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Morphological measurements and classification of the spinoglenoid notch: A three-dimensional reconstruction of computed tomography in the Chinese population☆

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ABSTRACT

Background: The spinoglenoid notch (SGN) is the second most common location for suprascapular nerve (SN) entrapment; however, there are few relative morphological reports on this condition. Hence, the present morphological study mainly explored the anatomical structure and classification of the SGN and the relationship with entrapment of SN.
Materials and methods: Four hundred seventy-eight scapulae were analysed thoroughly and systematically in this study. Anatomical structure and classification of the SGN were observed and measured by a three-dimensional (3D) reconstruction of computed tomography (CT). The measurement results were then analysed and recorded.
Results: Chinese scapulae were classified into three types at the SGN, and it was found that left scapulae had deeper SGN than right ones. Then, significant differences were also noted between sexes. Men had thicker, wider and deeper SGN than women. Type II (small U, 46.04%) was the most common. Type I (large U) was the widest (15.67 ± 1.43 mm) and deepest (13.71 ± 2.39 mm) compared with other types. Lastly, no significant differences in the above criteria were found in other measurements.
Conclusions: These morphological measurements of the SGN may help to improve the diagnosis and successful treatment rate of the surgery for the SN entrapment, but the relative clinical trial is necessary to support it.

1. Introduction

Entrapment of the suprascapular nerve (SN) most commonly occurs at the suprascapular notch (SSN), and the second most common location is the spinoglenoid notch (SGN) (Avery et al., 2002; Mall et al., 2013). The SN courses below the inferior transverse scapular ligament, and ends under the infraspinatus muscle in the infraspinous fossa (Warner et al., 1992; Demirhan et al., 1998). Through the SGN, the nerve trace is at an angle of approximately 60° (Demirhan et al., 1998). Therefore, the SGN, especially being compressed by ganglion cysts, tract injuries and some direct trauma, may be a limited location for the SN and adjacent vascular structures, which can result in SN entrapment syndrome (Callahan et al., 1991; Steinwachs et al., 1998; Schroeder et al., 2018).

Suprascapular nerve entrapment causes approximately 1–2% dysfunction pain of the shoulder girdle (Zehetgruber et al., 2002). The shape, classification, relative ligaments and vessels of SSN have been frequently reported, while few studies have reported the anatomical structure of the SGN (Bayramoğlu et al., 2003; Polguj et al., 2013; Łabętowicz et al., 2017). As the second most common location for entrapment of the SN, the anatomical structure of the SGN should not be involved in the relative reports a lot. Thus, the morphological study of the SGN is momentous in the disposal of SN entrapment neuropathy.

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Firstly, the literature studied by Kopell and Thompson (1959) was the first to report SN entrapment, while SN entrapment at the SGN was first described by Ganzhorn et al. (1981). As cases of this rare disease have increased, studies on the SN entrapment at the SGN have gradually analysed the different areas. Aiello et al. (1982), Rachbauer et al. (1996), Boerger and Limb (2000) and Soubeyrand et al. (2008) reported cases at the SGN in studies from Italy, Austria, England and France, respectively. Yoo et al. (2009) and Promsang et al. (2018) studied in Korea and Thailand. Piatt et al. (2002) and Mall et al. (2013) reported on the US. A study by Moriggl (1997) focusing on the German population, proposed that the SGN should be divided into four types,: fins form, ditch form, U form, and tick form; this is different from what we have observed, as only U form was observed in the Chinese population. According to the size of the SGN, the U form could be divided into two types: large U and small U, and the L form as a new type has been proposed in our study.

Chinese scapulae were measured at the SGN through a three-dimensional (3D) reconstruction of computed tomography (CT), and the aim of morphological measurements was to classify the SGN in terms of the shape and size for a primary and straightforward classification. To our knowledge, few variable morphological studies of the SGN have been reported in the Chinese population. This morphological study of the SGN is relevant for the alleviation of SN entrapment neuropathy.

2. Materials and methods

2.1. Materials

Ethical protocols were approved by the medical ethics committee of the Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University (SWMCTCM2017-0801). A total of 35 scapulae were excluded because of these conditions: (1) the undeveloped complete scapulae from patients under 20 years old; (2) congenital scapula deformities; (3) having a fracture, a shoulder surgery or any diseases in the scapulae. There were 266 male and 212 female (mean 52 years, range 20–92 years) scapulae belonging to the Chinese Han nationality. Four hundred seventy-eight scapulae (236 left and 242 right scapulae) were reconstructed, and recorded with an accuracy of up to 0.1 mm.

