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Morphological types and morphometrical measurements of the suprascapular notch in both dry bones and human cadavers: anatomical study to improve the outcomes of the diagnostic and interventional procedures in the shoulder region

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Abstract: Understanding the anatomy of suprascapular area helps the clinicians and surgeons in management of any disability at the shoulder region. This work aimed to clear the different morphological and morphometrical types of suprascapular notch (SSN). Unknown 120 dry human scapulae of both sides and 60 formalin-embalmed cadaveric upper limbs (40 males and 20 females) were used in the present study. Three main morphological forms of SSN were reported: J, U, and V-shaped. J-shaped notch showed the highest incidence followed by U-shaped then V-shaped one. Morphometrically, type (III) notch was the most prevalent in both dry bones and cadavers, while the incidence of type (II) was the lowest form. Also, the measurements of superior transverse diameter, middle transverse diameter and vertical dimension of the different types of the notch showed no side or sex significant difference. The suprascapular foramen with ossified superior transverse scapular ligament (STSL) was seen in 5.8% of dry bones and 10% of cadaveric specimens. Fan and band-shaped ossified transverse scapular ligaments were reported. Absence of SSN was seen in 10.8% of dry bones, 7.5% of male and 10% of female specimens with left side predominance. V-shaped, absence, and ossified STSL were considered as predisposing factors of suprascapular nerve entrapment syndrome. Knowledge of the morphology and morphometric parameters of SSN is of great clinical significance for anatomists, radiologists, physiotherapists, orthopedics and neurosurgeons to perform good diagnosis and best planning for surgical or arthroscopic interventions within the shoulder region.

Key words: Scapular, Notch, Cadaver, Morphology, Morphometry

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Introduction

The suprascapular notch (SSN) is a depression on the lateral part of the upper border of scapula. This notch transforms into a tunnel by the superior transverse scapular ligament (STSL). The suprascapular nerve (SN) enters SSN under STSL to supraspinous fossa deep to supraspinatus

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muscle. The SN continues its course to infraspinous fossa passing through the spinoglenoid notch, under the spinoglenoid ligament to supply infraspinatus and shoulder joint. SN originates commonly from the upper trunk of brachial plexus containing roots from C5 and C6. It passes laterally under trapezius muscle within posterior triangle of the neck to reach SSN. Along its course, SN gives motor branches to supraspinatus and infraspinatus muscles and sensory branches to the acromioclavicular joint, glenohumeral joint, subacromial bursa, coracohumeral ligament and coracoacromial ligament [1].

Suprascapular nerve suffers frequent entrapment by the transverse scapular and spinoglenoid ligaments producing pain and shoulder dysfunction, where 1%–2% of the total shoulder pain is caused by the entrapment of SN. Suprascapular nerve entrapment syndrome (SNES) has multifactorial causes including ganglion, cyst, tumor, trauma, rotator cuff tear, calcified ligament, excessive overhead sports practice, and nerve traction. The main symptoms of suprascapular entrapment are pain, weakness, paralysis, and atrophy of supra and/or infraspinatus muscles. Also, the shape and size of SSN are considered as predisposing factors to SNES [2, 3]. Narrow or V-shaped SSN is reported as a predisposing factor of SNES, where SN can be compressed against the sharp margin of SSN during movement of the upper limb, where excessive overhead movements with kinking of SN can induce microtrauma that results in neuropathy of SN [4]. Also in clinical practice, the shape of SSN has a great influence in the selection of arthroscopic technique used for decompression of SN [5].

Moreover, the morphometry and morphological variations in the suprascapular region have a significant role in the development of SNES [6]. Also, the side symmetry and sex distribution of SSN are considered as predisposing factors in SNES [7]. So, plentiful and clear anatomical knowledge of morphology and morphometry of the suprascapular region provides clear explanation of the most etiopathological factors of SNES. These data are essential in the clinical practice to facilitate the diagnosis and improve outcome of the different surgical or endoscopic procedures associated with the decompression of SN [5, 8].

Different methods were used for morphological and morphometrical classification of SSN in both dry bones and cadavers. The most common method of SSN morphological classification was described by Rengachary et al. [4] who classified SSN into six types based on its shape and degree of STSL ossification. Also, Ticker et al. [9] classified SSN into V-shaped and U-shaped forms only, while Iqbal et al. [10] reported U, V and J-shaped SSN. Meanwhile, Natsis et al. [8] classified SSN into five types based on the length of the maximum vertical diameter (MD) and superior transverse diameter (STD). Meanwhile, Polguj et al. [11] developed a new classification method of SSN based on the measurement of STD, middle transverse diameter (MTD) and MD of SSN into three main types: in type (I) MD>STD, in type (II) MD=STD=MTD, and in type (III) STD>MD. In addition, the bony canal (type IV) and the discrete or absent notch (type V) are also reported.

The aim of this study is to describe the different morphological types and morphometrical measurements of SSN as a preliminary study to avoid the iatrogenic injury of SN and improve the outcome of the different diagnostic and interventional techniques of SN decompression.

Materials and Methods

Unknown 120 dry adult human scapulae (60 right and 60 left) and 60 formalin-fixed cadaveric upper limbs (40 males and 20 females) were used in this study after approval of the Medical Ethical Committee of the Faculty of Medicine, King Abdulaziz University. The specimens were obtained from Anatomy Department, Faculty of Medicine, King Abdulaziz University, Jeddah, Saudi Arabia. Only those scapulae which were free from physical deformity were included in the study. Based on Polguj's classification [11], SSN was classified morphologically into five types: U, V, J-shaped, absent or discrete notch, and a complete foramen with ossified STSL (Fig. 1).

