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Original Article

Radiological study of the Asian coracoid process and clavicle: Implications for coracoclavicular ligament reconstruction

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ABSTRACT

Purpose: Iatrogenic coracoid and clavicle fracture is a known complication of drilling bone tunnels during anatomic coracoclavicular ligament reconstruction (ACCR). This study aims to measure the dimensions of coracoid process and clavicle in an Asian population to evaluate the suitability of drilling coracoid and clavicle tunnels for ACCR in Asians.

Methods: Width measurements of 196 coracoids and 189 clavicles were obtained after reviewing all computed tomography (CT) scans of the shoulder performed over a 6 years period. Coracoid measurements were made on the CT slice which showed the maximum cross sectional width of the coracoid base. Medial to lateral measurements of the coracoid width were taken on an axial view, 4 mm above the identified junction of the coracoid base and glenoid base. Antero-posterior clavicle width was measured through a point directly above the midpoint of the coracoid and perpendicular to the long axis of the clavicle.

Results: The overall mean coracoid width was 14.8 mm ± 2.54 mm (range 9.2–23.3 mm) and clavicle width was 17.1 mm ± 2.72 mm (range 11.1–25.3 mm).

Conclusion: The Asian coracoid process is smaller than its Western equivalent. More research is required to validate this conclusion as no cadaveric studies with equivalent measurement techniques have been performed on Asians. Given the potentially narrower dimensions of the Asian coracoid process, extra precautions are required to minimize the risk of iatrogenic coracoid and clavicle fractures.

Introduction

Much controversy and debate exists regarding the optimal surgical treatment of high-grade acromioclavicular (AC) joint instability.[1–4] No recently described surgical technique has shown to be conclusively superior due to the heterogeneity of described techniques and inconsistent outcome measures in the current literature.

Currently there has been a shift interest towards anatomic coracoclavicular ligament reconstruction (ACCR)[5] due to perceived biomechanical and clinical advantages. In this procedure, bone tunnels are drilled through the coracoid process and distal clavicle to allow for the passage of a ligament substitute or cortical fixation button (CFB). Consequently, complications unique to ACCR such as intraoperative coracoid and clavicle fractures have been reported.[6–9] Several recent cadaveric biomechanical studies have shown that eccentrically placed bone tunnels, larger drill diameters and multiple drill tunnels all cause an increased likelihood of iatrogenic coracoid and clavicle fracture.[10–15]

Our study aims to measure the coracoid process and clavicle in an Asian population, providing the baseline anatomical data to evaluate the suitability of drilling coracoid and clavicle tunnels for ACCR in Asians. To the best of our knowledge, few anatomical studies relating to the Asian clavicle and coracoid have been performed. We are not aware of any studies which specifically concerning ACCR in Asians.

Methods

All computed tomography (CT) scans of the shoulder done at an acute tertiary hospital over 6 years were reviewed by 2 independent observers (qualified orthopaedic surgeons). All patients

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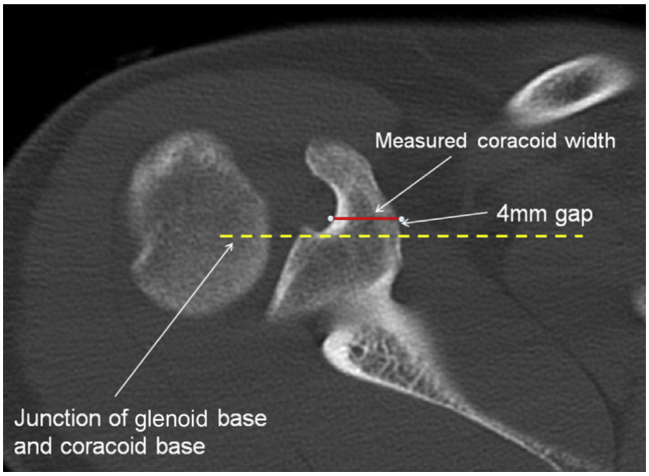

Fig. 1. Coracoid width measurement technique on axial computed tomography slice of shoulder.

