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ORIGINAL ARTICLE

Classification of the superior angle of the scapula and its correlation with the suprascapular notch: a study on 303 scapulas

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Abstract

Purpose The aims of this study had been to classify the superior angle of the scapula based on morphological features, and to investigate its correlation with the suprascapular notch.

Methods 303 samples of Chinese dried scapular specimens were collected from the Department of anatomy, Southwest Medical University. According to the anatomical morphological characteristics of the superior angle of the scapula, the morphological classification was performed to explore its correlation with the suprascapular notch (SSN).

Results The superior angle of the scapula was classified into three types (Hilly shape, Mountain Peak shape and Chimney shape). There were 143 cases of Hilly shape (47.20%), 144 cases of Mountain shape (47.52%), and 16 cases of Chimney shape (5.28%). The angle of Hilly shape (93.36° ± 7.76°) was significantly larger than the Mountain Peak shape (86.60° ± 6.61°) and the Chimney shape (86.22° ± 7.20°), and the difference was statistically significant ($P < 0.05$). The type I–III of Rengachary's classification to SSN was low risk of suprascapular nerve entrapment, while the type IV–VI was high risk of suprascapular nerve entrapment. Compared with the Mountain Peak shape and the Chimney shape, the Hilly shape corresponds to more types I–III of suprascapular notch but to fewer types IV–VI ($P < 0.05$).

Conclusions The superior angle of the scapula was divided into three types: Hilly shape (47.20%), Mountain Peak shape (47.52%) and Chimney shape (5.28%). The Mountain Peak shape might be more likely to result in inability of the levator muscle with acute or chronic overload mechanisms, and the risk of suprascapular nerve entrapment in Mountain peak shape was higher than that of Hilly shape. And, it might have a potential effect on neck pain.

Keywords Superior angle of the scapula · Suprascapular notch · Classification · Suprascapular nerve entrapment

Introduction

The suprascapular notch (SSN), located on the upper edge of the scapula, is a small, deep shoulder flap. The superior transverse scapular ligament (STSL) stretches across the SSN and forms a hole in which the superior scapular nerve passes through the upper trunk of the brachial plexus. The space of the SSN is limited and its shape is changeable, so it is easy to cause the suprascapular nerve entrapment [1, 10, 19]. In the Rengachary's classification, the most widely recognized classification, type I–III is relatively gentle on the base of the SSN, which makes it not easy to cause the compression of the suprascapular nerve; on the contrary, the type IV–VI has a narrow and deep notch or the ossification of the STSL, which leads to the narrow space of the SSN and easily causes the suprascapular nerve entrapment [2, 24]. The type I–III was called the "low risk group", while

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the type IV–VI was called "high risk group". At present, the methods to distinguish the shape of SSN are X-ray, CT, MRI and ultrasonography. For large-scale census shape of SSN, these methods have some defects [7, 9, 14, 22]: X-ray and CT have certain radioactivity hazards to patients; MRI is too expensive; ultrasonography is widely used in clinic because of its advantages of noninvasive, repeatable and low price, but is limited to the interference of suprascapular nerve, blood vessel and ligament around it as the deep position of SSN, and it is greatly influenced by the experience of radioactivity doctors. Is there another way to discriminate SSN with high risk of suprascapular nerve entrapment?

The superior angle of the scapula, as the attachment point of the levator scapula and the musculi supraspinatus, located on the medial upper marginal of the scapula, is a clinically important bone landmark. In the clinic, it was found that the superior angle of the scapula is as an extension of the scapular notch to the medial side; its shape was also varied, which might have a certain correlation with the shape of the SSN. At present, there is no report on the classification of the superior angle of the scapula and its correlation with suprascapular notch.

In this study, by observing 303 Chinese dry scapula specimens, the superior angle of the scapula was divided into three types according to the morphological characteristics, and to investigate its correlation with the suprascapular notch.

Materials and methods

Materials

Ethical approval was given by the medical ethics committee of Southwest Medical University with the following reference number: SWMCTCM2017-0701. 303 adult dry scapular specimens were collected from the Department of anatomy, Southwest Medical University, with 142 cases on the left side and 161 cases on the right side.

Features of scapula

(1) Generally intact; (2) complete development; (3) no deformity; (4) without the history of scapular fracture and scapular surgery.