The shoulder and suprascapular regions were dissected in all cadaveric specimens, where a horizontal skin incision along the clavicle was made to expose the underlying muscles. Then, trapezius and deltoid muscles were detached at their scapular attachments. The supraspinatus muscle was reflected to visualize the supraspinous fossa, SSN and STSL. Then, the morphological types of SSN were reported. Moreover, as described by Polguj et al. [12], SSN of dry bones and cadaveric specimens were classified morphometrically into three main types based on measurements of STD, MTD, and MD, where in type (I) STD<MD, in type (II) STD=MD, and in type (III) STD>MD (Figs. 2, 3). In addition, a fourth category entitled type (IV) was used for scapulae without any depression and type (V) is a bony canal by the ossified STSL. Also, the ossified STSL and its measurements were recorded

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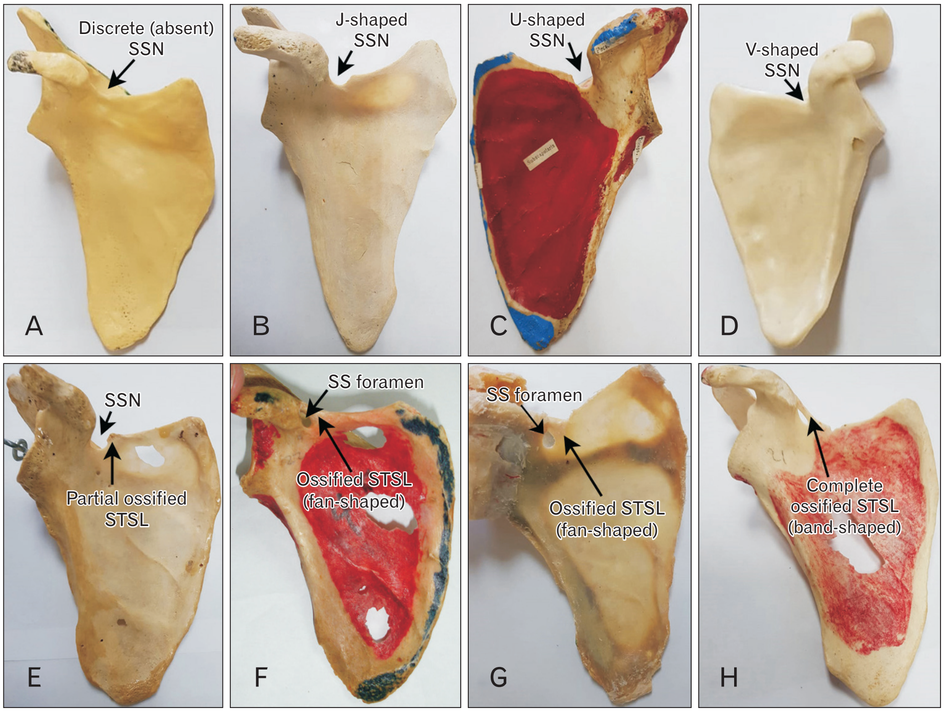

Fig. 1. Morphological types of the SSN based on Polguj's classification. (A) Discrete type, (B) J-shaped type, (C) U-shaped type, (D) V-shaped type, (E) partial ossified STSL, (F) foramen with complete ossified fan-shaped STSL, (G) foramen with complete ossified fan-shaped STSL, (H) foramen with complete ossified band-shaped STSL. SSN, suprascapular notch; STSL, superior transverse scapular ligament.

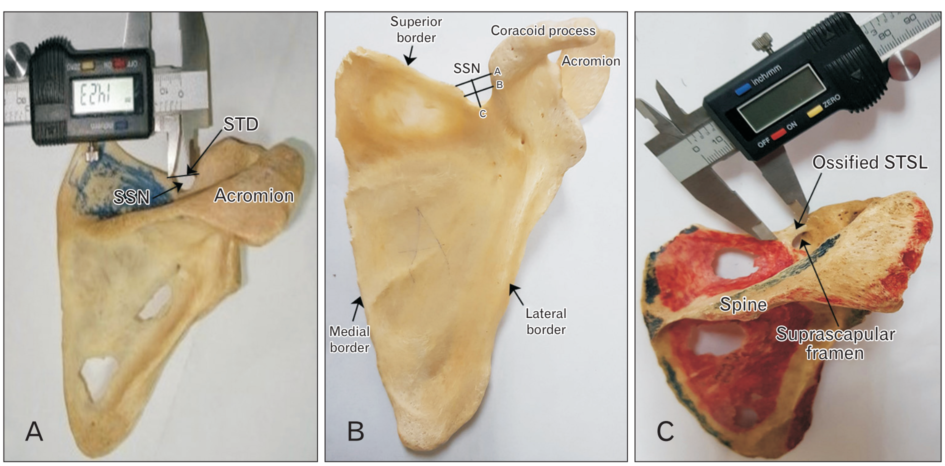

Fig. 2. Measurement of the different dimensions of SSN and STSL. (A) Measuring the STD of the notch. (B) Different parameters of the SSN including STD (A), MTD (B) and MD (C), (C) measuring the length of the ossified STSL that representing the STD. SSN, suprascapular notch; STSL, superior transverse scapular ligament; STD, superior transverse diameter; MTD, middle transverse diameter; MD, maximum vertical diameter; Line A, the STD of the notch; Line B, the MD of the notch; Line C, the MTD.

as well. All dimensions of SSN were measured by digital Vernier caliper of 0.01 mm accuracy as following: (1) The maximum vertical diameter or depth (MD) is the longitudinal measurement taken in the vertical plane from an imaginary line between the superior corners of SSN to its deepest point. (2) The STD is the horizontal length taken in the horizontal plane between the superior corners of SSN. (3) The MTD is the horizontal length taken in the horizontal plane between the opposite walls of SSN at a midpoint of MD and perpendicular to it.