2.2. Methods

Measurements were conducted by a 3D reconstruction in CT using a 16-slice spiral CT scanner (SOMATOM Emotian), which was used to scan the upper and lower edges of the scapula with the patients in a lying position, with scanning voltage 120 kV, tube current 120 mA s, and pitch 0.8. Then, the reconstructed scanned images were 0.75 mm thick, and the reconstructed interval was 0.75 mm. Next, the images were transmitted to MMWP workstation for 3D reconstruction. The SGN was morphologically classified based on its shape and size, which was observed by visual inspection. When the shape of the SGN seems like a capital letter “U”, we classified it large U when the width of the SGN was over 15 mm and small U when the width of the SGN was less than 15 mm. When the shape of the SGN appeared like a capital letter “L”, we classified it as L-shaped when the lateral corner of the SGN was approximately 90°. Lastly, other anatomical structures were recorded and analysed. The measurements were recorded for the following (Fig. 2):

(1) The depth (AP), the width (MN) and the thickness of the SGN;
(2) AB: The distance between point A and point B (point A the nadir of the SGN, point B the nadir of the SSN);
(3) AC: The distance between point A and point C (point C superior angle of scapula);
(4) AD: The distance between point A and point D (point D subscapular angle);
(5) AE: The distance between point A and point E (point E supraglenoid tubercle);
(6) AF: The distance between point A and point F (point F infraglenoid tubercle);
(7) AG: The distance between point A and point G (point G the middle of glenoid cavity);
(8) AH: The distance between point A and point H (point H the intersection point that was the common point between the spinae scapulae and the lateral border of the scapula body);
(9) $\angle\alpha$: The angle between spinae scapulae and the body of the scapula at the horizontal level when vertex was at A.

To avoid inter-observer and intra-observer variation, each measurement was carefully measured only once by an investigator, who performed the categorisation and had >5 years of experience in anatomical work.

2.3. Statistical analyses

All data were categorised according to morphology, sex and sides of body, and then were analysed by SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). Four hundred seventy-eight scapulae were used in the study, and the sample size was calculated according to the following formula $N = ZxPx(1-P)/E$ (where confidence level is 95%, $Z = 1.96$; E is an error value of 5%, P is a probability value of 0.5). Then as a statistic, N can be calculated. From the above calculation, $N = 478 > 384$. The results were expressed as mean and standard deviation unless otherwise stated. The chi-squared test was used to analyse the distribution of classification of the SGN between sexes and sides of body. Then, the Shapiro–Wilk test was used to assess the normality of the continuous data distribution. If the data were normally distributed, independent sample t-tests were used to analyse whether anatomical data had differences in men or women and right or left scapulae, respectively, or Mann–Whitney U was applied. Moreover, one-way analysis of variance (ANOVA) was used as a tool to compare anatomical data among types of SGN. If heterogeneity of variance existed in the data, the Kruskal–Wallis test was used. p value lower than 0.05 was considered to be statistically significant.

3. Results

Among 478 scapulae (236 left scapulae, 242 right scapulae), three types of the SGN were measured, and the shapes of the SGN are shown in Fig. 1. The frequency of type I (large U), type II (small U) and type III (L) was 26.57%, 46.03% and 27.41%, respectively. All data were normally distributed, and relative data of the SGN were measured according to classification (Fig. 2).

Difference significantly existed between sexes. For thickness of the SGN, AB, AC, AD, AE, AF, AH, AP and MN data in men were all greater than that in women: thickness of the SGN 10.78 ± 1.75 mm in men vs. 9.52 ± 2.03 mm in women, $p < 0.001$; AB 21.92 ± 4.67 mm in men vs. 20.06 ± 5.68 mm in women, $p < 0.001$; AC 73.34 ± 8.51 mm in men vs. 65.13 ± 6.15 mm in women, $p < 0.001$; AD 111.23 ± 12.276 mm in men vs. 97.79 ± 11.4 mm in women, $p < 0.001$; AE 27.63 ± 4.83 mm in men vs. 23.85 ± 4.02 mm in women, $p < 0.001$; AF 29.69 ± 3.39 mm in men vs. 25.94 ± 3.58 mm in women, $p < 0.001$; AG 13.51 ± 6.32 mm in men vs. 12.26 ± 2.23 mm in women, $p = 0.006$; AH 81.78 ± 5.40 mm in men vs. 73.29 ± 4.93 mm in women, $p < 0.001$; AP 13.61 ± 2.18 mm in men vs. 12.58 ± 2.19 mm in women,

