to shoulder or has major distortion of shoulder anatomy and cadavers without a consent form to perform medical practices. In this study, ten fresh-frozen cadaveric shoulders were used, which exceeds the calculated sample size.

2.2. Surgical dissection

Bilateral shoulders and arms of ten fresh-frozen cadavers were used for the present study. Skin incision was made from the coracoid process to the insertion of deltoids. The cephalic vein was the first structure identified as it was most superficial. Delto-pectoral approach was used to dissect the proximal humerus and the incision was then extended further to mid arm. As the cephalic vein lies at the delto-pectoral interval, it was placed at the lateral border of the pectoralis major muscle (its natural position) to prevent excessive displacement of the cephalic vein. Four surgical landmarks were identified: (1) proximal end of bicipital groove, (2) middle of bicipital groove, (3) upper border of pectoralis major insertion, and (4) lower border of pectoralis major insertion (Fig. 1). Then other vital structures were identified. There were four structures in total: (1) axillary nerve, (2) radial nerve, (3) articular surface of humeral head, and (4) cephalic vein (Fig. 2).

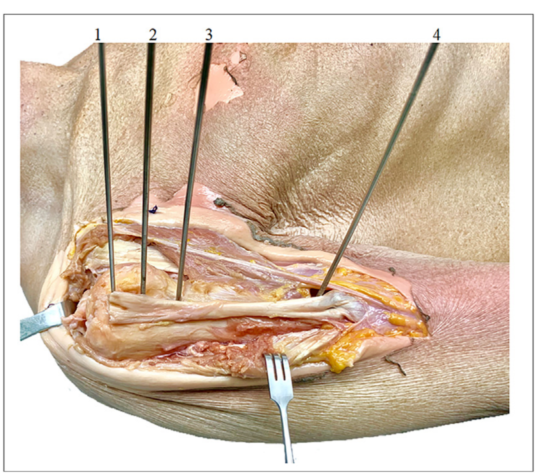

Fig. 1. Shows the dissection of the right proximal shoulder in a cadaver. Four pins are seen in the figure numbered from 1 to 4. These pins are marked for the location.
Number 1 – Pin at proximal end of bicipital groove
Number 2 – Pin at middle of bicipital groove
Number 3 – Pin at proximal border of pectoralis major muscle
Number 4 – Pin at distal border of pectoralis major muscle.

2.3. Bicortical drilling and measurement

Once all four surgical landmarks and all four vital structures were marked, the humeral length was measured from the proximal end of bicipital groove to the lateral epicondyle using a digital Vernier Caliper. Then, bicortical drilling at each surgical landmark was performed perpendicular to the humeral shaft using a Dyonic power drill and Beath pin was passed. Pinning was executed with the elbow flexed 90°, internally rotated 30°, and abducted 30° to simulate intra-operative drilling position of the arm. Drilling was stopped the moment the Beath pin pierced the posterior cortex. The displacement in-between the four entrance pins were measured. The displacement from the vital structures to the nearest pin was measured in reference to the humeral axis. All the measurements were assessed by two assessors independently. One assessor was an intern in sports medicine department at our hospital and another assessor was a fellow in sports medicine. Cephalic vein, which lies medially to all four entrance pins, was measured horizontally to each entrance pin. The axillary nerve was measured vertically to the exit pin at upper border of pectoralis major insertion. Positive (+) and negative (−) signs were used to represent the cranial and caudal direction, respectively. Similarly, the articular surface of humeral head was measured vertically using + and − signs to indicate the direction involved. The anterior cartilage was measured from its most inferior border to the entrance pin at the proximal end of bicipital groove. The posterior cartilage was measured from its most inferior border to the exit pin at the proximal end of bicipital groove. Lastly, the radial nerve was measured horizontally to the exit pin at lower border of pectoralis major insertion.