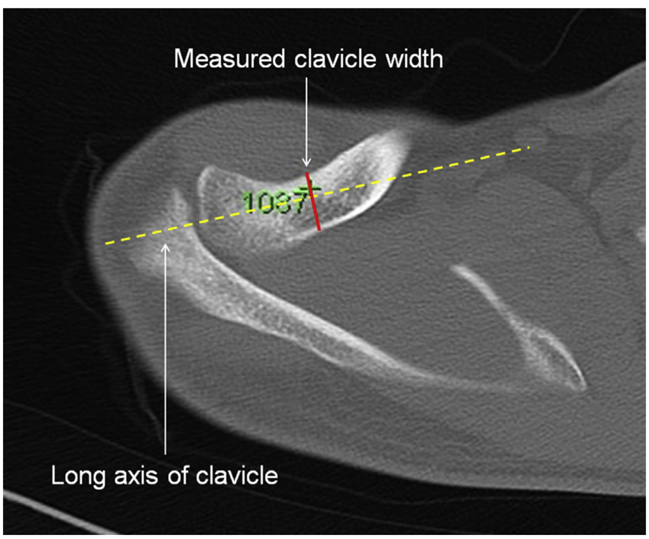

Fig. 2. Clavicle width measurement technique on axial computed tomography slice of shoulder.

included were above 18 years of age. Altogether 196 coracoid width measurements (132 male, 64 female) and 189 clavicle width measurements (127 male, 62 female) were obtained. Exclusion criteria included coracoid fractures, clavicle fractures, previous surgery to the coracoid and/or clavicle and scans which due to limitations of imaging software, precluded accurate measurement of the coracoid and/or clavicle dimensions.

Coracoid measurements were made on the CT slice which showed the maximum cross sectional width of the coracoid base. Medial to lateral measurements of the coracoid width were taken on an axial view, 4 mm above the identified junction of the coracoid base and glenoid base, which approximates the location of a centrally placed coracoid tunnel (Fig. 1). The antero-posterior clavicle width was measured through a point directly above the midpoint of the coracoid and perpendicular to the long axis of the clavicle (Fig. 2).

Results

The overall mean coracoid width was 14.8 mm ± 2.54 mm (range 9.2–23.3 mm) and clavicle thickness was 17.1 mm ± 2.72 mm (range 11.1–25.3 mm). Detailed data for gender are shown in Table 1.

Discussion

Surgical treatment of the acute (within 3–4 weeks) AC joint separation includes primary AC joint fixation and fixation between the clavicle and coracoid process. Primary AC joint fixation can be achieved using pins, K-wires or hook plates across the AC joint. Fixation between the clavicle and coracoid process includes rigid fixation using coracoclavicular (CC) screws and non-rigid fixation using suture anchors and CFB. CC cerclage using tendon autografts or synthetic ligamentous substitutes can also be performed.

Ligamentous reconstruction is usually performed for chronic or subacute (more than 3–4 weeks) high grade AC joint instability. Allowing for individual technical variations, ligamentous reconstruction can be broadly classified into non-anatomic procedures, e. g. Weaver-Dunntype procedures[16] or ACCR.[5]

Much controversy and debate exists regarding the optimal surgical treatment of high-grade AC joint instability.[1–4] Because of the heterogeneity of the various described techniques and inconsistent outcome measures across different studies, no recently described surgical technique has been shown to be conclusively superior.

Primary AC joint stabilization using K-wires and pins has largely fallen out of favour due to unacceptable risk of potentially life-threatening hardware migration, loss of reduction and various hardware-related complications including failure, pain and impingement. Although good outcomes have been reported with CC screws[17] and hook plates,[18,19] the risk of postoperative hardware failure, impingement,[20] discomfort, osteolysis[21] and need for subsequent hardware removal has limited their popularity.

