Morphometry of suprascapular notch in Egyptian dry scapulae and its correlation with measurements of suprascapular nerve safe zone for clinical consideration

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SUMMARY
The suprascapular notch is bridged by a superior transverse scapular ligament (STSL) and serves as a passage for the suprascapular nerve. The purpose of this study was to group suprascapular notches (SSN) and provide data on the association of the safe zone distances of the suprascapular nerve. Sixty-five Egyptian dried scapulae were classified into five groups; measurement of dimensions of SSN and measurement of safe zone for the suprascapular nerve were taken. The collected data were analyzed and the correlated parameters in the prevalent types of notches were done.

Scapulae were classified into five groups of which the most prevalent groups were Type III (47.63%) followed by Type I (40%). The mean measurements of ‘safe zone’ distances vary according to the type of notch and correlate with notch dimensions. The present work displayed the anatomical variants of SSN and analyzed the measurement of safe zone distances to help the clinicians to manage different pathological conditions of the shoulder, in order to avoid iatrogenic injury.

Key words: Egyptian Scapula – Safe zone – Suprascapular nerve – Suprascapular notch

INTRODUCTION
The suprascapular notch is a depression situated in the lateral part of the superior border of the scapula, adjacent to the base of the coracoid process. The SSN is bridged by a STSL. The ligament may ossify partially or completely to convert SSN into suprascapular foramen (SSF), which serves as a passage for the suprascapular nerve, whereas the suprascapular vessels pass above the ligament (Moore et al., 2013).

The suprascapular nerve is a mixed nerve that originates from the brachial plexus’ superior trunk containing roots from C5 and C6. It enters the supraspinous fossa through the SSN. It then runs deep to the supraspinatus and curves around the spinoglenoid notch to reach the infraspinous fossa. The nerve is prone to iatrogenic injury at these two notches due to its proximity to the operative field. It innervates the shoulder joint, acromioclavicular joint, supraspinatus and infraspinatus muscles, which are components of the rotator cuff (Vorster et al., 2008; Molony et al., 2011).

SNES is an acquired neuropathy in which the nerve is compressed along its course, most commonly at the SSN. It was first described by Kopell and Thompson (1959). It may occur following blunt trauma, rotator cuff tear, ganglion cysts (Hazrati et al., 2003), repetitive traction injury in overhead athletes like volleyball, baseball, tennis players (Khan et al., 2001), suprascapular veins varicose enlargement at the spinoglenoid notch (Van Meir et al., 2011), and also variations in SSN morphology where nerve space is limited by bony and ligamentous constraints (Bayramoğlu et al., 2003).

The clinical manifestations of this neuropathy include deep, dull and diffuse pain of the posterior and lateral aspects of the shoulder, weakened abduction and rotation of the upper extremity in the glenohumeral joint. All these symptoms are based

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Submitted: 1 June, 2018. Accepted: 3 August, 2018.
on progressive atrophy of the supraspinatus and infraspinatus muscles (Gosk et al., 2007). Males are more likely to suffer from the SNES than females (Boykin et al., 2011), mainly in patients under 35 years of age (Zehetgruber et al., 2002).

Morphological variations of the SSN are very important clinically because:

1) the size of the notch has been identified as one of the causes of SNES. The smaller the size of the notch, the greater the chance of nerve entrapment (Moore et al., 2013).

2) the measurements of the safe zone depend on these variations.

Safe Zone is defined as an area within which it is possible to avoid iatrogenic lesions of the suprascapular nerve. The measurements of the safe zone are critical during open surgical procedures (Gumina et al., 2011).

Very scant data are available in the adult Egyptian population on anatomical variations of SSN. Mahdy and Shehab (2013), Ali and Hassanein (2015) classified SSN based on Natsis et al. (2007) and Wang et al. (2011) classification. The purpose of this study was to:

1) group SSN in adult Egyptian scapulae using specific geometric parameters based on the classification system defined by Polguj et al. (2013).

