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Distribution and Morphological Measurement of Bony Spurs on the Coracoid Process in a Chinese Population

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Statistical Analysis C
Data Interpretation D
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Background: There are few studies on distributions or morphological measurements for bony spurs form at the attachment points of the ligaments and tendons on the coracoid process. The aim of this study was to investigate their most common sites and morphological characteristics, and to propose possible reasons.

Material/Methods: Scapulae with bony spurs on the coracoid process were selected from 377 intact and dry Chinese scapulae. The distribution, height, and transverse and longitudinal diameter of the bony spurs were measured in each coracoid process.

Results: We selected 71 scapulae, 36 left and 35 right, that had bony spurs, from 377 scapulae. The bony spurs were most commonly located at the attachment point of the superior transverse scapular ligament (STSL) (31, 23.66%), while the trapezoid ligament (TL) accounted for the smaller proportion (8, 6.11%). The TSL was the highest, with the minimum transverse and longitudinal diameter, while the TL had the greatest transverse and longitudinal diameters. Only the TSL and TL had a statistically significant difference between the left and the right bony spur regarding the longitudinal diameter ($P<0.05$).

Conclusions: Bony spurs are more likely to form at the attachment points of ligaments and tendons on the coracoid process, which has a greater risk of traction injuries or attachment points avulsion fractures.

MeSH Keywords: **Anatomic Variation • Anatomy • Scapula**

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Background

The coracoid process is an important anatomic structure on the scapula, which maintains the stability of shoulder joints by the association of tendons and ligaments on itself with the surrounding structures [1]. There are 3 tendons and 4 ligaments attached to the coracoid process. The 3 tendons are the pectoralis minor tendon (PMT), the coracobrachialis tendon (CBT), and the short head of the biceps brachii muscles tendon (SHBBMT), and the 4 ligaments are the superior transverse scapular ligament (STSL), coracoclavicular ligament (CCL), coracoacromial ligament (CAL), and coracohumeral ligament (CHL). By participating in the composition of the coracoacromial arch [2] and the superior shoulder suspensory complex (SSSC) [3], these structures together maintain the stability and activity of shoulder joints. However, due to biomechanical, immunological, and genetic factors, as well as direct or indirect injuries, including traction injuries of tendons or ligaments and attachment points avulsion fractures on the coracoid process, bony spurs can form at these attachment points of ligaments and tendons.

Research on the anatomical structure and morphometry of the coracoid process, which is the basis of the present study, is basically complete. The scapula is a complex anatomic unit [4,5], and one of the most important clinical parts of the scapula is the coracoid process [6], which has been a research area of interest for many researchers [7–9]. Gumina et al. [6] reported that the morphometry of the coracoid process showed differences in shape, length, and direction in an Italian population. Gallino et al. [10] studied its length in an Egyptian skeletal collection, which was extremely variable. Fathi et al. [11] conducted research on anatomic variation in morphometry in an Asian population. Nevertheless, we found no other studies investigating the formation of bony spurs on the coracoid process, not to mention the distribution and morphological measurement.

In fact, many studies have found that, with the gradually growth of bony spurs, aseptic inflammation can be caused by foreign matter and chemical stimulation, which produces acute shoulder pain in patients, with congestion and edema symptoms. The symptom of pain can also be caused by the friction between surrounding tissues and the calcification during exercise, and it is aggravated by rubbing and mechanical stimulation, especially when the shoulder is subjected to abduction and rotation [12,13]. Once the bony spur is formed, it cannot be eliminated by conservative treatments such as local injection of nonsteroidal anti-inflammatory drugs (NSAIDs), glucocorticoids, or topical shock waves, which can only relieve some symptoms [14,15]. In severe cases, they can be removed by surgery. However, the effects of these methods are often less than satisfactory, perhaps due to the lack of understanding of the distribution and cause of bone spurs. Safer and more effective treatment is expected to appear in clinical practice [16–18]. Early diagnosis and prevention are even more important. To achieve these objectives, it is necessary to determine the distribution, morphological characteristics, and possible causes of the formation of bony spurs, providing an anatomical basis and serving as important prophase research.