3. Results

The humeral length histogram did not have a normal deviation and was skewed to the right. Therefore, its data was represented by a median and interquartile range. For the remaining categories, there were 40 data values in each category as there were 2 assessors measuring 20 shoulder samples. An average value between the 2 assessor measurements was calculated, resulting in 20 summarized statistics per category. Each category was further classified into each direction involved. For each direction, its average and standard deviation was calculated and was reported in the form of 'mean' ± 'standard deviation'. IBM SPSS Statistics program was used to calculate the intraclass correlation, which determines the interobserver reliability between the two assessors. A two-way mixed model was used because the assessors were fixed but the shoulder subjects were chosen randomly. The intraclass correlation uses an absolute agreement definition to represent consistency between the two assessors.

The baseline characteristics of the samples in the study are summarized in Table 1.

The intraclass correlation coefficient was 0.998, which is a strong indicator that there is consistency between the findings of the two assessors. The strong correlation gives validity to data values.

In 75% of the samples, the axillary nerve was located 10.55 ± 2.87 mm inferior to the exit pin at upper border of pectoralis major. In 20% it was located 9.13 ± 6.15 mm superior to the supra-pectoral exit pin and in the remaining 5% it came in contact (0.00 mm) with the pin.

The radial nerve was 10.41 ± 2.18 mm medial to the exit pin at lower border of pectoralis major. The entrance pin at upper border of bicipital groove was consistently inferior to the anterior articular surface of humeral head and on an average, they were 11.39 ± 2.22 mm apart. However, 80% of exit pins at upper border of

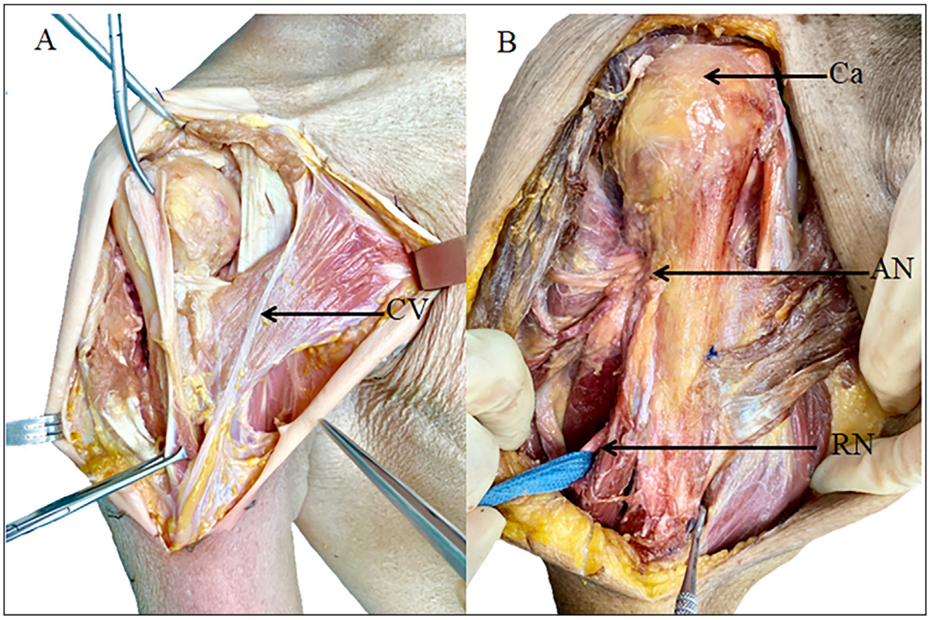

Fig. 2. Shows dissection of right proximal humerus in a cadaver. Fig. 2A shows cephalic vein (CV) at the lateral border of pectoralis major. Fig. 2B shows cartilage (Ca) of the head of the humerus, axillary nerve (AN) and radial nerve (RN).

Table 1
Shows the baseline characteristics of the sample cadavers.

Characteristics	Summarized Statistics
Age (at the time of death)	77.7 ± 12.37 Years
Gender	Male: 7
	Female: 3
Nationality	Thai
Humeral Length	27.96 (26.25–28.63) cm

bicipital groove either touched or punctured through the posterior articular surface of humeral head. 35% came in contact (0.00 ± 0.00 mm), while 45% penetrated 8.61 ± 3.15 mm into the cartilage.