2) provide data on the association of the safe zone distances of the SSN. Knowing the SSN anatomical variations is important for a better understanding of the entrapment syndrome and to improve the safety of arthroscopic nerve decompression.

**MATERIALS AND METHODS**

The present study was carried out on sixty five completely ossified Egyptian dried scapulae of unknown age and sexes were collected from:

1) Department of Anatomy, Faculty of Medicine, Minia University.

2) Department of Anatomy, Faculty of Physiotherapy, Deraya University.

In the selected specimens the exclusion criterion was the presence of injuries which made measurement collection impossible in the study area. For example scapulae with broken superior border, deformity, pathology and previous scapular sur-

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**Fig 1.** Photographs of dry human scapulae showing measurements of SSN and ‘safe zone’ distances. A: superior transverse diameter (STD), middle transverse diameter (MTD) and vertical diameter (VD) perpendicular to STD & MTD. B: distance (in mm) between the deepest point of the SSN and the supraglenoid tubercle. C: distance (in mm) between the spinoglenoid notch and the middle of the posterior rim of the glenoid cavity. D: distance (in mm) between the deepest part of the SSN and the spinoglenoid notch.
The research procedures were approved by the Research Ethics Committee, Faculty of Medicine, Minia University.

The scapulae with a distinct SSN (Fig. 2) were classified on the basis of gross examination and measurements (Fig. 1) in five groups according to the classification of Polguj et al. (2013).

A photographic method was used for measurements to avoid errors. The scapula was carried on an adjustable clamp at a fixed distance from the camera with a metric scale taped onto it to allow a measurement reference (Wang et al., 2011). Photographs were taken with a digital camera (Canon, 20 Megapixels). The digital images were processed using the image analyzer (image J) and two types of measurements were taken (Fig. 1):

1) Measurement of dimensions of the suprascapular notch (Fig. 1A):
   The diameters of SSN were measured in the most prevalent groups using an imaginary line joining the two superior corners of the notch.
   a) The vertical diameter (VD) was taken as the maximal length of SSN starting from the imaginary line and perpendicular to it to the deepest point of the SSN and not necessarily parallel to the vertical axis of the body.
   b) The Superior Transverse Diameter (STD): The maximum horizontal distance between the superior corners of the notch.
   c) The Middle Transverse Diameter (MTD): The maximum horizontal distance between the margins of the notch, perpendicular to the midpoint of the vertical diameter.

The scapulae with absent notch and those with a
SSF were excluded from the morphometric study, because it was not possible to collect the SSN dimensions as described. A photograph representing each type was documented using a digital camera and its percentage was calculated, recorded and tabulated.

2) Measurement of ‘Safe zone for the suprascapular nerve’ distance

To measure the distance of suprascapular nerve, along with its course in the most prevalent groups:

- a) The distance between the deepest point of the SSN and the supraglenoid tubercle (Fig. 1B).
- b) The distance between the spinoglenoid notch and the middle of the posterior rim of the glenoid cavity (Fig. 1C).
- c) The distance between the deepest part of the SSN and the spinoglenoid notch (Fig. 1D).

Each measurement was made by two medical Colleges (skilled in anthropometric measurements and shoulder disorders) and the mean of the values was taken. The collected data were studied, analyzed and presented in tables. Analysis of the correlated parameters in the prevalent types of notches was done.

Methods of statistical analysis:

- For quantitative data: range, mean (X~) and standard deviation (SD).
- For qualitative data: number (n) and percentage (%).

Analytical statistics: Bivariate Pearson correlation analysis for association analysis.

Probability (p) was considered: Non-significant if ≥ 0.05; Significant if < 0.05; Highly significant if < 0.01; Very highly significant if <0.001.

Grade of Pearson’s correlation coefficient: 0.00 to 0.24: weak or no association; 0.25 to 0.49: fair association; 0.50 to 0.74: moderate association; 0.75+: strong association.