The present study was primarily designed to investigate the distribution and morphological characteristics of the formation of bony spurs on the coracoid process by measurement and analysis of specimen data, and to discuss their possible causes based on this information. In addition, our study was conducted in a Chinese population, in which such research has been lacking.

Material and Methods

Ethics statement

All procedures were approved by the Ethics Committee of the Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University (No. SWMCTCM2017-0701).

Subjects

We obtained 377 intact and dry Chinese scapulae from the Department of Anatomy, School of Basic Medical Science, Southern Medical University, China, selecting scapulae with 1 or more bony spurs on the coracoid process by visual inspection. The identities (sex and birth details) of these specimens were unknown.

Anatomical observation

The distribution, height, and transverse and longitudinal diameter of bony spurs were measured in each coracoid process. Furthermore, morphological features of bony spurs were observed and recorded in all coracoid processes.

Measurement methods

The specimens were fixed on the measuring platform during observation and measurement. The investigator, from the Department of Clinical Anatomy, and who had engaged in anatomical work for more than 5 years, measured the distribution, height, and transverse and longitudinal diameters of the bony spurs. He repeated each of the measurements 3 times. The results were averaged and recorded. The distance was measured with a Vernier caliper (the minimum scale was 0.02 mm; China National Machinery Import & Export Corp, Beijing, China). The morphometric measurements were as follows:

Height: the distance between the highest point and the base of the bony spur;

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Table 1. The location, frequency, and size of the bony spurs (mean ±SD).

Distribution*	Frequency	Height (mm)	Transverse diameter (mm)	Longitudinal diameter (mm)
TSL	23.66 (31)[d,e,f]	3.36±2.78	3.52±1.14[a,b,c,d,e,f]	1.90±0.72[b,c,d,e]
CAL	19.08 (25)[e,f]	2.62±0.81	6.40±2.63	3.19±1.92[b]
PMT	19.08 (25)[e,f]	2.46±0.89	8.58±2.36[e]	5.72±2.63[d,e]
CL	13.74 (18)	1.96±0.74	7.46±1.35	4.94±1.73[d,e]
CBT	11.45 (15)	2.69±1.16	6.91±2.18	3.37±0.63
SHBBMT	6.87 (9)	2.49±0.60	5.90±1.17	3.36±0.60
TL	6.11 (8)	2.51±1.29	9.09±2.52	5.96±2.54

TSL – transverse scapular ligament; CAL – coracoacromial ligament; PMT – pectoralis minor tendon; CL – conoid ligament; CBT – coracobrachialis tendon; SHBBMT – short head of the biceps brachii muscles tendon; TL – trapezoid ligament. [a] P<.05 *vs.* CAL; [b] P<.05 *vs.* PMT; [c] P<.05 *vs.* CL; [d] P<.05 *vs.* CBT; [e] P<.05 *vs.* SHBBMT; [f] P<.05 *vs.* TL. * Data of the size are shown as the mean ± standard deviation; data of the frequency are shown as the% (N).

Transverse diameter: the maximum length of bony spur parallel to the central axis of the coracoid process;

Longitudinal diameter: the maximum length of bony spur perpendicular to the central axis of the coracoid process.

Statistical analysis

We performed Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov statistical tests to determine adherence to the normal distribution of each measurement. In addition, the Fisher F test was used to determine the equality of variances in each set of measurements. One-way ANOVA was used to compare types, except for frequency data. The frequency analysis was performed using binomial distribution of non-parametric tests. All hypothesis tests were carried out with a 5% significance level, and their respective descriptive levels (P value) are given. Hypotheses with P value <0.05 were rejected. Statistical analysis was performed using IBM SPSS version 23.0.