Statistical analysis

All data were categorized according to morphology and side of the body. Each measurement was done twice and the mean of values was taken. Revision, tabulation, and analysis of the data was done using SPSS version 28 (IBM Co.). Mean±SD expressed on the continuous variables as descriptive statistics. Also for qualitative data, number, frequency and percentage (%) were used to provide descriptive statistics in tables. Using one way ANOVA followed by a Tukey Kramer *post-hoc* analysis, the significant difference between right and left, also between male and female measurements was encountered; the significance was considered at *P*-value <0.05.

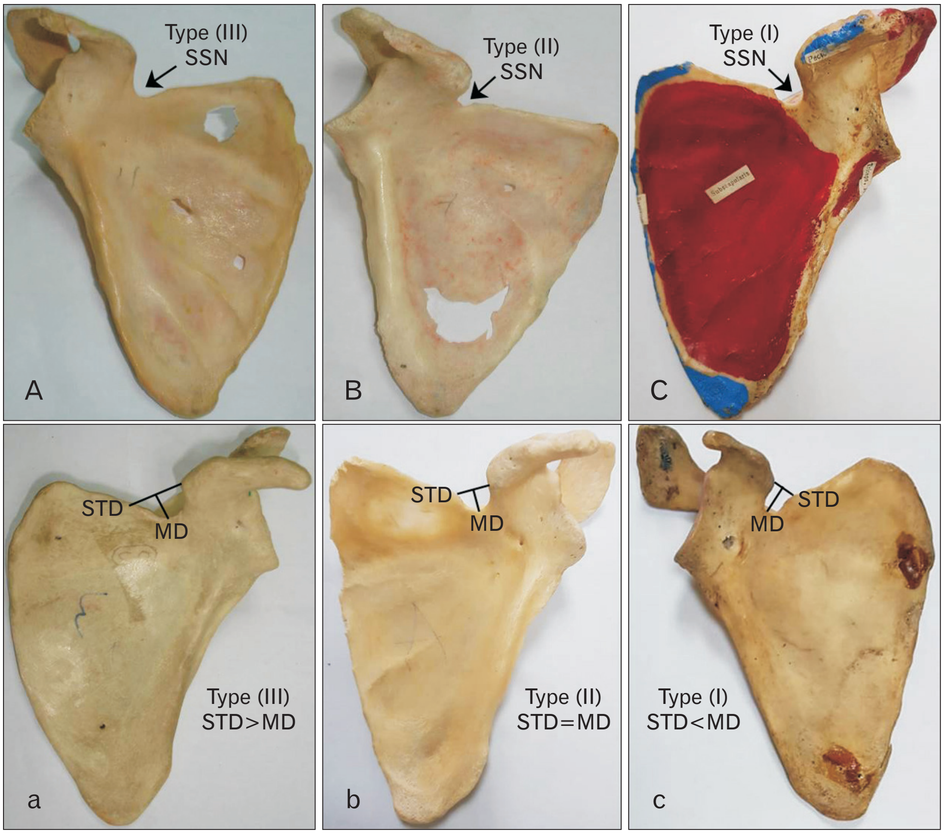

Fig. 3. Morphometric types of the SSN based on Polguj's classification. (A) Type III SSN, (a) having STD longer than the MD. (B) Type II SSN, (b) equal length of STD and MD type II SSN. (C) Type I suprascapular notch SSN, (c) showing the length of STD shorter than the MD. SSN, suprascapular notch; STD, superior transverse diameter; MD, maximum vertical diameter.

Results

Incidence of the morphological types of SSN according to Polguj's classification revealed the J-shaped form was the highest and more predominant in the right side of both dry scapulae and cadaveric limbs. Where, it was seen in 40% of right and 35% of left dry scapulae; 45% of right and 40% of left male limbs; 40% of right and 30% of left female limbs. The second type of SSN was the U-shaped form that was seen in 25% of right and 30% of left dry scapulae, 25% of right and 30% of left male limbs, and 30% of both right and left female limbs. However, the V-shaped form was seen in 20% of right and 16.7% of left dry scapulae, 15% of right and 10% of left male limbs, 10% of right and 20% left female limbs. The presence of suprascapular foramen (type IV) was seen in 5% of right and 6.7% of left dry scapulae, 10% of both right and left male and female limbs. However, the indolent or absent notch (type V) was observed in 10% of right and 11.7% of left dry scapulae, 5% of right and 10% of left male and 10% of both right and left female limbs. No side or sex significant difference were reported in the incidence of the different morphological types of SSN (Table 1).