Lastly, the cephalic vein was 38.59 ± 5.89 mm, 30.50 ± 4.88 mm, 21.36 ± 4.55 mm, and 13.04 ± 3.13 mm medial to the entrance pins at upper border of bicipital groove, middle of bicipital groove, upper border of pectoralis major, and lower border of pectoralis major, respectively. These results are summarized in Table 2 and Fig. 3.

With the assumption that entrance pins are in the same horizontal plane, the safe zone was established. The safe zone for bicortical biceps tenodesis is at the middle of bicipital groove, which is 18.00 ± 4.02 mm inferior to the groove's upper border. The boundaries of the safe zone lie 9.39 mm superiorly and 9.40 mm inferiorly.

4. Discussion

Although the bicortical technique has many advantages, many research studies recommend caution in the bicortical technique mainly because it poses a risk to adjacent structures. In the subpectoral approach, it risks injury to the radial nerve[6] while in the suprapectoral approach, it risks injuring the axillary nerve.[7] Ding et al.[5] suggested that the safest biceps tenodesis placement was at the inferior aspect of the bicipital groove as it avoids penetrating both the axillary and radial nerve. However, further studies should be conducted before establishing this “safe” landmark as a standard due to difficulty in locating the inferior aspect of bicipital groove solely from surface anatomy. Furthermore, because an error of less than 4° is expected during drilling[8], establishing a safe zone would be more fitting. Other limitations in the study include the small sample size of 6 male cadaveric shoulders. In our study, a safe zone

Table 2
Shows the displacement of the vital structures from the nearest pin.

Vital Structures	Direction	Frequency (in 20 samples)	Mean ± SD (mm)
Axillary Nerve	Superior to Suprapectoral Exit Pin	4	9.13 ± 6.15
	At Suprapectoral Exit Pin	1	0.00
	Inferior to Suprapectoral Exit Pin	15	10.55 ± 2.87
Radial Nerve	Medial to Subpectoral Exit Pin	20	10.41 ± 2.18
Posterior Cartilage	Superior to Exit Pin (Proximal End of Bicipital Groove)	4	5.21 ± 4.93
	Directly at Exit Pin (Proximal End of Bicipital Groove)	7	0.00 ± 0.00
	Inferior to Exit Pin (Proximal End of Bicipital Groove)	9	8.61 ± 3.15
Anterior Cartilage	Superior to Entrance Pin (Proximal End of Bicipital Groove)	20	11.39 ± 2.22
Cephalic Vein	Medial to Entrance Pin (Proximal End of Bicipital Groove)	20	38.59 ± 5.89
	Medial to Entrance Pin (Middle of Bicipital Groove)	20	30.50 ± 4.88
	Medial to Entrance Pin (Upper Border of Pectoralis Major Insertion)	20	21.36 ± 4.55
	Medial to Entrance Pin (Lower Border of Pectoralis Major Insertion)	20	13.04 ± 3.13

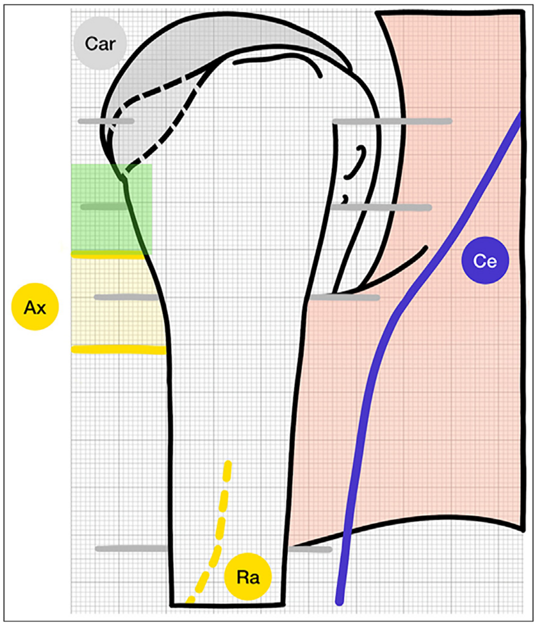

Fig. 3. Shows a schematic diagram of the pins and their relation to the posterior vital structures. It shows the variability of the extension of the posterior articular cartilage (Car) marked with two black dash lines. It also shows the variability in the position of axillary nerve (Ax) marked with two horizontal yellow lines. Cephalic vein (Ce) is represented by a blue line running vertically and radial nerve (Ra) is shown in vertical yellow line in the lower part of the figure. The pins are depicted by four transverse grey lines at the specific positions. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