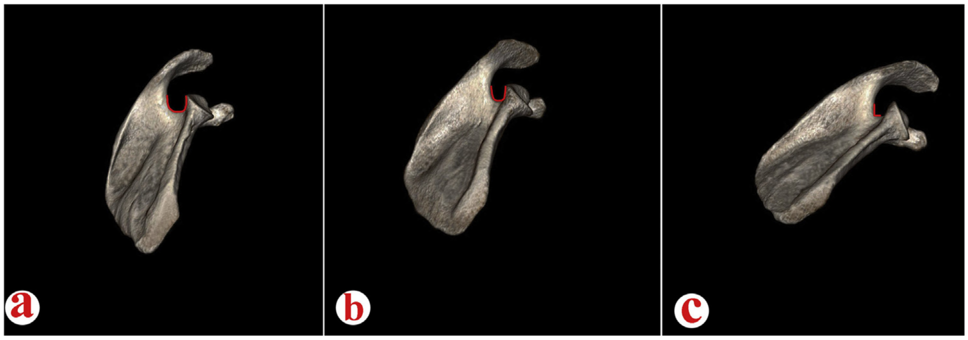

Fig. 1. The types of the SGN. (a) Type I (large U); (b) Type II (small U); (b) Type III (L).

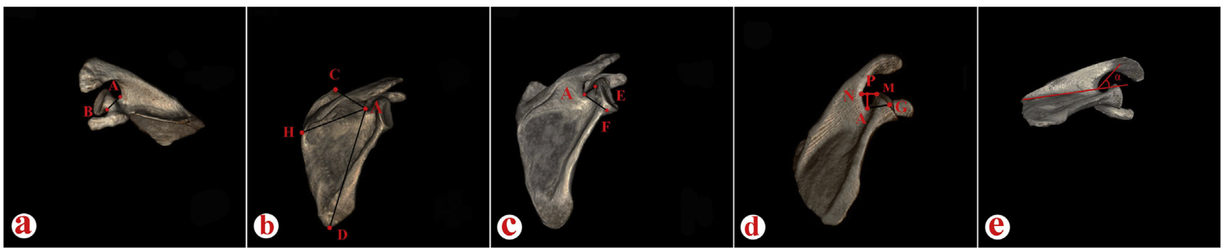

Fig. 2. Morphological measurements were described as follows.
Point A: the nadir of the SGN, point B: the nadir of the SSN, point C: superior angle of scapula, point D: subscapular angle, point H: the intersection point that is the common point between the spinae scapulae and the lateral border of the scapula body, point E: supraglenoid tubercle, point F: infraglenoid tubercle, point G: the middle of glenoid cavity; the depth (AP), width (MN) and thickness of the SGN, and ∠α: the angle between spinae scapulae and the body of the scapula at the horizontal level when vertex was at A.

Table 1
Measured values of the SGN based on sides of the body.

	Left	Right
AB (mm)	21.64 ± 3.43*	20.56 ± 6.47
AC (mm)	71.74 ± 9.51*	67.71 ± 7.04
AD (mm)	107.03 ± 13.19*	103.55 ± 13.90
AE (mm)	26.64 ± 4.85*	25.28 ± 4.79
AF (mm)	27.96 ± 3.69	28.10 ± 4.17
AG (mm)	13.57 ± 6.67*	12.35 ± 2.21
AH (mm)	78.80 ± 6.90*	77.25 ± 6.41
AP (mm)	13.89 ± 2.19*	12.43 ± 2.03
MN (mm)	14.49 ± 7.48	13.71 ± 1.98
Thickness of the SGN (mm)	10.06 ± 1.85	10.37 ± 2.09
∠α (°)	55.35 ± 5.35*	54.05 ± 5.07

* $p < 0.05$ vs. right.

$p < 0.001$; MN 14.63 ± 7.07 mm in men vs. 13.42 ± 1.89 mm in women, $p = 0.016$.