Results

We selected 71 specimens that had 1 or more bony spurs on the coracoid process from 377 scapulae, accounting for 18.83%. These specimens included 36 left and 35 right scapulae, with 131 bony spurs discovered in total. The maximum number of bony spurs on a coracoid process was 4 and the average number was 1.87±0.97. However, there was no significant difference (P>0.05) between the left (2.08±1.00) and the right (1.66±0.97) scapulae in the amount of the bony spur on a coracoid process.

The distribution, frequency, and size (height and transverse and longitudinal diameters) of the bony spurs are reported in Table 1. All of them were located at the attachment points of ligaments and tendons on the coracoid process. The attachment points of these ligaments and tendons are displayed in Figures 1–3. Most bony spurs were located at the attachment point of the STSL (31, 23.66%), while the TL accounted for the smaller proportion (8, 6.11%). The heights of bony spurs were not significantly different among the groups (P>0.05). In terms of frequency, the bony spurs located at the attachment point of the STSL were significantly different compared with the CBT (P<0.05), SHBBMT (P<0.05), and TL (P<0.05), while the CAL and PMT, which had the same frequency, were significantly more common than the SHBBMT (P<0.05) and TL (P<0.05). In terms of the transverse diameter, there were significant differences between the TSL and all the others (P <0.05). The PMT was significantly different from the SHBBMT (P<0.05). Finally, in terms of the longitudinal diameter, the STSL revealed a significant difference from the PMT (P<0.05), conoid ligaments (CL) (P<0.05), CBT (P<0.05), and SHBBMT (P<0.05), while the CAL was significantly different from the PMT (P<0.05), which was the same between the PMT and the CBT (P<0.05) and SHBBMT (P<0.05), as well as between the CL and the CBT (P<0.05) and SHBBMT (P<0.05). The STSL had the highest height, with the minimum transverse and longitudinal diameters, while the TL had the greatest transverse and longitudinal diameters.

The results of assessments of the height and transverse and longitudinal diameters of the left and the right bony spurs are listed in Table 2. There was no significant difference between the bilateral body (P>0.05) except for the longitudinal diameter in the STSL and TL. There were 3 bony spurs resulting from the STSL of scapulae that were completely calcified, making

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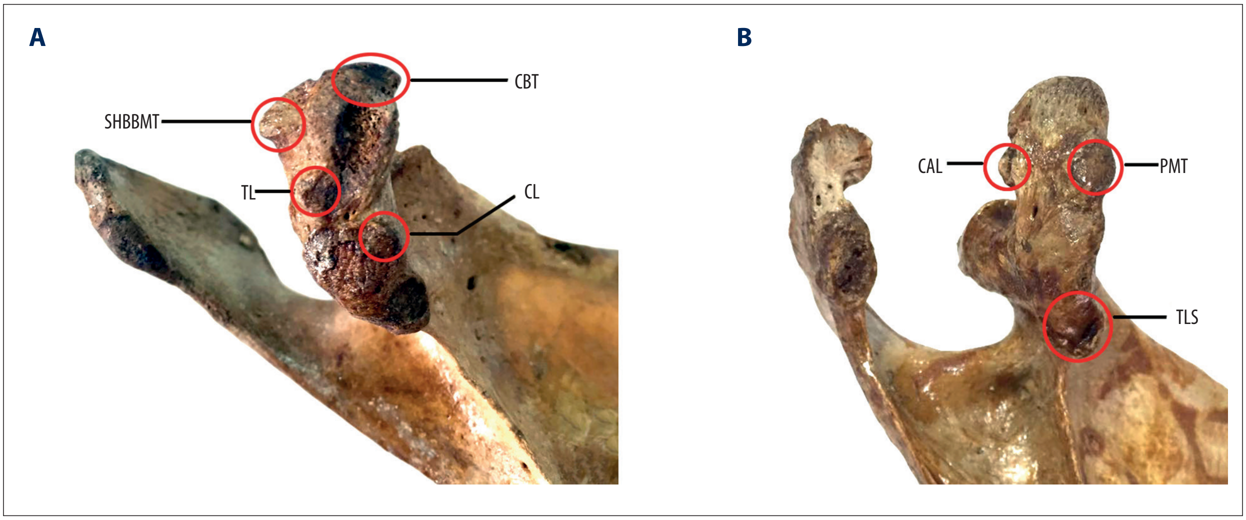