The age, sex and symptom of suprascapular nerve entrapment were unknown. Measurements were made using the digital vernier caliper (TAJIMA, Japan; accuracy up to 0.01 mm); thickness at these locations of the spine was measured using the digital micrometer caliper (MASTERPROOF, Germany; accuracy up to 0.001 mm), and the angle was measured using universal protractor (Mitutoyo, Japan; accuracy up to 5′). All the pictures were processed using Adobe Photoshop CS6.

The classification of scapula

A morphological classification of a scapula was carried out by two researchers, and the third researcher eventually decided the classification if there was a divergence. All the researchers were engaged in anatomic work for more than 5 years. According to the morphological characteristics, the superior angle of the scapula was divided into three types: Hilly shape, Mountain Peak shape and Chimney shape. The Hilly shape of the superior angle of the scapula was gentle, excessively smooth, without obvious protrusions and like a hill; the Mountain Peak shape was steeper, with a distinct single vertex and like a mountain peak; the Chimney shape had a prominent protuberance which was larger than the Mountain Peak shape; the protruding part was more rounded and it was shaped like a chimney (Fig. 1).

The SSN was classified into six types according to Rengachary's classification [20]:

Type I, wide depression; Type II, wide blunted V shape; Type III, symmetric U shape; Type IV, very small V shape; Type V, partially ossified suprascapular ligament; Type VI, completely ossified suprascapular ligament (Fig. 2).

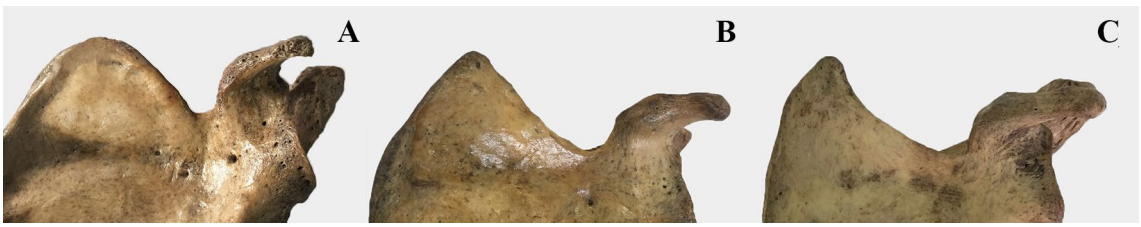

Fig. 1 Three morphological classifications of the superior angle of the scapula. **a** Hilly shape; **b** Mountain Peak shape; **c** Chimney shape

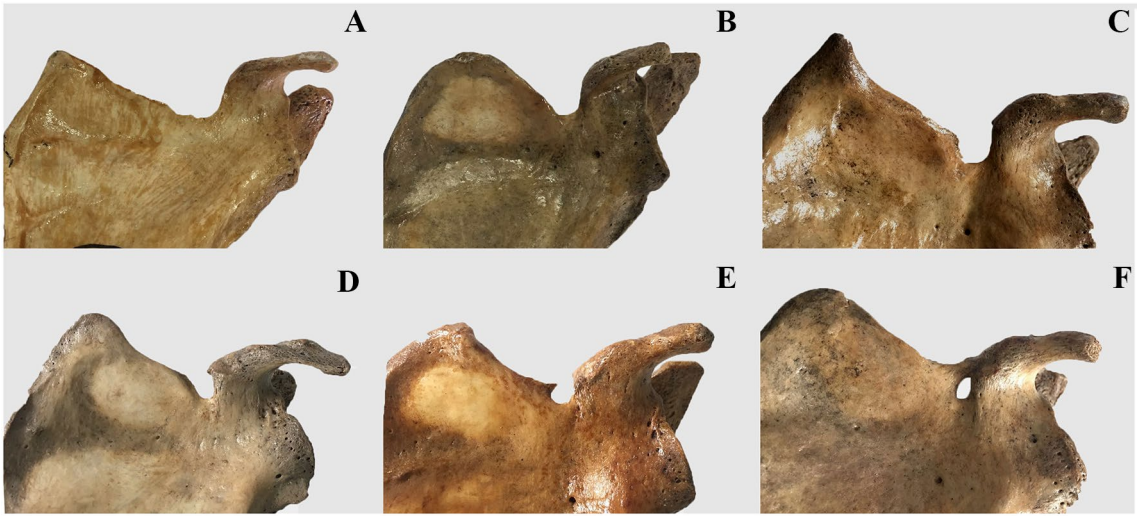

Fig. 2 The morphological classification of the suprascapular notch. **a** Type I, wide depression; **b** Type II, wide blunted V shape; **c** Type III, symmetric U shape; **d** Type IV, very small V shape; **e** Type V, partially ossified suprascapular ligament; **f** Type VI, completely ossified suprascapular ligament

