ORIGINAL ARTICLE

Eur. J. Anat. 22 (2): 127-134 (2018)

3D computed tomographic mapping of ossified transverse scapular ligaments and their relationship to coracoid, glenoid and acromion: Landmarks assisting safe release for suprascapular nerve decompression

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SUMMARY

Operative treatment of suprascapular nerve (SSN) entrapment consists of decompression of the nerve by surgical release of superior transverse scapular ligament (STSL) and spinoglenoid ligament (SGL). The surgical explorations rely on the relationship of anatomic landmarks such as coracoid, glenoid and acromion to these ligaments. Anatomical data for the relationship of bony landmarks to ossified STSL and ossified SGL are deficient. The aim of our study was to quantify the radio-anatomic distances from ossified STSL and ossified SGL to bony landmarks.

Multidetector CT (128-slice) scans of dry scapulae having ossified superior transverse scapular ligament (STSL) and ossified spinoglenoid ligament (SGL) were acquired. 3D volume rendered reconstruction of ossified suprascapular ligaments, and their distances from Coracoid, Glenoid and Acromion were recorded. In addition, morphometric parameters of unusual bony tunnels in the supraspinous fossa were documented.

Twenty-seven dry scapulae having ossified transverse scapular ligaments and two scapulae having bony tunnels were evaluated. The length of ossified ligaments was 1.31-2.31 cm and width was 0.3-0.9 cm. The distances from lateral edge of ossified ligaments to Coracoid was 3.92-4.42cm, to Glenoid was 1.37-3.01cm and to Acromion was 4.43-5.92cm.

Knowledge of the 3D morphometry of ossified transverse scapular ligaments described in this study will be helpful in planning their safe endoscopic and open resection. This study uniquely quantifies a rare variant of SGL and bony tunnels in supraspinous fossa.

Key words: Nerve entrapment – Suprascapular notch – Spinoglenoid notch – Ossified superior transverse scapular ligament – Ossified spinoglenoid ligament

INTRODUCTION

The suprascapular region is the most common site for suprascapular nerve (SSN) entrapment (Zehetgruber et al., 2002). The SSN arises from the upper trunk of the brachial plexus (C4, 5, 6) in the neck. It, then, enters the supraspinous fossa through the suprascapular notch, inferior to the superior transverse scapular ligament (STSL). Distally, it runs deep to the supraspinatus muscle and

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Submitted: 27 November, 2016. *Accepted:* 3 January, 2018.

curves around the base of the scapular spine (spinoglenoid notch), to reach the Infraspinatus muscle. In the spinoglenoid notch, SSN passes inferior to the spinoglenoid ligament (SGL). SGL is also known as the inferior transverse scapular ligament (Bhatia et al., 2006).

SSN is a mixed peripheral nerve. Its motor component supplies the supraspinatus and infraspinatus muscles, while its sensory component supplies the acromioclavicular and glenohumeral joints. Its entrapment or compression leads to SSN neuropathy, clinically characterized by posterior shoulder pain, atrophy of the supraspinatus and infraspinatus muscles. Other features are weakness of the arm's external rotation and abduction.

Operative treatment of SSN entrapment consists of decompression of the nerve either at the suprascapular notch or the spinoglenoid notch (Romeo et al., 2010), ensured by surgical release of STSL, SGL with or without notchplasty. Arthroscopic techniques are increasingly preferred over traditional open procedure for SSN decompression (Ghodadra et al., 2009). The establishment of arthroscopic portals relies on palpable bony points in the area around the shoulder region. The bony landmarks commonly used for reference are anterolateral acromion, posterolateral acromion, coracoid, lateral end of clavicle, acromioclavicular joint and glenoid (Sergides et al., 2009; Lafosse et al., 2011).