Figure 1. Painting diagram of the attachment points of the ligaments and tendons on the coracoid process. (**A**) Anterior (top) projection of the left coracoid process. CBT – coracobrachialis tendon; PMT – pectoralis minor tendon; CL – conoid ligament; SHBBMT – short head of the biceps brachii muscles tendon; CAL – coracoacromial ligament; TL – trapezoid ligament. (**B**) Posterior projection of the right coracoid process. CAL – coracoacromial ligament; CHL – coracohumeral ligament.

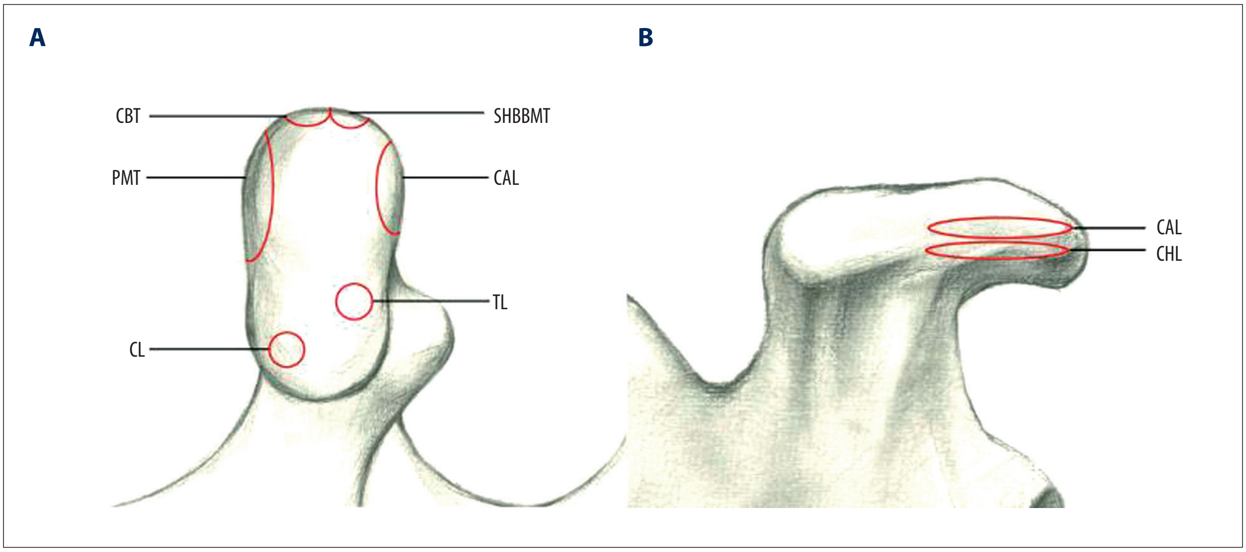

Figure 2. Posterior projections of the left coracoid process. Incompletely calcified (**A**) and completely calcified (**B**) bony spurs on the attachment points of the TSL on the specimens.

the scapular notch form a closed ring. Incompletely calcified and completely calcified bony spurs on the attachment points of the TSL are shown in Figure 2. In addition, because the CHL is located right under the CAL (Figure 1B), making their attachment points superimposed and mixed; they were adjacent and hard to distinguish, so the bony spurs on the attachment points of the CHL may have been counted in the CAL in our study.