According to Polguj's classification, the SSN was classified morphometrically into three main types depending on the ratio between the measurements of their different dimensions (STD, MTD, and VD). The incidence of type (III), that has VD<STD, was the highest one (50% of dry bones, 47.5% of male scapulae, and 45% of female scapulae) with right predominance, while the incidence of type (II), that has VD=STD, showed the lowest incidence (7.5% in dry bones, 12.5% in male scapulae, and 10% in female scapulae). Meanwhile, the incidence of type (I), that has VD>STD, was 25.8% of dry bones, 22.5% of male and 25% of female scapulae. No side or sex significant difference was reported in the incidence of the different morphometric types of SSN (Table 2).

Morphometrically, in type (I), where VD>STD, the mean of VD was 12.9±2.8 mm and that of STD was 10.9±2.2 mm in right dry scapulae, while the mean of VD measured 11.8±2.8 mm and that of STD was 7.8±2.7 mm of the same type in left dry scapulae. In type (II), the mean of VD and STD was approximately equal to 11 mm in right scapulae and 10 mm in left scapulae. In type (III), the mean of VD

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Table 1. Incidence of the morphological types of suprascapular notch based on Polguj's classification

Shape of SSN (Polguj's classification)	Dry scapulae (n=120)		Cadaveric scapulae (n=60)					
			Male (n=40)		Female (n=20)		Total (n=60)	
	Right	Left	Right	Left	Right	Left	Right	Left
J-shape (type I)	24 (40)	21 (35)	9 (45)	8 (40)	4 (40)	3 (30)	13 (43.3)	11 (36.7)
U-shape (type II)	15 (25)	18 (30)	5 (25)	6 (30)	3 (30)	3 (30)	8 (26.7)	9 (30)
V-shape (type III)	12 (20)	10 (16.7)	3 (15)	2 (10)	1 (10)	2 (20)	4 (13.3)	4 (13.3)
Foramen (type IV)	3 (5)	4 (6.7)	2 (10)	2 (10)	1 (10)	1 (10)	3 (10)	3 (10)
Absent (indolent) (type V)	6 (10)	7 (11.7)	1 (5)	2 (10)	1 (10)	1 (10)	2 (6.7)	3 (10)

Values are presented as number (%). SSN, suprascapular notch.

Table 2. Incidence of the different types of suprascapular notch according to the morphometric classification of Polguj

Type of SSN	Dry scapulae (n=120)			Cadaveric scapulae (n=60)							
				Male scapulae			Female scapulae			All cadavers	
	Right	Left	All	Right	Left	All	Right	Left	All	Right	Left
VD>STD (type I)	15 (25)	16 (26.7)	31 (25.8)	4 (20)	5 (25)	9 (22.5)	2 (20)	3 (30)	5 (25)	6 (20)	8 (26.7)
VD=STD (type II)	5 (8.3)	4 (6.7)	9 (7.5)	2 (10)	3 (15)	5 (12.5)	1 (10)	1 (10)	2 (10)	3 (10)	4 (13.3)
VD<STD (type III)	31 (51.7)	29 (48.3)	60 (50)	11 (55)	8 (40)	19 (47.5)	5 (50)	4 (40)	9 (45)	16 (53.3)	12 (40)
Foramen (type IV)	3 (5)	4 (6.7)	7 (5.8)	2 (10)	2 (10)	4 (10)	1 (10)	1 (10)	2 (10)	3 (10)	3 (10)
Absent (discrete) (type V)	6 (10)	7 (11.7)	13 (10.8)	1 (5)	2 (10)	3 (7.5)	1 (10)	1 (10)	2 (10)	2 (6.7)	3 (10)

Values are presented as number (%). VD, vertical depth; STD, superior transverse diameter; MTD, middle transverse diameter.

Table 3. Morphometric measurements of the suprascapular notches' dimensions according to Polguj's classification

Scapulae	Side	VD>STD (type I)	VD=STD (type II)	VD<STD (type III)	Foramen (type IV)
Dry scapulae (mm)	Right	VD=12.9±2.8	VD=11.0±2.65	VD=7.7±2.6	VD=2.4±1.2
		STD=10.9±2.2	STD=10.9±2.53	STD=12.9±3.1	TD=7.3±0.71
		MTD=8.7±2.4	MTD=8.04±3.0	MTD=7.6±2.2	
	Left	VD=11.8±2.8	VD=10.16±1.66	VD=7.5±2.3	VD=3.6±0.78
		STD=9.8±2.7	STD=10.13±1.63	STD=13.9±3.5	TD=6.6±0.57
		MTD=7.7±2.3	MTD=7.5±1.6	MTD=8.6±2.5	
Male scapulae (mm)	Right	VD=13.4±1.9	VD=12.54±2.86	VD=9.9±1.1	VD=4.2±0.78
		STD=11.5±1.3	STD=12.52±2.53	STD=13.9±2.9	STD=8.5±0.99
		MTD=10.2±1.4	MTD=9.9±1.6	MTD=8.9±1.95	
	Left	VD=12.0±3.4	VD=11.82±1.84	VD=8.9±2.02	VD=4.7±0.78
		STD=9.7±3.3	STD=11.94±1.90	STD=12.9±2.6	STD=7.2±0.92
		MTD=7.9±2.2	MTD=8.93±1.1	MTD=10.2±1.9	
Female scapulae (mm)	Right	VD=12.2±1.6	VD=11.4±1.81	VD=8.9±1.5	VD=3.7
		STD=10.3±1.7	STD=11.3±1.51	STD=12.61±2.6	STD=7.5
		MTD=8.4±2.5	MTD=10.6±1.7	MTD=8.5±1.6	
	Left	VD=11.4±2.9	VD=11.13±1.98	VD=8.3±2.1	VD=3.2
		STD=9.1±2.6	STD=11.09±1.73	STD=13.1±3.8	STD=6.3
		MTD=7.2±2.7	MTD=9.8±1.6	MTD=8.2±1.9	