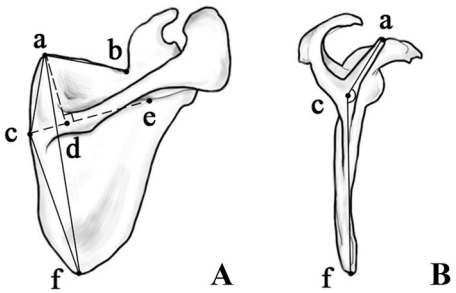

Fig. 3 The measuring position of scapula. **A** Back view of the scapula; **B** medial view of the scapula. The thickness of point a: the point a was the superior angle of the scapula; ab: the point b was the lowest point of the SSN, the distance of point a to point b; ac: the point c was the intersection between the scapula spine and the inner margin of the scapula, the distance of point a to point c; ad: the point e was the spinoglenoid notch, the point d was the vertical point of the point a on the line ce, the distance of point a to point d; ∠a: the angle between the straight line ab and the straight line ac; ∠acf (vertical plane): the angle at the sagittal plane (the point f was the lowest point of the inferior angle of scapula); ∠acf (coronal plane): the angle at the coronal plane

The parameters of measurement (Fig. 3)

The thickness of point a (the point a was the superior angle of the scapula);

ab: ab (the point b was the lowest point of the SSN, the distance of point a to point b);

ac: ac (the point c was the intersection between the scapula spine and the inner margin of the scapula, the distance of point a to point c);

ad: ad (the point e was the spinoglenoid notch, the point d was the vertical point of the point a on the line ce, the distance of point a to point d);

∠a: the angle of ∠a (the angle between the line ab and the line ac);

∠acf (vertical plane): the angle at the sagittal plane (the point f was the lowest point of the inferior angle of scapula);

∠acf (coronal plane): the angle at the coronal plane.

Statistical analysis

Statistical analysis was performed using SPSS 20.0 software (Chicago, IL, USA). All data were presented by means of the mean and standard deviation ($\bar{x} \pm s$). Categorical variables were expressed by frequencies and percentages. The homogeneity of variance was performed using Shapiro–Wilk test. Statistical analysis was performed by one-way ANOVA (one-way ANOVA) when the variances were homogeneous; non-parametric tests were used when the variances were not equal; Chi-square test was used for classification data, and considering a P value < 0.05 as statistically significant.

Results

The superior angle of the scapula was classified into three types (Hilly shape, Mountain Peak shape, Chimney shape) according to morphological features. There were 143 cases of Hilly shape (47.20%), 144 cases of Mountain shape (47.52%), and 16 cases of Chimney shape (5.28%). The thickness of the point a in the Hilly shape was thinner than the Mountain Peak shape ($P < 0.05$); the angle a (∠a) of

Hilly shape (93.36° ± 7.76°) was significantly larger than the Mountain Peak shape (86.60° ± 6.61°) and the Chimney shape (86.22° ± 7.20°), and the difference was statistically significant ($P < 0.05$). In ac and ad, the Hilly shape was longer than the Mountain Peak shape and the Chimney shape; in the angle at the coronal plane (∠acf), the Hilly shape was less than the Mountain Peak shape ($P < 0.05$). In the thickness of the point a, ab, ac, ad, ∠a, ∠acf (vertical plane) and ∠acf (Coronal plane), there was no statistical difference between the Mountain Peak shape and Chimney shape ($P > 0.05$). In addition to that, there was no statistically significant difference between left and right sides of the scapula in this study ($P > 0.05$) (Tables 1, 2, 3).

Among the different types of the SSN, type III (119 cases, 39.28%) was the most, in descending order followed by type II (89 cases, 29.37%), type I (55 cases, 18.15%); type IV–VI (40 cases, 13.20%) is relatively small. The number of type IV–VI (high risk group, 12 cases), which is the Hilly type corresponded, was significantly less than the Mountain Peak type (24 cases), and the difference was statistically significant ($P < 0.05$), while there were no statistically significant differences between the Hilly shape and the Chimney shape, the Mountain Peak shape and the Chimney shape.