RESULTS

By gross examination and comparing the measured vertical and transverse diameters of the SSN, scapulae were classified into five groups according to the classification of Polguj et al. (2013) of which the most prevalent groups were Type III followed to the classification of Polguj et al. (2013) of which scapulae were classified into five groups according to the measurement of the distance between the deepest part of the SSN and the supraglenoid tubercle (Fig. 1B).

The measurements of the distance between the spinoglenoid notch and the posterior rim of the glenoid cavity (Fig. 1C) and the middle of the posterior rim of the glenoid cavity (Fig. 1D).

The analysis of the scapulae with type II SSN showed equal diameters; the VD, the STD and the MTD (Fig. 2).

The scapulae with type-III were again subclassified into two subtypes; type-IIIA (21.53%) and type-IIIB (26.15%) SSN where the VD was shorter than the STD in both types and the MTD was longer than the STD in type-IIIA while it was shorter than it was in type-IIIB (Fig. 2 & Table 1). Type-III SSN had a mean VD of 5.86 ± 1.27mm & a mean STD of 8.56 ± 1.80 mm and a mean MTD of 6.46 ± 1.79 mm (Table 2).

Diameters of types IV and V SSNs could not be measured because type V had an absent notch and type IV had a completely formed bony SSF (Fig. 2).

The measurements of the distance between the SSN and supraglenoid tubercle varied with the type of notch; the highest mean value had been detected for Type I, followed by Type III. The difference was statistically significant (Table 3).

Also, the mean value of the distance between the spinoglenoid notch and the posterior rim of the SSN and the supraglenoid tubercle (Fig. 1C).

Table 1. Distribution of different types of SSN (based on Polguj’s classification).

<table>
<thead>
<tr>
<th>Type of SSN</th>
<th>Description</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - IA</td>
<td>VD &gt; STD &lt; MTD</td>
<td>10</td>
<td>15.38%</td>
</tr>
<tr>
<td>Type - IB</td>
<td>VD &gt; STD &gt; MTD</td>
<td>16</td>
<td>24.61%</td>
</tr>
<tr>
<td>Type - II</td>
<td>VD = STD = MTD</td>
<td>1</td>
<td>1.54%</td>
</tr>
<tr>
<td>Type - IIIA</td>
<td>VD &lt; STD &gt; MTD</td>
<td>14</td>
<td>21.53%</td>
</tr>
<tr>
<td>Type - IIIB</td>
<td>VD &lt; STD &lt; MTD</td>
<td>17</td>
<td>26.15%</td>
</tr>
<tr>
<td>Type - IV</td>
<td>Bony suprascapular foramen</td>
<td>2</td>
<td>3.08%</td>
</tr>
<tr>
<td>Type - V</td>
<td>Absent notch</td>
<td>5</td>
<td>7.69%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>65</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 2. Dimensions of suprascapular notches

<table>
<thead>
<tr>
<th>Type of notch (Polguj’s Classification)</th>
<th>Superior transverse diameter (STD) Mean ± SD</th>
<th>Middle transverse diameter (MTD) Mean ± SD</th>
<th>Maximum depth (VD) Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - I</td>
<td>5.79 ± 0.98</td>
<td>3.69 ± 0.97</td>
<td>8.7 ± 1.43</td>
</tr>
<tr>
<td>Type - III</td>
<td>8.56 ± 1.80</td>
<td>6.64 ± 1.79</td>
<td>5.86 ± 1.27</td>
</tr>
</tbody>
</table>

Table 3. Distance (in mm) between the SSN and supraglenoid tubercle in various types of notches.

<table>
<thead>
<tr>
<th>Type of notch (Polguj’s Classification)</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - I</td>
<td>26.83 ± 1.82</td>
<td>23.0 – 30.1</td>
</tr>
<tr>
<td>Type - III</td>
<td>25.62 ± 1.83</td>
<td>22.9 – 33.5</td>
</tr>
</tbody>
</table>
glenoid cavity were higher for Type I followed by Type III. The difference in the mean values between both types was not statistically significant (Table 5).