Although good clinical outcomes have been reported after modified Weaver-Dunn procedures with supplemental fixation,[22,23] there has been a shift in interest towards ACCR due to its perceived biomechanical and clinical advantages. It has been suggested that non-anatomical reconstructions lead to residual anteroposterior instability[24] and that the transferred coracoacromial ligament is not strong and stiff enough to replace the native coracoclavicular ligament.[25]

ACCR is a technically demanding procedure with a steep learning curve. Due to a lack of long-term outcome data in the literature, there is no consensus regarding accepted complication rates. The reported short term complication rates are highly variable and mostly derived from case series and isolated case reports. In a series of 59 primary anatomic CC ligament reconstructions using either tendon grafts (TG) or CFB, Martetschläger et al.[7] reported an overall complication rate of 27.1%, with the complication

Table 1
Measurements of 196 coracoid width and 189 clavicle width.

Measurement	Coracoid width (mm)			Clavicle thickness (mm)		
	Total ($n = 196$)	Male ($n = 132$)	Female ($n = 64$)	Total ($n = 189$)	Male ($n = 127$)	Female ($n = 62$)
Mean	14.8 ± 2.54	15.7 ± 2.37	13.0 ± 1.91	17.1 ± 2.72	17.2 ± 2.59	15.5 ± 2.25
Range	9.2–23.3	10.2–23.3	9.2–16.8	11.1–25.3	12.5–25.3	11.1–21.2

Table 2
Previously reported coracoid width measurements.

Study	Year	Reported coracoid width (mm)	Location of measurement	Type of study	Purpose of study
Young et al.[29]	2013	14.1 ± 1.8 (superior) 13.3 ± 1.8 (inferior)	Superior drill hole, inferior drill hole	Coracoid graft for Latarjet procedure	Latarjet procedure
Bueno et al.[30]	2012	14.5 ± 1.9	Point of largest medial to lateral thickness	Cadaveric	Anatomic study
Armitage et al.[31]	2011	15.0 ± 2.2	Not stated	CT-3D reconstruction	Latarjet procedure
Lian et al.[32]	2016	15.3 ± 1.7	Coracoid midpoint	Cadaveric	Latarjet procedure
Terra et al.[33]	2013	21.1 ± 2.0	Coracoid tip	Cadaveric	Latarjet procedure
Rios et al.[34]	2007	24.9 ± 2.5	Coracoid base	Cadaveric	CC ligament reconstruction

rate for the TG and CFB group being 23.1% and 28.2% respectively. One coracoid fracture and two clavicle fractures were reported. Milewski et al.[6] reported a complication rate of 52% in 27 cases of ACCR using a tendon graft passed through a coracoid tunnel or looped around the coracoid base. The coracoid fracture rate was 20% (2/10) in the coracoid tunnel group, while the clavicle fracture rate was 18% (3/17) in the coracoid loop group.[6] In a multicenter case series of 38 patients who underwent ACCR using either a CFB or TG technique, Rush et al.[26] reported an overall complication rate of 42.1% with two coracoid fractures reported. Reported complications include loss of reduction, recurrence of deformity, coracoid fractures, clavicle fractures, infection, adhesive capsulitis, graft failure, clavicular or coracoid osteolysis, hypertrophic distal clavicle, brachial plexus injuries, hardware-related complications and osteoarthritis of the AC joint.