VD, vertical depth; STD, superior transverse diameter; MTD, middle transverse diameter. No side or sex significant difference was reported between the different dimensions of SSN of dry bones and cadaveric specimens (P>0.05).

was 7.7±2.6 mm and that of STD measured 12.9±3.1 mm in right scapulae and the mean of VD measured 7.5±2.3 mm and that of STD was 13.9±3.5 mm in left scapulae. Moreover, In type (I) of cadaveric male specimens, the mean of VD was 13.4±1.9 mm and that of STD measured 11.5±1.3 mm in right scapulae, while in left scapulae the mean of VD was 12.0±3.4 mm and that of STD measured 9.7±3.3 mm. In type (II) of male limbs, the main of right VD and STD was approximately 12.5 mm and that of left scapulae was about 12 mm. In type (III), the VD main of right male scapulae

Table 4. Morphometric measurements and type of the ossified superior transverse scapular ligament of dry scapulae

Dry scapulae	Right	Left	*P*-value	*t*-value
Dimensions of the ossified STSL (mm)				
Length	13.4±0.14 (0.1)	12.5±2.1 (1.5)	0.48	0.8
Middle width	4.15±1.6 (1.15)	4.7±0.28 (0.2)	0.57	0.63
Lateral width	4.4±1.9 (1.35)	5.5±2.4 (1.7)	0.63	0.54
Medial width	5.4±3.4 (2.4)	8.9±2.97 (2.1)	0.31	1.12
Thickness	2.65±0.5 (1.20)	2.8±0.28 (0.2)	0.83	0.23
Fan-shape	2 (3.3)	3 (5)		
Band-shape	1 (1.7)	1 (1.7)		
Incidence of ossified STSL	3 (5)	4 (6.7)		
Absent SSN	6 (10)	7 (11.7)		

Values are presented as mean±SD (SEM). SSN, suprascapular notch; STSL, superior transverse scapular ligament.

measured 9.9±1.1 mm and that of STD was 12.9±2.6 mm, while in left scapulae the mean of VD measured 8.9±2.0 mm and that of STD was 13.9±2.9 mm. However in cadaveric female specimens, the mean of VD was 12.2±1.6 mm and that of STD measured 10.3±1.7 mm in right scapulae, but in left scapulae, the mean of VD measured 11.4±2.9 mm and that of STD was 9.1±2.6 mm in type (I). In type (II), the mean of both VD and STD was approximately 11.3 mm in right and 11.1 mm in left scapulae. In type (III), the means of VD was 8.9±1.5 mm and that of STD measured 12.6±2.6 mm in right scapulae, but in left scapulae the mean of VD was 8.3±2.1 mm and that of STD measured 13.1±3.8 mm (Table 3).

A significant correlation (r) was observed between STD, MTD, and VD of right scapulae (R=0.009; *P*=0.01) in all three types of SSN, and type (III) of left dry bones. Also, a significant correlation was determined between VD and STD of type (II) of left scapulae as well. However, there is no significant correlation was reported between STD and VD in type (I) and between MTD and both STD and VD of type (II) of left scapulae. Meanwhile, in male cadavers, there is a significant correlation between VD and STD in type (I) and type (II) of right and type (II) of left scapulae. Also, there is a significant correlation between STD and VD of type (I) and type (II) of left male scapulae. Moreover, the MTD showed a significant correlation with STD and VD of type (III) of left male scapulae. However, in the limbs of female cadavers, all dimensions of type (II) revealed a significant correlation with the dimensions of type (I) and type (III) of right and left scapulae.

The incidence of the ossified STSL in dry bones was 5% in right and 6.7% in left-side bones; 3.3% of right and 5% of left was fan-shaped STSL, while the remaining 1.7% of them was band-shaped in both right and left-side. STSL was absent in 10% in right and 11.7% in left sided-bones. The measurements of these ossified ligament revealed that the mean of its length was 13.4±0.14 mm of right and 12.5±2.1 mm of left STSL, while the widths and thickness of the left-side ligaments were larger than those of right-side ones with no significant (*P*>0.05) difference (Table 4).

Discussion

Updated morphological and morphometrical data on the suprascapular region help clinicians and surgeons in the diagnosis and treatment of suprascapular neuropathies and decompression of SN [13]. Suprascapular nerve entrapment syndrome was commonly reported in the sport persons who excessively abduct and lateral rotate the upper limbs such as volleyball, tennis players and weight lifting [11]. The incidence of SNES is 1%–2% of all patients with male predominance under the age of 35 years [3, 12, 14].

Morphology and morphometric dimensions of SSN in one country could not be used as a standard reference for other locations, where the race, genetic structure, environmental difference and geographic nature were considered as population specific factors responsible for the variations across the populations [13, 15, 16]. The morphological variations of SSN were considered as one of the predisposing factors to SNES, mainly the narrow or V-shaped SSN [8, 13, 16], where excessive rotation and abduction of the upper limbs could induce marked kinking with subsequent irritation, microtrauma, injury and entrapment of SN. Such effect was described as the sling effect of SSN on SN [4].