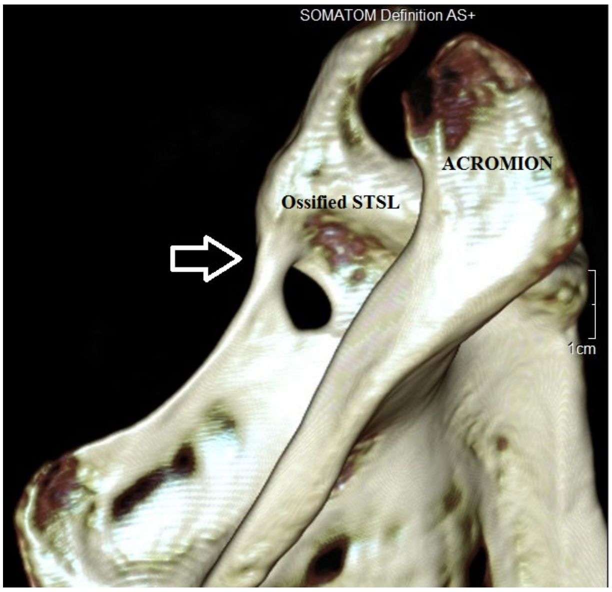

Fig 1. 3D CT reformatted image of right scapula from dorsal view, showing ossified superior transverse scapular ligament (Arrow).

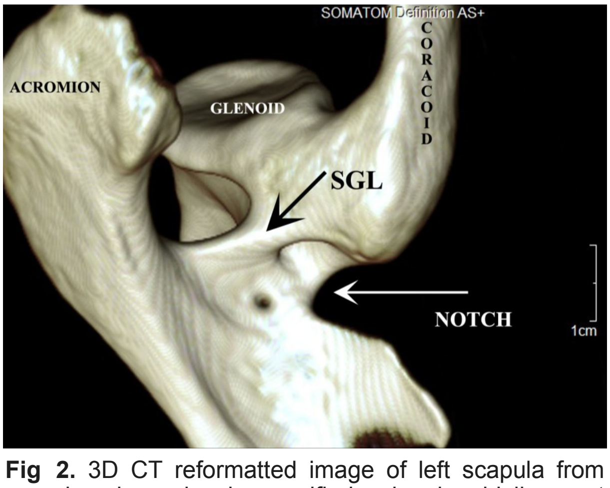

Fig 2. 3D CT reformatted image of left scapula from superior view, showing ossified spinoglenoid ligament (black arrow). Suprascapular notch is seen distinct and separate from it (white arrow).

Anatomical data for the relationship of bony landmarks to the suprascapular notch is available but similar data for ossified suprascapular ligaments (ossified STSL & ossified SGL) are deficient. Only two case-reports are published in the literature of arthroscopic release of ossified STSL (Millet et al., 2006; Agrawal, 2009). In fact, previously surgeons considered an ossified STSL a contra-indication to arthroscopic release (Dietrich et al., 2015). Even in the above mentioned case reports, though the sequential steps of surgery are mentioned, distances from palpable bony landmarks were not documented. The present study is relevant as the reported incidence of ossified STSL is as high as 12.6% in Indian population (Kannan et al., 2014).

This study is an endeavour to collect morphometric 3D CT data of ossified ligaments of scapula. The chosen modality to study the ossified ligaments is 3D CT, because a new study has evaluated it to be the most accurate imaging depiction of anatomic distances compared to MRI, CT and roentgenogram. 3D CT has the highest correlation with anatomical distances measured intra-operatively in the suprascapular region (Dietrich et al., 2015).

Radio-anatomical studies on ossified transverse scapular ligaments, delineating the exact relationship to anatomical landmarks such as Coracoid, Glenoid and Acromion, would assist the pre- and intra-operative strategic planning. Our study provides comparative data for ossified and unossified suprascapular ligaments that are not readily available. The present study aims to measure the -dimensional morphometry of ossified STSL and ossified SGL and quantify their radio-anatomic distances from coracoid process, glenoid and acromion.