Discussion

Previous research indicates that the main causes of bony spurs are biomechanical, immunological, and genetic factors [19]. It was hypothesized that demineralized bone matrix contains transforming factors, allowing mesenchymal cells to differentiate into osteoblasts [20]. In this dynamic equilibrium of bone mineralization and demineralization, many inductive agents have been implicated in the bone formation process, such as bone morphogenetic protein-4 [21] and, more recently discovered, bone morphogenetic protein-9 [22]. In the pediatric population, heterotopic ossification (HO) commonly presents in

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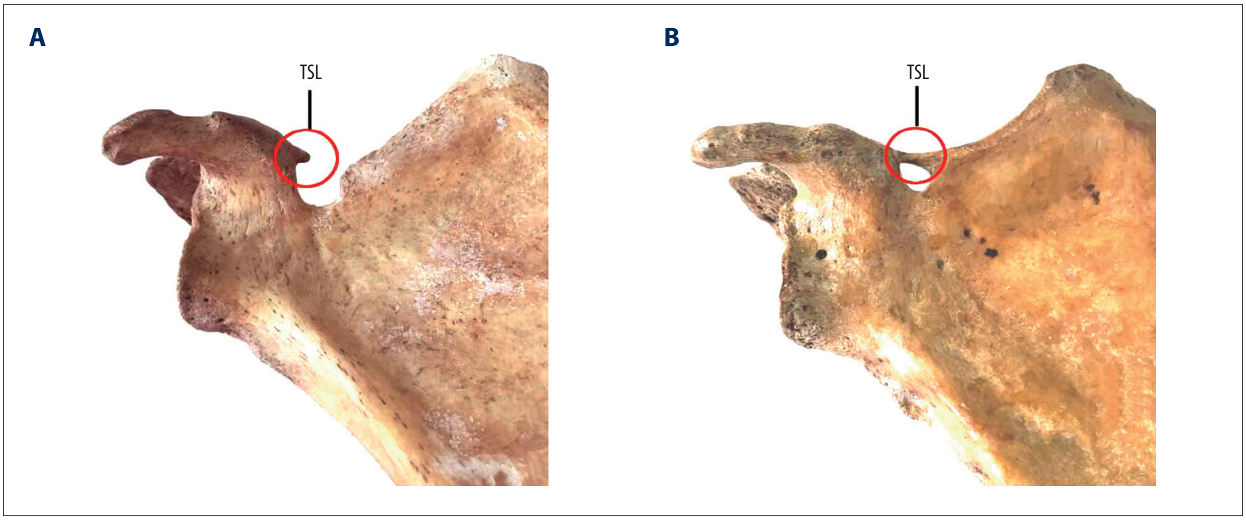

Figure 3. The attachment points of the ligaments and tendons on the right coracoid process on the specimens on the anterior (top) projections. (**A**) SHBBMT – short head of the biceps brachii muscles tendon; TL – trapezoid ligament; CBT – coracobrachialis tendon; CL – conoid ligament. (**B**) CAL – coracoacromial ligament; PMT – pectoralis minor tendon; TSL – transverse scapular ligament.

the genetic form, including familial disorders such as progressive osseous heteroplasia, Albright's hereditary osteodystrophy, and fibrodysplasia ossificans progressiva [20,21]. HO is an abnormal formation of mature lamellar bone in soft tissues [23], and an example of dystrophic calcification that is distinguishable from other forms by the trabecular pattern of bone [21]. It results from 3 basic etiologies: traumatic, neurogenic, and genetic [22]. In orthopedics, HO is commonly diagnosed in the setting of localized trauma, which results in improper differentiation of progenitor cells, leading to aberrant tissue formation [24]. Other possible etiologies discussed in the literature involve various endocrine disorders, including thyroid disorders with associated osteopenia and traumatic sequelae, and hypoparathyroidism, which is associated with calcium deposition in various organ systems, including diabetes. Vitamins are also important factors. Vitamin D resistance, which is thought to be associated with low calciuric response, is implicated in calcification. Additionally, it was reported that hypervitaminosis A administered in animal models in excess also results in osteophytes and heterotopic ossification [25]. Ultimately, medication- induced hypercalcemia and hypomagnesemia may also contribute to calcification in concert with trauma [26]. However, the exact mechanism is still unclear, especially for localized area such as the coracoid process, which has been the subject of very few relevant studies, and even the distribution and morphometry characteristics of bony spurs on the coracoid process have not been investigated to date.