So, SSN was classified morphologically by different methods. The most popular one was that produced by Rengachary et al. [4] who classified the SSN into six types based on its

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morphologic and geometric feature: type (I) (absent notch or shallow notch), type (II) (shallow V-shaped notch), type (III) (U-shaped notch), type (IV) (deep V-shaped notch), type (V) (partial ossification of STSL) and type (VI) (complete ossification of STSL with foramen transformation). Another method was reported by Tubbs et al. [16] who simply classified SSN into U-shaped and V-shaped morphological types only, while Iqbal et al. [10] reported three morphological types of SSN including J-shaped, U-shaped, and V-shaped. Moreover, Natsis et al. [8] classified SSN, based on the vertical and transverse dimensions of SSN, into five main types as following: no discrete SSN (type I), SSN with longest STD (type II), SSN with longest vertical diameter (type III), boy foramen (type IV), and notch with bony foramen (type V). Meanwhile, Polguj et al. [11] classified SSN into five main types by a more specific method based on the measurements of STD, MTD, and MD. In type (I), MD was greater than STD, while in type (II) MD, STD and MTD were equal. But, type (III) exhibited longer STD than MD; type (IV) was bony canal, and a discrete notch described as a type (V).

In the present study, based on Polguj's morphological classification of SSN, the J-shaped SSN revealed the highest prevalence followed by U-shaped then V-shaped forms, where the J-shaped SSN was seen in 40%–45% of right and 30%–40% of left scapulae in both dry bone and cadaveric specimens of both sexes, while the U-shaped notch was observed in 25%–30% of with left predominance and the V-shaped notch was reported in 10%–20% with right predominance in both dry bones and male cadaveric specimens, but with left predominance in female cadaveric specimens. In agreement with the results of the present study, the J-shaped SSN was the common form of SSN in Indians 39% [17] Pakistani 22% [10] populations. However, in disagreement with the results of this study, the more prevalent form of SSN was the U-shaped followed by V-shaped then J-shaped in Polish [7] and Indians [18]. Also, the incidence of the U-shaped followed by the J-shaped then V-shaped forms was reported in other studies [15, 19-22]. Meanwhile, only two main forms U- and V-shaped SSN were reported, where the U-shaped SSN revealed higher prevalence than V-shaped form in these studies [9, 23, 24].

On contrary, SSN of type (I) of Rengachary classification was the most common type in adult Malawian scapulae, which was found in 46 scapulae (36.8%) and SSN of type (III) was reported in 37 (29.6%) scapulae. The authors added that, the least common type was type (VI), which was found in only one (0.8%) scapula [25]. In consistent with the findings of the previous study, Kumar et al. [26] found 87 scapulae (32.46%) of type (I). On the other hand, type (II) of SSN was the most prevalent one, where it was observed in 171 (58.16%) of Chinese [27] scapulae. Meanwhile, type (IV) was the most common type in Italian population which was observed in 156 (31.1%) scapulae [10]. Based on a Rengachary classification system, the narrow SSN, particularly of type (VI) seemed to be as one of the common causes of SNES [22, 24]. Clinically, due to their short dimensions and foramen formation, the incidence of SNES was more commonly reported among the persons having smaller SSNs such as type (III), (IV), and (VI) than the persons who have larger SSN like type (I), (II), and (V) [4, 11]. The morphological differences of SSN were explained by the fact that the shape of the SSN could be influenced by the ossification of coracoid process [19].

With reference to Polguj et al. [3] and Natsis et al. [8] classification methods, who considered the measurements of STD, MD, and MTD as parameters to classify SSN, the results of this study revealed that type (III) (STD>MD) was the highest prevalence followed by type (I) (MD>STD) and the lowest incidence was type (II) (MD=STD). Where, type (III) was seen in 50% of dry bones, 47.5% of male specimens and 45% of female specimens with right predominance, while type (I) was observed in 25% of females and dry bone and in 22.5% of male specimens with left side predominance. However, the incidence of type (II) was higher in male (12.5%) than that of female (10%) and dry bone (7.5%) specimens. In accordance with the results of the present study, the incidence of type (III) (STD>MD) of SSN was the commonest form with right predominance followed by type (I) then type (II) in Indians [17, 23]; in Polish [3, 6, 7, 11] and in Kenyan [21]. However, Polguj et al. [12] reported that the prevalence of type (I) of SSN (narrow and deep) was higher in male than in female's specimens. This discrepancy might be due to the difference in number and/or the race of the specimens used in each study. From clinical point of view, these findings could explain why males are approximately three to four times more likely suffering from a neuropathy of SN than females and confirmed the sling effect of the narrow and deep SSN on SN [4]. Also, such observation demonstrated that SNES seemed to be more likely correlated with type (I) (VD>STD) than other types of SSN [2].

Meanwhile, type (I) of SSN was the highest incidence followed by type (III) then type (II) in Americans [4]. On the other hand, only SSN of types (I) and (III) with absence of type (II) were reported in different literatures including Ticker et al. [9] (Americans), Urgüden et al. [28] (Turkish), Lucena et al. [29] in Brazilians, Mahdy and Shehab [30] in Egyptians, and Wang et al. [27] in Chinese. So, the incidence difference of SSN types could be related to the number and race of the specimens used in each study.