Table 1 The measurement results of the three types of the superior angle of the scapula

	Hilly shape	Mountain peak shape	Chimney shape
Number	143	144	16
Ratio	47.20%	47.52%	5.28%
The thickness of the point a (mm)	3.12 ± 1.01*	3.80 ± 0.96	3.45 ± 0.54
ab (mm)	45.68 ± 6.39*	49.38 ± 7.70	45.92 ± 6.90
ac (mm)	43.99 ± 6.08*,#	47.65 ± 6.39	48.10 ± 5.26
ad (mm)	30.07 ± 4.46*,#	34.47 ± 4.86	33.94 ± 4.45
∠a (°)	93.36 ± 7.76*,#	86.60 ± 6.61	86.22 ± 7.20
∠acf (vertical plane, °)	157.04 ± 7.18	156.47 ± 7.42	155.94 ± 8.39
∠acf (Coronal plane, °)	144.64 ± 7.45*	146.45 ± 8.02	146.94 ± 9.06

*$p < 0.05$ vs Mountain peak type

# $p < 0.05$ vs Chimney type

Table 2 The measurement of the superior angle of the scapula of the left and right side

	Left	Right	Total
Number	142	161	303
Ratio	47.5%	52.5%	100%
The thickness of the a point (mm)	3.50 ± 1.06	3.42 ± 0.99	3.46 ± 1.02
ab (mm)	47.84 ± 7.06	47.11 ± 7.47	47.45 ± 7.28
ac (mm)	45.67 ± 6.52	46.18 ± 6.40	45.95 ± 6.45
ad (mm)	32.07 ± 5.12	32.62 ± 5.13	32.36 ± 5.12
∠a (°)	88.97 ± 7.74	90.48 ± 8.08	89.77 ± 7.95
∠acf (vertical plane, °)	157.53 ± 7.93	155.99 ± 6.72	156.71 ± 7.34
∠acf (Coronal plane, °)	144.82 ± 8.12	146.33 ± 7.54	145.62 ± 7.84

*$p < 0.05$ the left side *vs* the right side

Table 3 The classification of the superior angle of the scapula and the SSN

	Type I	Type II	Type III	Type IV	Type V	Type VI	Total	Ratio
Hilly shape	**21**	**41**	**69**	**10**	**1**	**1**	143	47.20%
Mountain Peak shape	**32**	**43**	**45**	**13**	**5**	**6**	144	47.52%
Chimney shape	**2**	**5**	**5**	**1**	**1**	**2**	16	5.28%
Total	55	89	119	24	7	9	**303**	–
Ratio	18.15%	29.37%	39.28%	7.92%	2.31%	2.97%	–	100%

Discussions

Classification of the superior angle of the scapula

The superior angle of the scapula, located on the upper part of the scapula, flat to the second rib, is the attachment point of the levator scapula muscle and an important clinical landmark [6]. Clinically, the pain in the superior angular region of scapula with soreness of neck is often associated with levator scapulae syndrome [4, 11]. Previously, the main pathogeny of the scapular muscle syndrome was considered as caused by acute or chronic overload of the levator scapula such as unhealthy sitting posture and multi-degree activities of the upper limb, but less related to the anatomic morphological characteristics of the superior angle of the scapula. It was found that the anatomical characteristics of the superior angle of the scapula were variable, which might have a potential impact on the biomechanics of the levator scapula, and further affect the levator scapula syndrome [3, 11].

By measuring the medial angle of the scapula (the same as ∠acf at the coronal plane in this study), Oladipo et al. [13] found that alteration of the medial angle of the scapula might increase the steepness of the muscle, altering the attachment of the fiber of the levator muscle; this might also create slacks within the lower fibers at the origin resulting in the inability of the levator muscle to pull the scapulae superomedially and possible loss of the burden-bearing ability of the muscle when a heavy load was carried on the shoulder.

In this study, the superior angle of the scapula was classified into three types (Hilly shape, Mountain Peak shape and Chimney shape) according to morphological features. Generally, samples of Hilly shape and Mountain Peaks shape both take closely large part of total cases (47.20%, 47.52%), while CS covers relatively less (5.28%). As to∠acf at the coronal plane, the Mountain Peak shape ($146.45 \pm 8.02)^\circ$ was obviously larger than that of the Hilly shape ($144.64 \pm 7.45)^\circ$, and the difference was statistically significant ($P < 0.05$); this illustrated that the steepness of the levator scapula muscle fibers in the Mountain Peak shape was significantly higher than that of the Hilly shape, and the Mountain Peak shape was more likely to result in inability of the levator muscle with acute or chronic overload mechanisms. In the ∠acf at the coronal plane, the Chimney shape ($146.94 \pm 9.06)^\circ$ was similar to the Mountain Peak shape ($146.45 \pm 8.02)^\circ$, but there was no statistical difference between them, that might result from the small amount of the Chimney shape.