MATERIALS AND METHODS

Two hundred and sixty eight human scapulae (unknown sex) were evaluated for presence of complete ossification of STSL and complete ossification of SGL. All scapulae belonged to adult skeletons available from the bone bank of the department. The study was approved by the Institutional Ethics Committee. Ossified STSL was identified as a bony bridge converting suprascapular notch into osseous foramen (Fig. 1). Ossified SGL was identified as a bony bridge converting spinoglenoid notch into osseous foramen (Fig. 2). Anomalous bony tunnels in the supraspinous fossa were also studied. All specimens with incomplete bony bridges or broken coracoid, glenoid or acromion were excluded. Scapulae having complete ossified ligaments (ossified STSL, ossified SGL) were included and segregated. They were numbered and quantitative estimation was done using three-dimensional computed tomography. Multidetector CT (128-slice) was performed using the Siemens Somatom volume zoom plus (Siemens Germany Std.). Scanning parameters included 180 mAs, 120KV, tube rotation time of 1 second, slice thickness of 1mm, pitch of 0.8. 3D images were reconstructed with a slice thickness of 5 mm at increments of 1 mm by the Advantage Windows 3D Analysis Package release 2.1 (GE Medical Systems).

The lateral edge of ossified ligaments was assigned for the distance measurement from palpable bony landmarks. The points considered for measurements from ossified STSL are depicted in Fig. 3, for distances from superior part of Glenoid (SG) and tip of coracoid process (CT). Similar points were assigned for ossified SGL.

Three separate points were designated for Acromion process in 3D reconstruction images (Fig. 4).

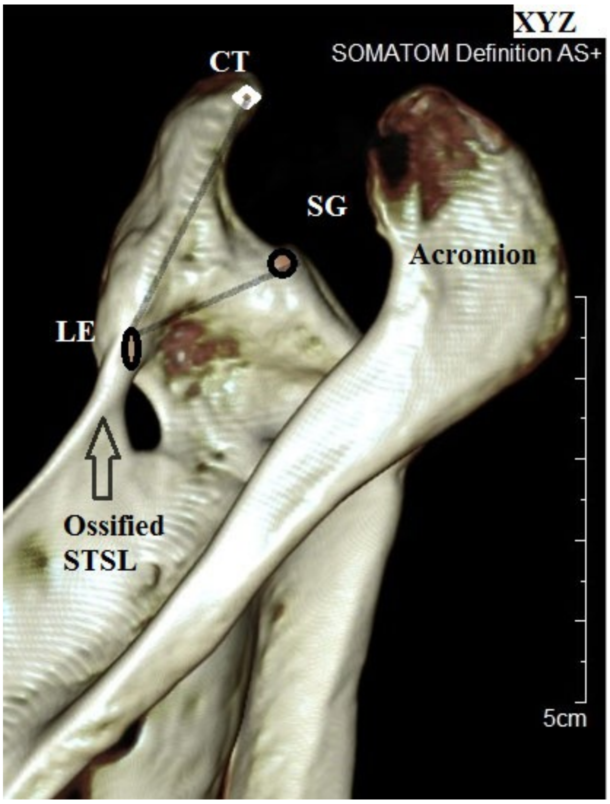

Fig 3. 3D CT reformatted image of right scapula from dorsal view, showing points designated for lateral edge (LE) of ossified superior transverse scapular ligament, tip of coracoid process (CT) and superior aspect of glenoid (SG).

They were defined as follows: 1) AT: Tip of anterolateral acromion. 2) ACIM: Middle of inferior margin of facet on acromion for lateral end of clavicle. 3) ACMM: Medial most margin of facet on acromion for articulation with lateral end of clavicle.

The following parameters were measured:

1. Length of ossified STSL and ossified SGL.
2. Width of ossified STSL and ossified SGL. The width was measured at the lateral edge of the ossified STSL. For ossified SGL, proximal and distal width at both ends of ligament was measured.
3. Distance from tip of coracoid to lateral edge of ossified suprascapular ligament (CT-LE).
4. Distance from supraglenoid tubercle of Glenoid to lateral edge of ossified suprascapular ligament (SGT-LE).
5. Distance from anterolateral tip of acromion to lateral edge of ossified suprascapular ligament (AT -LE).
6. Distance from middle of inferior margin of facet on acromion for lateral end of clavicle to lateral edge of ossified suprascapular ligament (ACIM-LE).
7. Distance from medial margin of facet on acromion for lateral end of clavicle to lateral edge of ossified suprascapular ligament (ACMM-LE).
8. Lateral edge of right and left bony tunnels was marked as a line joining the lateral limits of proximal and distal openings of the tunnel (Figs. 5a, 5b, 5c). The mid-point of this line was designated for measuring the distances to CT, SG, AT, ACIM and ACMM (Fig. 6).