In our study, by investigating the distribution and morphological characteristics of bony spurs on the coracoid process by the measurement and analysis of specimen data and discussing their possible causes based on this information, we conclude that shoulder injuries may be a main cause of the formation of bony spurs. These injuries involve acromioclavicular dislocation (ACD), glenohumeral dislocation (GHD), traction injury of tendons or ligaments, and attachment points avulsion fracture on the coracoid process, which may result in poor blood supply or inflammatory disease [27–30], leading to local hypoxia within soft tissues, followed by metaplasia and formation of fibrocartilage, eventually resulting in deposition of dystrophic calcifications, which then become bony spurs [28,31].

In the results of our study, the prevalent bony spur was located at the attachment point of the STSL (31, 23.66%), and there were 3 bony spurs, resulting from its being calcified completely, making the scapular notch form a closed ring, which can lead to suprascapular nerve entrapment syndrome. Polguj et al. [32–35] performed the largest study on ossified superior transverse scapular ligament, concluding that the ossified band-shaped superior transverse scapular ligament should be considered as a potential risk factor in suprascapular nerve entrapment because the space below the bony bridge is significantly reduced compared with the ossified fan-shaped ligament. They discovered a unique anatomical variation of the suprascapular notch from 610 analyzed specimens [35]. They found 2 bony bridges and converted it into a double suprascapular foramen in the left upper extremity of a 56-year-old white female. Thinking this variation might be a risk factor for suprascapular nerve entrapment, they believed that anterior the coracoscapular ligament and trifid STSL play an important role, and the suprascapular (SN) at the suprascapular notch (SNN) probably is protected by the STSL, but is also considered to be an important factor causing suprascapular entrapment [34]. The STSL is a fibrous band connecting 2 borders of the (SNN) on the

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Table 2. The size of the left and the right bony spur (mean ±SD).

Variable*		Height (mm)	Transverse diameter (mm)	Longitudinal diameter (mm)
TSL	Left	2.62±1.29	3.54±0.85	2.08±1.02[a]
	Right	3.71±3.23	3.51±1.27	1.81±0.54
CAL	Left	2.76±0.76	6.90±2.82	3.52±2.44
	Right	2.45±0.87	5.77±2.34	2.77±0.87
PMT	Left	2.44±0.84	8.19±2.43	5.28±2.62
	Right	2.49±1.01	9.16±2.24	6.37±2.65
CL	Left	1.87±0.64	7.56±1.37	1.73±0.48
	Right	2.17±1.00	7.21±1.41	1.89±0.84
CBT	Left	2.73±1.31	6.66±2.20	3.20±0.48
	Right	2.63±0.91	7.40±2.32	3.71±0.80
SHBBMT	Left	2.80±0.38	5.93±1.37	3.49±0.76
	Right	2.10±0.65	5.87±1.07	3.20±0.37
TL	Left	2.56±1.18	8.53±2.52	5.24±1.04[a]
	Right	2.38±2.17	10.78±2.28	8.12±5.23

TSL – transverse scapular ligament; CAL – coracoacromial ligament; PMT – pectoralis minor tendon; CL – conoid ligament; CBT – coracobrachialis tendon; SHBBMT – short head of the biceps brachii muscles tendon; TL – trapezoid ligament. [a] P<.05 *vs.* Right.
* Data on the size are shown as mean ± standard deviation.

upper border of the scapula. The frequency of completely ossified STSL varies throughout the world [33]. In Chinese populations, it was estimated to affect 4.08% of cases [36]. From the above discussion, it may be understood why the prevalent bony spur was located at the attachment point of the STSL, and thus in terms of the frequency, the bony spur located at the attachment point of the TSL revealed a significant difference compared with the CBT (P<0.05), SHBBMT (P<0.05), and TL (P<0.05). In addition, the reason why the TSL was the highest may be the same factor determining that both of the frequency and the height are involved with the degree of the continued force exerted on the attachment point.