in terms of avoiding injury to posterior structures was established in reference to the proximal end of the bicipital groove, which is in between the greater and lesser tubercles. This study was conducted using a larger sample size.

The main limitation in this study is the accuracy of the safe zone boundaries as it was calculated under the assumption that all anterior and posterior drill holes are in the same horizontal plane and are perfectly parallel to each other (Fig. 4). This assumption was made because although the structures and measurements were at the posterior aspect, the safe zone must be established at the anterior aspect. However, Brioschi et al. stated that less than a 4° error can be made in bicortical drilling regardless of experience. This gives room for improvement in future studies that may be conducted in a more accurate manner.

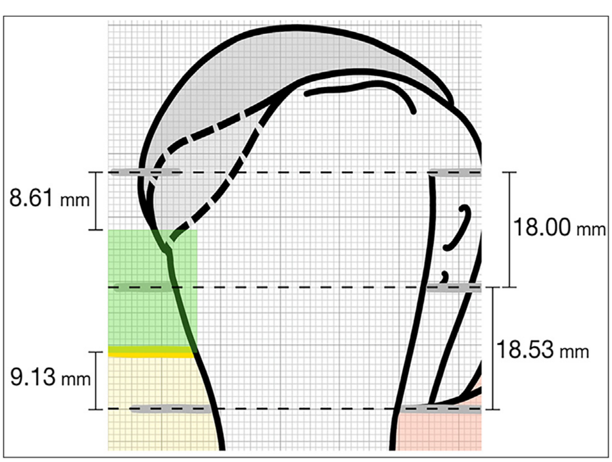

Fig. 4. Shows the safe zone for bicortical drilling. It extends proximally from the distal end of posterior articular cartilage of the humeral head and ends distally at the proximal position of the axillary nerve. Thus the safe zone lies at the center of the bicipital groove extending approximately one cm proximal and distal (shaded green area). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

This study can also be improved in terms of precision. The center of the safe zone is established in reference to the middle of the bicipital groove. However, the definition of the middle of bicipital groove is extremely imprecise, and has a standard deviation of 4.02 SDs. From the collected data, the middle of bicipital groove location ranges from 9.47 mm to 26.78 mm inferior to the upper border of bicipital groove. Even then, the validity of the safe zone is not impaired because all 40 data values fall within the borders of the established safe zone.

Moreover, there are also limitations regarding the safe zone borders. To our knowledge, there is no current literature on how to establish the safe zone in regards to avoiding vital structures. Therefore, determination of the appropriate proximity of the safe zone border to the vital structures is out of scope of this research.

Another major limitation in this study is the subjects used. This study uses fresh-frozen cadaveric shoulders as subjects in hope that they can accurately represent shoulders in living humans. The fact that this study is not an in vivo study also limits the data from assessing the functions and long-term effects of the safe zone. This study concludes that the safe zone provides low risks in injuring adjacent structures, but in practice it may have other complications, such as a higher incidence of muscle cramps, residual pain, or poor function which need to be assessed by further studies.

Furthermore, there were only four vital structures identified. However, the rotator cuff muscles were also penetrated during the drilling process. Rotator cuff injury cannot be avoided as the muscles circumferentially surround the humeral head. Fortunately, the injury is not significant as the Beath pin has a diameter of only 2.4 mm, which is compared to the muscle and is unlikely to affect function. The nerves and vessels, however, can cause major complications when injured.