Correlation between the classification of superior angle of the scapula and SSN

The risk factors of the suprascapular nerve entrapment syndrome (SNES) are varied: the morphology of the SSN, the ossification of the STSL, inferior transverse scapular ligament (ITSL), the anterior coracoscapular ligament, the suprascapular nerve and blood vessels [5, 8, 15–17]. Among them, the morphology of the SSN is a more important factor leading to SNES. One of most recognized is Rengachary's classification of the SSN in 1979, which divided the SSN into six types according to the anatomic characteristic and the degree of ossification of STSL. The main purpose of classification of suprascapular notch is to provide anatomic basis for the diagnosis and treatment of suprascapular nerve syndrome [18, 21, 23, 25]. Recent studies [1, 10, 12, 19] have shown that the shape of the SSN, especially the "narrow and deep" of SSN, is an important factor affecting the suprascapular nerve entrapment. In Rengachary's classification, type I–III is relatively gentle on the base of the SSN and its space of the notch was relatively large, which makes it not easy to cause the compression of the suprascapular nerve, while the type IV–VI has a narrow and deep notch or the ossification of the STSL, which leads to the narrow space of the SSN and easily causes the suprascapular nerve entrapment [2, 24]. Meanwhile, because the number of the type IV–VI in the study is relatively small (the proportion of epidemiology is relatively low), it was merged into a whole to research. The type I–III was called the "low risk group", while the type IV–VI was called "high risk group" (Table 4).

In this study, Hilly type corresponding to type IV–VI (high risk group, 12 cases) was significantly less than Mountain peak shape (low risk group, 24 cases), and the difference was statistically significant ($P < 0.05$). The proportion of high suprascapular nerve entrapment risk in Hilly shape was 9.16% (12/131), which was significantly lower than that of Mountain peak shape (20%, 24/120). It was concluded that the risk of suprascapular nerve entrapment in Hilly shape

Table 4 The classification of the superior angle of the scapula and the SSN

	Type I–III (low risk group)	Type IV–VI (high risk group)	Total	Ratio
Hilly shape	131	12	143	47.20%
Mountain Peak shape	120	24	144	47.52%
Chimney shape	12	4	16	5.28%
Total	263	40	**303**	–
Ratio	86.80%	13.20%	–	100%

was significantly lower than that of Mountain peak shape of superior angle of the scapula, but the specific reason is not clear at present so that it needs further study to confirm. The risk of suprascapular nerve entrapment in Chimney shape was 33.33% (4/12), but there was no statistical difference from the Mountain peak shape ($P > 0.05$), which might be related to the small number of Chimney shape, and it needed larger sample studies yet.

Limitations of the study

(1) Only the relationship between the classification of the superior angle of the scapula and the suprascapular notch was investigated, while its potential mechanism was not further studied. (2) The scapula specimen of this study was limited to the Chinese population, so the results might not be so universal as there are certain bias. (3) The objective of this study is dry scapula specimens, so it is impossible to calculate the relationship between shoulder and back pain in patients and the superior angle of the scapula.

Conclusions

The superior angle of the scapula was divided into three types: Hilly shape (47.20%), Mountain Peak shape (47.52%) and Chimney shape (5.28%). The Mountain Peak shape might be more likely to result in inability of the levator muscle with acute or chronic overload mechanisms. The risk of suprascapular nerve entrapment in Mountain peak shape was higher than that of Hilly shape. By studying the relationship between the superior angle of the scapula and the suprascapular notch, it might provide some anatomical basis for screening patients with a high risk of suprascapular nerve entrapment syndrome, so as to intervene earlier.

Author contributions LZ and SJ-F: Conception and design, XG-G: Manuscript writing/editing, YL and MO: Protocol/project development, XY-L: Data analysis, JQ and YX-X: Data collection. GY-W: Provision of materials and literature search.

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Compliance with ethical standards

Conflict of interest No conflict of interest exists in the submission of this manuscript, and the manuscript was approved by all authors for publication.

Ethical approval Ethical approval was given by the medical ethics committee of Southwest Medical University with the following reference number: SWMCTCM2017-0701.

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