Differences also existed between sides of body. For AB, AC, AD, AE, AG, AH, AP and ∠α, left scapulae were all larger than right ones: AB 21.64 ± 3.43 mm on the left side vs. 20.56 ± 6.47 mm on the right side, $p = 0.023$; AC 71.74 ± 9.51 mm on the left side vs. 67.71 ± 7.04 mm on the right side, $p < 0.001$; AD 107.03 ± 13.19 mm on the left side vs. 103.55 ± 13.90 mm on the right side, $p = 0.005$; AE 26.64 ± 4.85 mm on the left side vs. 25.28 ± 4.79 mm on the right side, $p = 0.002$; AG 13.57 ± 6.67 mm on the left side vs. 12.35 ± 2.21 mm on the right side, $p = 0.007$; AH 78.80 ± 6.90 mm on the left side vs. 77.25 ± 6.41 mm on the right side, $p = 0.011$; AP 13.89 ± 2.19 mm on the left side vs. 12.43 ± 2.03 mm on the right side, $p < 0.001$; ∠α 55.35 ± 5.35° on the left side vs. 54.05 ± 5.07° on the right side, $p = 0.007$.

Significant differences were also observed in MN, AP, AB and AF among different types. MN and AP in type I (large U) (MN 15.67 ± 1.43 mm; AP 13.71 ± 2.39 mm) were greater than ones in type II (small U) (MN 13.41 ± 7.70 mm, $p < 0.001$; AP 12.82 ± 2.13 mm, $p = 0.004$) and type III (L) (MN 13.73 ± 1.96 mm, $p < 0.001$; AP 13.17 ± 2.15 mm, $p = 0.048$). AB in type II (small U) (21.69 ± 5.86 mm) was larger than type III (L) (20.15 ± 3.77 mm, $p = 0.007$) and AF in type I (large U) (28.52 ± 3.68 mm) was larger than type III (L) (27.50 ± 4.34 mm, $p = 0.039$).

No significant differences were found between sexes for the classification of the SGN ($p = 0.228$), nor for left or right scapulae ($p = 0.170$). Measured values of the SGN based on sides of body including both sexes and sides of body are listed in Tables 1 and 2, respectively, while morphological measurements in three types are presented in Table 3.

4. Discussion

Suprascapular nerve entrapment causes approximately 1–2% of chronic shoulder pain cases (Zehetgruber et al., 2002). Weakness, pain and atrophy of the supraspinatus or infraspinatus muscles are the main symptoms, which are also related to other pathologies around the shoulder, such as impingement syndrome or a rotator cuff tear (Zehetgruber et al., 2002; Clavert and Thomazeau, 2014). The most common locations of SN entrapment were the SSN and the SGN (Avery et al., 2002; Mall et al., 2013). Some other potential factors also play an important role in the causes of SN entrapment, including the presence and classification of the spinoglenoid ligament (Demirhan et al., 1998; Plancher et al., 2005; Won et al., 2014), the presence of the anterior coracoscapular ligament (Avery et al., 2002), the anatomical structure of the inferior transverse scapular ligament (Podgórski et al., 2015; Polguj et al., 2016) and the course of the suprascapular vessels and nerve (Łabętowicz et al., 2017). Nevertheless, the morphologic features of the SGN were the second most common predisposing factors of SN entrapment (Avery et al., 2002; Mall et al., 2013). Several recent studies focusing on this rare disease at the SGN have been conducted in people of different countries. However, little attention has been paid to this topic in Chinese population, let alone their classification. The present study

Table 2
Measured values of the SGN based on sexes.

	Female	Male
AB (mm)	20.06 ± 5.68*	21.92 ± 4.67
AC (mm)	65.13 ± 6.15*	73.34 ± 8.51
AD (mm)	97.79 ± 11.46*	111.23 ± 12.27
AE (mm)	23.85 ± 4.02*	27.63 ± 4.83
AF (mm)	25.94 ± 3.58*	29.69 ± 3.39
AG (mm)	12.26 ± 2.23*	13.51 ± 6.32
AH (mm)	73.29 ± 4.93*	81.78 ± 5.40
AP (mm)	12.58 ± 2.19*	13.61 ± 2.18
MN (mm)	13.42 ± 1.89*	14.63 ± 7.07
Thickness of the SGN (mm)	9.52 ± 2.03*	10.78 ± 1.75
∠α (°)	54.94 ± 5.20	54.49 ± 5.28

* $p < 0.05$ vs. male.