The second was the CAL (25, 19.08%), with which the PMT had an equal level. The CAL presents with variable morphology and plays an important role in the development of subacromial impingement syndrome. It is also a part of the coracoacromial arch, which is considered to be involved in shoulder impingement [37,38]. This may be why it has a high frequency of bony spurs.

Coracoid process fractures with ipsilateral ACD usually occur at the base or neck of the coracoid process, with an intact CCL attached to the fracture fragment [39–42]. The CCL is composed of the CL and TL. The CL arises from the coracoid process posterior and medial to the attachment of the TL. The ACD [43,44], accounting for approximately 9% of shoulder girdle injuries [45], is one of the most common clinical orthopedic traumas. At present, Allman and Tossy's trichotomy is most frequently used in clinical practice; type II means occurrence of CCL injury, while type III means CCL rupture. Others are the GHD, traction injury of tendons or ligaments, and attachment points avulsion fracture on the coracoid process [46–49]. Coracoid process fractures are uncommon, with an incidence between 3% and 13% of all scapular fractures, which constitute less than 1% of all fractures [50,51]. Coracoid process fractures are mostly located in the basal part of the coracoid process, and are mainly caused by the ACD and anterior dislocation of the shoulder joint. The mechanism of injury may that indirect violence, such as external force, acts on the shoulder, leading to the ACD, causing a coracoid process fracture by avulsion injury because of CCL stretching. The fracture load under the uniaxial stress load of the CCL is about 500 N, while the CL is about 394 N and the TL is about 440 N [44]. This means that the CL is more easily injured than the TL, which agrees with the result of our study that the former (18, 13.74%) is more likely to form bony spurs than the latter (8, 6.11%).

Coracobrachialis injury has rarely been described during traumatic shoulder dislocation. When its rupture is reported, the

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location of the injury was within the muscle belly or distal insertion at the humerus rather than the tendinous origin at the coracoid process [52]. The SHBBMT follows a rectilinear course and inserts onto the coracoid process. However, to the best of our knowledge, no lesions have ever been described at this level [53]. The fact that these 2 tendons have less damage may contribute to the existence of fewer bony spurs at their attachment points on the coracoid process.

We found that, in terms of the transverse diameter, there was a significant difference between the STSL and all the others (P<0.05). PMT was significantly different from the SHBBMT (P<0.05). In terms of the longitudinal diameter, the TSL revealed significant differences compared with the PMT (P<0.05), CL (P<0.05), CBT (P<0.05), and SHBBMT (P<0.05), while the CAL was significantly different from the PMT (P P<0.05), which was the same between the PMT and the CBT (P<0.05), the SHBBMT (P<0.05), as well as between the CL and the CBT (P<0.05), SHBBMT (P<0.05). The above findings indicate that the main reason may be that the transverse diameter and longitudinal diameter are related to the size of the attachment points, which is an anatomic factor, and may explain why the TL had the greatest transverse and longitudinal diameters.

Moreover, contrary to expectation, there was no significant difference between the left and right bony spurs (P>0.05), except for the longitudinal diameter in the STSL and TL, and we expected that Chinese subjects would be more likely to form bony spurs on the right coracoid process because they use their right hands more.

There are a few limitations to this study. Firstly, we reported morphologic measurements of 377 specimens of unknown sex and age, which were collected from a single university; therefore, this may have some impact on the conclusions of the study, and generalizations to the general population cannot be made. Secondly, measurements were made on dry specimens and not *in vivo*, which may have affected our findings. Thirdly, this study was restricted to morphological observation, and the description of bony spurs on the coracoid process and conjecture about the possible causes were made without experimental evidence.

Conclusions

We investigated the distribution and morphological characteristics of the formation of bony spurs on the coracoid process by measurement and analysis of specimen data. The bony spurs were more likely to form at the attachment points of ligaments and tendons on the coracoid process, which have a greater risk of traction injuries or attachment points avulsion fractures. Our results may help in early diagnosis, prevention, and finding safer and more effective treatments.

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Conflict of interests

None.

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