However, the mean value of the distance between the SSN and the spinoglenoid notch was higher for Type III than it was in Type I. The difference in the mean values between both types was not statistically significant (Table 6).

As the deepest point of the SSN was considered in measuring distances between the SSN and supraglenoid tubercle or spinoglenoid notch, these distances were correlated with VD in Types I and III SSN.

A weak to fair positive but statistically significant correlation between VD and distance between the SSN notch and supraglenoid tubercle in Type II and Type I respectively (Table 4). On the other hand, a weak negative correlation was observed between VD and distance between the SSN and spinoglenoid notch in Type I, while a weak positive correlation was found between the same parameters in Type III. The correlation was statistically not significant in both types (Table 7).

**DISCUSSION**

Potential morphological factors which predispose a patient to SNES include the shape of the SSN (Dunkelgrun et al., 2003; band-shaped (Polguj et al., 2013), bifurcated (Polguj et al., 2012a, b), or completely ossified (Tubbs et al., 2013) STSL; the presence of the anterior coracocapular ligament (ACSL) (Polguj et al., 2012a, b); the course of the suprascapular nerve and vessels (Polguj et al., 2015); hypertrophy of the infraspinatus muscle (Duparc et al., 2010).

Several morphological variations and classification of the SSN were reported in many populations (Rengachary et al., 1979; Iqbal and Khan, 2010; Sinkeet et al., 2010; Wang et al., 2011). This study concerned with measurements of the SSN and the safe zone distances in Egyptian scapulae.

Polguj et al. (2011) reported that the size and shape of the SSN may be a factor in SNES. In the current study, five types of SSN were observed based on the measured parameters according to Polguj classification. In the studied scapulae, 7.69% revealed the absence of a SSN (Type V).

The above finding is consistent with the study by Soni et al. (2012) However, this was contrary to a study conducted by Wang et al. (2011) who recorded this type in 28% of Chinese studied scapulae.

In addition, Rengachary et al. (1979) reported that absent SSN may be responsible for suprascapular nerve compression by the ossified superior transverse scapular ligament.

In this work, type IV with SSF was only observed in 3.08% of studied scapulae. This was supported by the study of Natsis et al. (2007) in which this type was detected in 7.3% of 423 scapulae, and it was concluded that the presence of foramen was associated with the ossified STSL. Furthermore, Polguj et al. (2011) observed the ossification of this ligament in German, Turkish, Italian, Polish and French.

However, it was later described by Polguj et al. (2013) three types of STSL. The STSL may appear as a fan-shaped ligament (Type I), band-shaped ligament (Type II) and a bifid structure (Type III). The ossified band-shaped STSL should be considered as a potential risk factor in SNES because the space below the bony bridge is significantly reduced compared with the case of the ossified fan-shaped ligament (Polguj et al., 2014). On the other hand, the presence of ossified STSL may be associated with a predilection for a traction-type injury of the suprascapular nerve (Rengachary et al., 1979).

In addition, according to the case given by Polguj et al. (2012a), the ACSL is located below the STSL. The suprascapular artery and nerve ran below ACSL, which increases the likelihood of SNES.

However, interestingly, the ACSL may prevent the development of SNES when the suprascapular nerve runs over the ACSL, in which case the ligament acts as a support for the nerve. Later four
types of the arrangement of the suprascapular triad at SSN were distinguished by Polguj et al. (2011). In case the entire triad runs below the ligament, resulting in the most significant reduction of the space beneath the STSL. In contrast, suprascapular notch veins (SNV), by running along the bottom of the SSN, may protect the suprascapular nerve from irritation by the bone borders of the notch (Reineck and Krishnan, 2009).