Recent biomechanical studies have provided conclusive evidence that drilling bone tunnels in both the coracoid and clavicle increases the risk of iatrogenic fracture. Martetschläger et al.[10] compared the stability of the coracoid process after an anatomic double tunnel technique using two 4 mm drill holes or a single tunnel technique using either one 4 mm or one 2.4 mm drill hole and concluded that one 2.4 mm drill hole led to less coracoid destabilization than one or two 4 mm drill holes. Campbell et al.[27] showed that a 4.5 mm tunnel in the coracoid provided greater strength for cortical button fixation than a 6 mm tunnel, and that centrally placed tunnels provided more strength than eccentrically placed tunnels. Dumont et al.[28] studied the effects of tunnel drilling and tenodesis screw placement on load to failure in the distal clavicle models and concluded that use of clavicle tunnels in ACCR significantly reduces the load required to cause clavicle fractures. Spiegl et al.[14] compared clavicle strength following preparation with either 2.4 mm drill tunnels for CFB passage or 6 mm drill tunnels for hamstring tendon graft passage and found that the a larger drill tunnel diameter caused significantly more reduction of clavicle strength and that relative tunnel width (quotient of tunnel diameter and clavicle width) correlated highly with strength reduction. However, due to a lack of long term outcome data, the effect of smaller tunnels on long term ACCR failure rates is still uncertain. Furthermore, there are no clear guidelines for maximum safe tunnel diameter or maximum relative tunnel width as postulated by Spiegl et al.[14]

In the current literature, there is a distinct lack of anatomical studies describing the anatomy of the clavicle and coracoid process with specific regard to ACCR. Most of the reported coracoid width measurements are specific to the Latarjet procedure for treatment of glenohumeral instability. The reported coracoid width is summarized in Table 2.[29–34]

Rios et al.[34] performed a dry osteology study of 120 cadaveric clavicles and scapulae to define the anatomy specific to ACCR and determined that the mean medial to lateral width of the base of the coracoid was 24.9 mm. In our study, the measured coracoid base width was 14.8 mm, significantly smaller than this reported value raising the possibility that the Asian coracoid is narrower than its Western counterpart. In an anatomic study of 30 Mongolian male cadaveric shoulders, Lian et al.[32] reported that the mean coracoid tip width was 13.6 mm ± 2.0 mm, while the mean coracoid midpoint width was 15.3 mm ± 1.7 mm. Although the coracoid base was not measured in this study, the reported dimensions are again significantly smaller than those reported by Rios et al.,[34] supporting this conclusion. To our knowledge, we were unable to identify any anatomical studies of the clavicle which utilized comparable measurement techniques.

We acknowledge that our study has several limitations. While all the patients in our study were of Asian ethnicity, there was an insufficient number of CT scans to recreate an accurate representation of our local population demographics. The majority of these scans were performed in a setting of Acute Trauma and Sports Injuries, hence young, male patients were over-represented while older, female patients were under-represented. Although our measurement technique has not been validated by other studies, we felt that it most suitably addresses the anatomic considerations faced by a surgeon who is performing ACCR. It is impossible to determine if radiological studies underestimate the true width of the coracoid base compared to cadaveric studies, as no cadaveric studies of the Asian coracoid process which utilize comparable measurement techniques have been reported in the current literature. It was challenging to determine the exact measurement landmarks across all scans due to the complex 3D anatomy of the clavicle and coracoid and the limited resolution provided by standard CT scan image slices.

In conclusion, our data suggests that the Asian coracoid process is smaller than its Western equivalent, but more research is required to validate this conclusion as no cadaveric studies with equivalent measurement techniques have been performed on Asians.

Given the potentially narrower dimensions of the Asian coracoid process, extra precautions should be taken in order to minimize the risk of iatrogenic coracoid and clavicle fractures during ACCR. We would suggest routine preoperative measurement of the coracoid base on axillary view shoulder radiographs. Preoperative CT scans of the shoulder can be considered if the coracoid and clavicle dimensions remain in doubt. Should the coracoid base prove to be too narrow, suture tapes or tendon grafts can be looped around the coracoid base, avoiding coracoid bone tunnels altogether. Bone tunnel diameter should be minimized and central tunnel placement ensured through routine use of intraoperative fluoroscopy.

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Nil.

Ethical Statement

This study has been approved by the local ethics committee.

Declaration of Competing Interest

Authors declared no potential conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cjtee.2019.05.007.

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