In the present study, the measurement of VD and STD of type (I) SSN of right-sided scapulae was longer than that of left-sided scapulae in both dry and cadaveric specimens. Where, the measurement of VD varied from 12.2±1.6 mm to 13.4±1.9 mm in right-sided scapulae and from 11.4±2.9 mm to 12±3.4 mm in left-sided scapulae. Also, the mean of STD of right-sided scapulae ranged from 10.3±1.7 mm to 11.3±1.3 mm and that of left-sided scapulae was 7.8±2.7 mm to 9.7±3.3 mm. However, the mean of both VD and STD in female specimens revealed higher values than that of male specimens in both right and left-sided scapulae of type (I). But in type (II), the mean of both VD and STD of male scapulae were higher than that of female scapulae with right-sided predominance in all dry and cadaveric specimens. Meanwhile, the mean of VD of right-sided scapulae of type (III) was higher than that of left-sided scapulae but the mean of STD of right-sided scapulae showed lower value than that of left-sided ones in all dry and cadaveric specimens. Where, the mean value of VD varied from 7.7±2.6 mm to 9.9±1.1 mm and that of STD was 12.6±2.6 mm to 13.9±2.9 mm. This means that the right SSN of type (III) had narrow STD and deep VD, while the left-sided SSN had wide STD and shallow VD.

Similar findings were reported by Polguj et al. [3, 11] who stated that the measurements of all dimensions of SSN of Polish population showed a high significant difference between male and female specimens but the recorded values were less than that of the present study. Meanwhile, Yücesoy et al. [31] by US investigation of SSN showed only a significant difference in VD of SSN between male and female specimens but STD revealed no significant sex difference. Moreover, by US investigation of 120 adult Poland patients, Jezierski et al. [6] found a significant side difference of VD and STD, where the mean of right STD was 14.8±4.8 mm and VD measured 6.3±2.1 mm while the measurement of STD and VD of left sided SSN was 13.8±4.0 mm and 6.6±2.3 mm respectively. Also, Lucena et al. [29] reported significant side difference between VD and STD of 97 dry Brazilians scapulae in both type (I) and type (III) SSN, where VD and STD of right SSN of type (I) measured 10.1±2.1 mm and 8.4±2.1 mm but the mean of VD and STD of left-sided SSN was 7.8±1.3 mm and 7±1.7 mm respectively. In type (III), VD and STD of right SSN measured 4.9±2.4 mm and 8.2±2.9 mm but that of left-sided SSN was 3.9±2.1 mm and 7.9±2.5 mm. However, Manikum et al. [14] reported that, no morphometrical significant difference was recorded in all types of SSN between male and female scapulae but a significant difference was observed between right and left-sided SSN in dry Indian adult scapulae, where MD of the notch was larger in males, while STD was wider in females, also MD of right sided SSN (7.5) was significantly deeper than the left-sided (6.14) SSN but STD showed no side significant difference. Meanwhile, Albino et al. [2] concluded that gender, age, and scapular dimensions were not related to the dimensions and types of SSN.

In the present study, SSN was absent in 10%–11.7% of dry scapulae, 5%–10% of male scapulae and 10% of female scapulae without sex or side significant difference. Similar incidence was reported in different populations: 8.3% in German [8], 10% in Egyptians [32], and 12.4% in Italians [2]. However, higher values of the bony foramen was reported: 15%–20% in Indians [20], 22.5% in Pakistani [10], 29.9% in Brazilians [29]. Meanwhile, lower incidence rates were recorded in other studies; 6% in Poland [3], 2.2% in Kenyan [22], 6.1% in Egyptians [30], and 5.1% in Indians [17]. The absence of SSN was considered as a predisposing factor for SNES, where the possibility of SN compression by the upper border of the scapula. Also, the complete absence of SSN, ossification of STSL, and V-shaped SSN were hypothesized as etiopathological factors of SNES [3, 6].

Ossification of STSL with foramen transformation of SSN was considered as a predisposing factor for SNES due to the reduction of SSN size [2, 3]. In the present study, the ossified STSL was seen in 5.8%; 4.16% of them was fan-shaped and 1.7% was band-shaped of the dry bones with no side significant difference. In the literature, the incidence of complete ossification of STSL was stated to be between 3 to 12.5% [3], where its incidence was 12.5% and 6% in Turkish [28], 7.3% in Germans [8], 7% in polish [3], 8% in Indians [23], and 8% in Uganda [13]. However, lower incidence rates were reported in other studies; 1.36% in Chinese [27], 2.47% in Anatolian population [33], 3% in Egyptian [30], 3% in Kenyan [22] and 3.7%–4% in Americans [4, 16]. Meanwhile, the highest incidence rate of the ossified STSL was reported in Brazilians 30.6% [34]. Conversely, this type was not found in 193 dry

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Nigerian adult scapulae [15]. Moreover, the ossified STSL was observed only in one (0.8%) out of 125 Malawian scapulae [25].

The exact cause of the diversity and mechanism of STSL ossification was not identified yet, where the incidence of complete STSL ossification seemed to be population specific with genetic and geographic relation in each ethnic group [33]. Moreover, the difference in STSL ossification might be related to the variation in the classification methods of SSNs used in each study [27]. Meanwhile, Moriggl et al. [35] supposed another explanation depending on the aging process and mechanical load on STSL, where the progression of endochondral ossification induced bony spurs at superior edge of the SSN with subsequent shortening of the STSL. So, the tendency of STSL to ossify might be related to the fibrocartilaginous character of the ligament in adding to the mechanical and genetic differences [32]. The difference in the shape of the ossified STSL could be related to the extent of the ossification within the STSL, where the ossification of tendon and ligament was suspected in the metabolic bone diseases and disorder of mineral metabolism [35].