In this study, the most prevalent groups were Type III accounting for 47.63% where the VD was shorter than the STD. This is in agreement with Ticker et al. (1998) in Americans, Wang et al. (2011) in Chinese, Polguj et al. (2011) in Poles, Soni et al. (2012), Sangam et al. (2013) in Indian, Mahdy and Shehab (2013) in Egyptians. Type I SSN was seen in 40% and had longer VD compared with STD. This is in accordance with Natsis et al. (2007) who found this type I in 41.85%, having a notch with the longest VD.

The previously described five types of the SSN in the present study are in accordance with the results of Polguj et al. (2011), who reported five types of SSN. Type I had longer maximal depth than the STD. Type II had equal MD, STD, and MTD. In type III STD was longer than maximal depth. In type IV a bony foramen was present. Type V was without a distinct notch.

However, Natsis et al. (2007), in scapulae of German origin, distinguished five types of SSN having a different description. They reported a Type I without a discrete notch; Type II, a notch which had the longest in its transverse diameter; Type III, a notch that was the longest in its vertical diameter; Type IV, a bony foramen and type V, a notch with a bony foramen. Typing of the SSN may have clinical significance for suprascapular nerve entrapment, as a narrow SSN has been found in patients with SNES (Rengachary et al., 1979).

The mean value of safe zone distances differed with the type of SSN. Different authors revealed variable findings. A comparative analysis of such results with the present study for safe zone distances was displayed in (Table 8).

The present statistical study revealed a weak positive but statistically significant correlation between VD and distance between the SSN and the spinoglenoid notch in Type I. On the other hand, Hafezji (2016) found a weak positive correlation between the same parameters in Type III with non-significant correlation in both types, which is in good agreement with the results of the present study.

The above findings contradict the study by Sinkeet et al. (2010), Vyas et al. (2013) and Wang et al. (2011): these authors examined safe zone distances and reported no significant correlation with dimensions of the SSN.

Furthermore, Natsis et al. (2008) reported that the surgeons should be aware of the SSN typing through the radiological examination. Preoperative notch identification allows for a proper choice of the surgical interventions to decompress the suprascapular nerve.

CONCLUSION

The present work displayed the anatomical variants of SSN and analyzed the measurement of safe zone distances to help the clinicians and surgeons to manage different pathological conditions of the shoulder, in order to avoid iatrogenic injury. However, the present study was done with a limited number of Egyptian dry scapulae. More anatomical, radiological and surgical studies should be done with histopathological examination of the suprascapular nerve.

ACKNOWLEDGEMENTS

Authors would like to thank the Heads of Anatomy departments of Faculty of Medicine, Minia University and Faculty of Physiotherapy, Deraya University, for permitting me to study the scapulae available in their anatomy labs.

REFERENCES


Table 8. Comparative analysis of safe zone distances in different studies of the world.

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<tbody>
<tr>
<td>between suprascapular notch &amp; supraglenoid tubercle</td>
<td>Type-I</td>
<td>27.35</td>
<td>27.52</td>
<td>31.59</td>
<td>28.23</td>
<td>26.83</td>
</tr>
<tr>
<td></td>
<td>Type-II</td>
<td>29.03</td>
<td>27.44</td>
<td>33.33</td>
<td>28.42</td>
<td>25.62</td>
</tr>
<tr>
<td></td>
<td>Type-III</td>
<td>16.5</td>
<td>15.61</td>
<td>16.28</td>
<td>15.39</td>
<td>13.99</td>
</tr>
<tr>
<td>between spinoglenoid notch &amp; the posterior rim of the glenoid cavity</td>
<td>Type - I</td>
<td>17.2</td>
<td>15.61</td>
<td>16.36</td>
<td>15.08</td>
<td>13.68</td>
</tr>
<tr>
<td></td>
<td>Type - II</td>
<td>20.13</td>
<td>22.48</td>
<td>21.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>between the suprascapular notch and the spinoglenoid notch</td>
<td>Type - I</td>
<td>20.80</td>
<td>22.83</td>
<td>21.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type - II</td>
<td></td>
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