All measurements were taken by a certified radi-

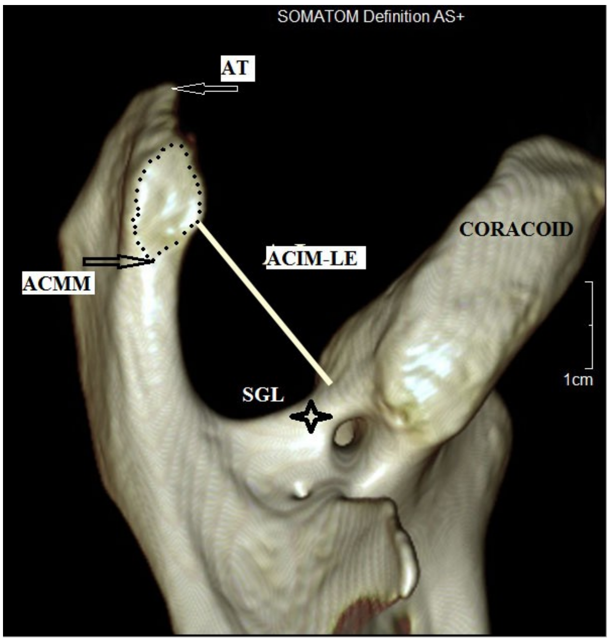

Fig 4. 3D CT reformatted image of left scapula from superior view, showing points designated for lateral edge (LE) of ossified spinoglenoid ligament, tip of anterolateral acromion (AT), Acromioclavicular articular facet inferior margin (ACIM) and medial margin (ACMM).

ologist (> 20 years' experience) in triplicate, and the mean of each measurement set was taken for analysis. Microsoft Excel 2010 was used for compiling the data and for deriving statistical mean as well as standard deviation.

RESULTS

26 Scapulae (14 right and12 left) having ossified STSL, 1 scapula (left) having ossified SGL, 2 scapulae (1 right and 1 left) having bony canals were found.

One left sided scapula had ossified SGL converting the spinoglenoid notch into a spinoglenoid foramen. The suprascapular notch was seen distinctly proximal to the ossified SGL. The proximal opening of the spinoglenoid foramen was oval in shape (Fig. 2). The mean length and width of ossified STSL and ossified SGL are documented in Table 1.

The lateral edge of ossified ligaments was assigned for the distance measurement from palpable bony landmarks. The distances from lateral edge (LE) of ossified ligaments to Coracoid and Glenoid are documented in Table 2. The points considered for measurements from ossified STSL are depicted in Fig. 1, for distances from superior part of Glenoid (SG) and tip of coracoid process (CT). Similar points were assigned for ossified SGL.

Three separate points were designated for Acromion process in 3D reconstruction images (Fig. 4). The distances from these points on acromion to the lateral edge of ossified STSL and ossified SGL are tabulated in Table 3.

Two scapulae (1 right and 1 left) had osseous/bony tunnel in suprascapular region. The tunnel was roofed by a *bony bridge* in the supraspinous fossa. The suprascapular notch as well as the spinoglenoid notch was seen distinctly in both scapulae (Figs. 5a, 5b, 5c and 6). The medial and lateral width of the right *bony bridge* was 1.75 cm and 1.42 cm, respectively. The medial and lateral width of the left *bony bridge* was 1.29 cm and 1.47 cm, respectively. For measuring the distances