The correlation of the incidence rate of the ossified STSL with sex and side of the scapulae is a controversy, where Polguj et al. [7] and Tubbs et al. [16] reported that the ossified STSL showed higher incidence rate in males and in right scapulae. Conversely, a higher frequency of ossified STSL was reported in female cadavers [3, 36]. Meanwhile, Albino et al. [2] did not found any relation between SSN type and sex of the individuals. But, they observed more ossified STSL on the right side scapulae. The higher incidence of the ossified STSL on right side scapulae could be related to the predilection for right-sided handedness in most people [16].

In the present study, the ossified STSL in dry bones were of two forms; fan-shaped in 4.16% and band-shaped in 1.7% without side significant difference. However, the ossification of the band-shaped STSL was found to be three times more frequently than the fan-shaped type [7]. Clinically, complete ossification of STSL [4, 33] and shape of the ossified STSL were considered as predisposing factors for SNES, where the space below the ossified band-shaped STSL showed a significant reduction compared with that in case of the ossified fan-shaped ligament. Thus, the ossified band-shaped STSL was considered as a potential risk factor in SNES [7, 16]. Such observation could explain the discrepancy between the rate of STSL ossification and the occurrence of SNES, where a higher percentage of the ossified STSL (30.7%) was reported in Brazilian population without concomitant increase in the percentage of SNES [34]. Moreover, the risk of SN neuropathy could be increased by the presence of a bifid STSL or trifid STSL [7].

Recently, Honoki et al. [37], who studied the correlation of SSN morphology with SN palsy in Japanese patients, concluded that the ossification of STSL was an age-related change process without significant sex difference, where the authors noticed a significant increase of the ossified STSL in patients >40 years-old. Also, the authors reported no relation between the narrow notch and the ossification of STSL with the onset of SSN palsy. Moreover, the authors added that, there was no statistical significant difference in the distribution of SSN morphological types, mean age, sex and ossification rate of STSL between SN palsy and non-SN palsy groups. Such previous results were in strong agreement with Yamakado [38] who demonstrated progressive ossification of STSL over time with no significant sex difference in the SSN types and STSL ossification rate. In agreement with Yamakado [38]; the medial ossification of STSL was the commonest form with lower rate of lateral and central ossification [37]. So, SN palsy seemed to be a multifactorial syndrome including dynamic effect such as sling effect, mass or ligament compression.

The coexistence of SSN and suprascapular foramen (SSF) was rarely observed in the literature, where its frequency was often below 1%. The authors supposed that the frequency of this anatomical variation depend on the population [3]. Such type was not observed in this study. However, Natsis et al. [8] found 3 cases among a 432 German dried scapulae (0.07%). Similarly, Saikia et al. [24] found one out of 138 Kenyan scapulae (0.72%). Polguj et al. [3] found two left and one right out of 616 (0.33) scapulae of Polish patients by CT investigation. Moreover, the frequency of coexistence of SSN and foramen in Indians varied from 0.56% to 1.33% [39]. It was supposed that the presence of coexistence SSN and foramen could increase the risk of SN entrapment syndrome, because of the additionally reduced size of the foramen [3]. Such bony foramen was mostly formed by the complete ossification of a wide and flat STSL [27].

In the present study, the morphometrical measurements of the ossified STSL in dry bones revealed a significant side difference, where its mean length measured 13.4±0.14 mm on right and 12.5±2.1 mm on left-side bones and the mean of its medial width was 5.4±3.4 mm on right and 8.9±2.97 mm on left, while the mean of its lateral width measured

4.4±1.9 mm on right and 5.5±2.2 mm on left-sided scapulae with significant difference. The mean of its thickness was 2.65±0.5 mm on right and 2.8±0.28 mm on left-sided ligaments. However, Saha et al. [40] found 11.4% ossified STSL with 57.5% of them fan-shaped and 42.2% band-shaped. The mean length, width, and thickness of all STSL were 7.5±1.5 mm, 3.4±0.9 mm, and 2.2±0.6 mm respectively. Meanwhile, Kharay et al. [41] reported that the ossified STSL was seen in 9.7% of the bones, 61.5% of them were fan-shaped with equal distribution on both sides and 38.5% of them were band-shaped form with right predominance. The measurements of the fan-shaped STSL were 17.4±2.3 mm length, 12±1.6 mm medial width, and 4.5±1 mm lateral width, while that of the fan-shaped STSL were 15.6±1.2 mm length, 5.2±1.2 mm medial width, and 5±1 mm lateral width. Also, Rekha and D'sa [42] showed ossified STSL in 9.2% of the specimens. The fan-shaped STSL revealed a higher incidence that band-shaped form with left side predominance. The mean length of STSL was 9.8 mm on left and 8.8 mm on right and its medial width measured 4 mm and that of lateral width was 4.1 mm. The difference in the incidence and measurements might be related to number or race of the specimens used.

In conclusion, the difference of morphological types and morphometrical measurements of SSN dimensions are multifactorial and population specific. These variations may be related to the sample size, genetic structure, race, and age of the individuals used in the study. So, knowledge of the morphological and morphometrical parameters of SSN can provide an excellent guide to the clinicians, radiologists, neurosurgeons and orthopedic surgeons to obtain clear diagnosis and making proper planning for the surgical or endoscopic interventions at the shoulder region with better results and low complications.

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Author Contributions

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Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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