Table 3
Morphological measurements in three types.

	Type I	Type II	Type III
AB (mm)	21.05 ± 5.21	21.69 ± 5.86#	20.15 ± 3.77
AC (mm)	69.37 ± 8.71	70.34 ± 8.59	68.95 ± 8.44
AD (mm)	105.01 ± 12.19	105.00 ± 13.70	105.96 ± 14.94
AE (mm)	26.35 ± 4.88	25.83 ± 4.79	25.78 ± 4.98
AF (mm)	28.52 ± 3.68#	28.06 ± 3.81	27.50 ± 4.34
AG (mm)	13.53 ± 2.45	12.79 ± 6.87	12.66 ± 2.27
AH (mm)	77.83 ± 6.45	77.88 ± 6.74	78.42 ± 6.86
AP (mm)	13.71 ± 2.39	12.82 ± 2.13*	13.17 ± 2.15*
MN (mm)	15.67 ± 1.43	13.41 ± 7.70*	13.73 ± 1.96*
Thickness of the SGN (mm)	10.00 ± 2.36	10.34 ± 1.78	10.20 ± 1.90
∠α (°)	55.48 ± 5.67	54.42 ± 5.25	54.38 ± 4.74

* $p < 0.05$ vs. Type I.
\# $p < 0.05$ vs. Type III.

provided morphologic features of the SGN, especially a primary and straightforward classification of the SSN in the Chinese population.

The first case of SN entrapment at the SGN in an American population was conducted by Ganzhorn et al. (1981), and during the operation, they dissected the cyst free, removed the ganglion, and used two hemoclips for preventing recurrence, because an isolated infraspinatus atrophy was usually caused by ganglions at the SGN (Zehetgruber et al., 2002). Later, Aiello et al. (1982) published their findings among an Italian population, suggesting entrapment of the SN at the SGN by electromyographic examination, and excising a hypertrophied inferior transverse scapular ligament for nerve decompression in the operation. Then, sonography and magnetic resonance imaging also helped to reveal a ganglion cyst at the SGN (Rachbauer et al., 1996) in an Austrian patient. Except for the surgical treatment we have mentioned above, a new strategy having of the base of the scapular spine was proved effective for two athletes with suprascapular neuropathy at the SGN in Japan (Hama et al., 1992). Moreover, Moriggl (1997), who mainly aimed at German population, measured the width and depth of the SGN, and classified the SGN into four types: fins form, ditch form, U form, and tick form.

Several studies mostly focused on the treatment of the SGN ganglion cysts, Piatt et al. (2002) stated that an arthroscopic approach could be attempted for treatment, especially intra-articular arthroscopic decompression. Since then, more arthroscopic approaches have been developed for the treatment of SN entrapment at the SGN. The study by Lichtenberg et al. (2004) showed that if the cyst formation is limited at the SGN, by an all arthroscopic technique, arthroscopic decompression of SN can be achieved. Additionally, a study by Loirat et al. (2017) revealed that the subacromial approach was effective and had satisfactory clinical outcomes without recurrence in the SGN decompression. Moreover, Wee and Wu (2018) used an ultrasound-guided aspiration of the paralabral cyst, rather than a more invasive surgical intervention, for effectively treating shoulder pain. Therefore, during the past several decades, several case series have aimed at the diagnosis and treatment of SN entrapment at the SGN while few morphological studies of the SGN have been published. Using macerated scapulae and cadaver shoulders, Moriggl (1997) just did the width and depth of the SGN, divided the SGN into four types, but there was little discussion and relation with SN entrapment.

Our study offered three types of the SGN in all, declaring a primary classification in a Chinese population. In a German population, the fin-shape type was the most common, and the tick-shape was rare (Moriggl, 1997). A different consequence in Chinese population was expressed in our study, indicating that the large U-shape type was the most common and the small U-shape was rare. We proposed an L-shape type of the SGN that was not reported in western population. Leschinger et al. (2017), in a German study, declared the distance from the glenoid centre to the SGN (11.8 ± 4.7 mm) in the anteroposterior direction, which was involved in constructing an anatomical foundation of analysing the risk of SN injury in reverse total shoulder arthroplasty. Miller et al. (2003) measured the distance from the SGN to the glenoid rim (25 ± 2.89 mm), which was helpful when performing arthroscopic release and rotator cuff repair. Moriggl (1997) only declared the width and depth of the SGN in macerated scapulae and cadaver shoulders for four types.