Another obstacle encountered in this study was the mobility of the cephalic vein. In contrast to the other three vital structures, the cephalic vein was most mobile. The cephalic vein was attached to the muscle underneath at the deltopectoral junction. Deltopectoral approach was used and the cephalic vein was placed at the lateral border of the pectoralis major muscle. However, we understand there are chances that the vein could have been displaced a little from its position. This variability certainly impacts the validity of the collected data as this study is based on accurate placement and location. However, we attempted to reduce the effect of this variable factor by measuring the cephalic vein at its most natural position (lateral border of pectoralis major muscle).

5. Conclusion

The safe zone for bicortical biceps tenodesis pinpoints at the middle of bicipital groove, which is 18.00 mm inferior to the groove's upper border. The boundaries of the safe zone lie 9.39 mm superiorly and 9.40 mm inferiorly. With clinical application of the safe zone, surgeons can conduct bicortical biceps tenodesis at the center of the safe zone with the reassurance that posterior structures will not be injured.

Conflicting interests

None.

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Ethical approval

Human Research Ethics Committee of Thammasat University Hospital has approved the study.

Study number

MTU-EC-OT-0-087/62.

Informed consent

NA.

Authorship

Conception and design of study: Dr Bancha Chernchujit; acquisition of data: Dr Amolnat Chiarnpattanodom, Dr Sumit Agrawal; analysis and/or interpretation of data: Dr Bancha Chernchujit, Dr Amolnat Chiarnpattanodom,Dr Sumit Agrawal, Drafting the manuscript: Dr Amolnat Chiarnpattanodom,Dr Sumit Agrawal, revising the manuscript critically for important intellectual content: Dr Bancha Chernchujit, Approval of the version of the manuscript to be published (the names of all authors must be listed):Dr Bancha Chernchujit, Dr Amolnat Chiarnpattanodom,Dr Sumit Agrawal.

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References

1. Sears BW, Spencer EE, Getz CL. Humeral fracture following subpectoral biceps tenodesis in 2 active, healthy patients. *J Shoulder Elbow Surg*. 2011 Sep;20(6): e7–e11. https://doi.org/10.1016/j.jse.2011.02.020.
2. Dein EJ, Huri G, Gordon JC, et al. A humerus fracture in a baseball pitcher after biceps tenodesis. *Am J Sports Med*. 2014 Apr;42(4):877–879. https://doi.org/10.1177/0363546513519218.
3. Snir N, Hamula M, Wolfson T, et al. Long head of the biceps tenodesis with cortical button technique. *Arthrosc Tech*. 2013 Mar 25;2(2):e95–e97. https://doi.org/10.1016/j.eats.2012.12.001.
4. Buchholz A, Martetschläger F, Siebenlist S, et al. Biomechanical comparison of intramedullary cortical button fixation and interference screw technique for subpectoral biceps tenodesis. *Arthroscopy*. 2013 May;29(5):845–853. https://doi.org/10.1016/j.arthro.2013.01.010.
5. Ding DY, Gupta A, Snir N, et al. Nerve proximity during bicortical drilling for subpectoral biceps tenodesis: a cadaveric study. *Arthroscopy*. 2014 Aug;30(8): 942–946. https://doi.org/10.1016/j.arthro.2014.03.026.
6. Dickens JF, Kilcoyne KG, Tintle SM, et al. Subpectoral biceps tenodesis: an anatomic study and evaluation of at-risk structures. *Am J Sports Med*. 2012 Oct;40(10):2337–2341. https://doi.org/10.1177/0363546512457654.
7. Lancaster S, Smith G, Ogunleye O, et al. Proximity of the axillary nerve during bicortical drilling for biceps tenodesis. *Knee Surg Sports Traumatol Arthrosc*. 2016 Jun;24(6):1925–1930. https://doi.org/10.1007/s00167-014-3214-z.
8. Brioschi V, Cook J, Arthurs GI. Can a surgeon drill accurately at a specified angle? *Vet Rec Open*. 2016 Jul 14;3(1), e000172. https://doi.org/10.1136/vetreco-2016-000172.