Our study, however, measured the distance from the SGN to the sides of body when other anatomical measurements of the SGN were seldom reported. During the past few decades, suprascapular neuropathy has increasingly been recognised as a pathologic process and cause of shoulder pain and weakness (Momaya et al., 2018). Meanwhile, Ganzhorn et al. (1981) first described the case of SN entrapment at the SGN. The shape, classification, relative ligaments and vessels of SSN were frequently reported, but few studies exist regarding the anatomical structure of the SGN (Bayramoğlu et al., 2003; Polguj et al., 2013; Łabętowicz et al., 2017). Accordingly, our study explored the classification of the SGN and other relative morphological measurements. We analysed the mean values of the SGN based on sides of body, sex and classification respectively, and found that left scapulae had deeper SGN than right ones (AP 13.89 ± 2.19 mm on the left side vs. 12.43 ± 2.03 mm on the right side, $p < 0.001$). Differences also existed between sexes. Men had thicker, wider and deeper SGN than women (thickness of the SGN 10.78 ± 1.75 mm in men vs. 9.52 ± 2.03 mm in women, $p < 0.001$; AP 13.61 ± 2.18 mm in men vs. 12.58 ± 2.19 mm in women, $p < 0.001$; MN 14.63 ± 7.07 mm in men vs. 13.42 ± 1.89 mm in women, $p = 0.016$). Type I (large U) was the widest (15.67 ± 1.43 mm) and deepest (13.71 ± 2.39 mm) compared with other types. Moreover, Matsuki et al. (2011) proposed that the mobility of the dominant scapula was greater which should be taken into account in the clinical assessment of shoulder pathology. As dominant scapula, right scapula usually undertakes more activities, which might explain why right scapulae are smaller than left ones in some measurements of our study. The length and width of scapula indicated no sexual differences in their growth patterns in the mice and pigs (Shimizu and Awata, 1984). The experimental data suggested that male scapulae had a faster rate to grow and lasted for a longer period than females in the mountain gorilla (Taylor, 1995), which could explain why men scapulae were greater than that in women ones in some measurements of our study. Besides, during the peri-pubertal period, increased loading may reinforce the bone of both sexes (Rantalainen et al., 2015), when sex hormone could play a fundamental regulatory role in the development of scapula (Olson et al., 2011), and man often beared more loading than woman, as were also the possible mechanisms of the differences between two genders. Lastly, no significant differences were found in other measurements among the above.

A total of 478 Chinese scapulae at the SGN were measured through a 3D reconstruction of CT, and all data were analysed. This provided the primary classification in the Chinese population.

According to observation and quantitative analysis, three types of SGN were measured. Few relative studies existed on the classification of the SGN, which required more data about classification of these structures. During the past several decades, many case series have been published regarding pathological changes of the SGN. As the second most common location for entrapment of the SN, it is essential to explore the morphological anatomical structure of the SGN, which could help to determine the appropriate surgical treatment to prevent unnecessary structural insult.

The present study has some limitations. First, we lack sufficient clinical data to make the connection between the morphology of the SGN and SN entrapment, and we do not know whether all participants are asymptomatic because this is an anatomical research rather than a clinical trial. Types of SGN are also somewhat limited, and the samples in this study are restricted to in the western part of China. The inferences about the SGN are also limited, especially anatomical studies of the SGN. A professional researcher has already measured all the samples only once carefully because there are 478 scapulae and 11 relative morphological measurements to be measured, and a few observational errors could not be avoided. Finally, we only measured and analysed the mean values of the SGN based on sides of body, sex and classification, but the mechanisms of the differences between bilateral scapulae and between two genders are still not very clear.

5. Conclusion

We have discussed that morphologies of the SGN are observed in the Chinese population associated with SN entrapment. The results suggest that women are more likely to suffer SN entrapment at the SGN site than men. This anatomical study might also help to improve the diagnosis and treatment of successful rate of the surgery for the SN entrapment, but a relative clinical trial is needed.

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Ethical note

The research complied with protocols approved by the medical ethics committee of the Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University (SWMCTCM2017-0801).

Conflict of interest

All authors approved this manuscript for publication without any conflict of interest.

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