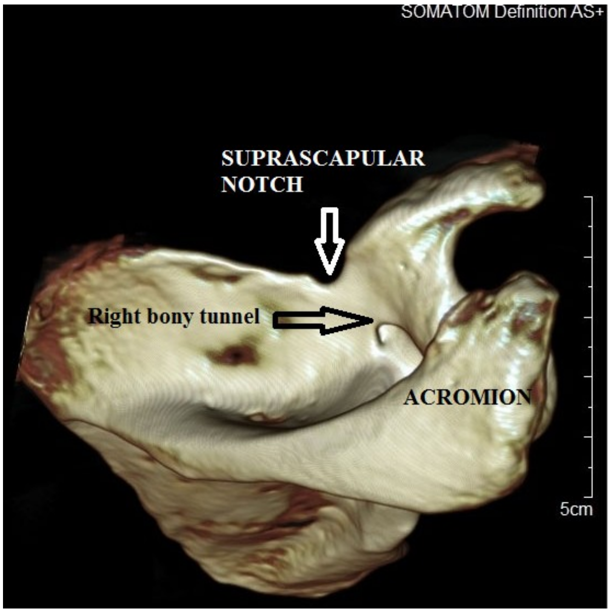

Fig 5. 3D CT reformatted images of right scapula for unusual bony tunnel between suprascapular notch and spinoglenoid notch. 5a - Right bony tunnel (black arrow) and suprascapular notch (white arrow). 5b - Proximal opening of right bony tunnel is seen (bold arrow). 5c - Distal opening of right bony tunnel is seen (bold arrow).

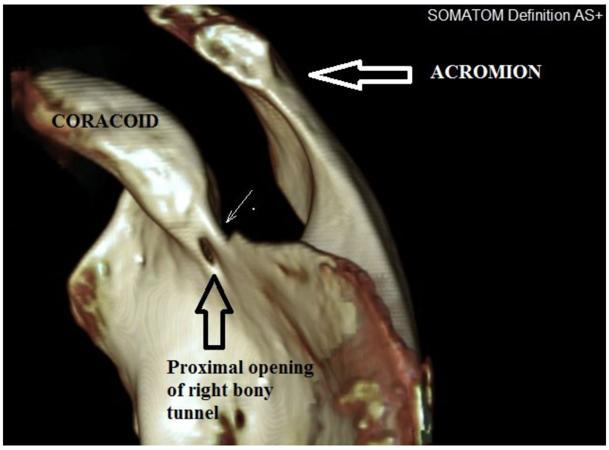

Fig 5b

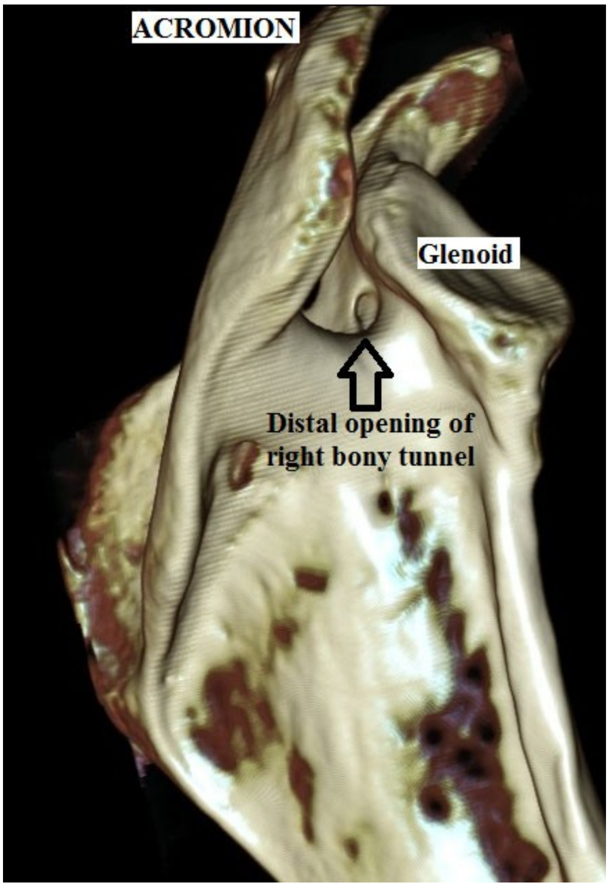

Fig 5c

from anatomical landmarks to the bony tunnels, a line marking the lateral edge of the *bony bridge* was drawn. This line joined the lateral most point of proximal opening to the lateral most point of distal opening of the tunnel. The relevant distances were then measured from the middle of this line (Fig. 6). The measurements are tabulated in Tables 2 and 3.

DISCUSSION

Complete ossification of STSL has been implicated by various authors in SSN entrapment (Kim et al., 2005; Gosk et al., 2007; Polguj et al., 2014). Similarly, reports propose the role of SGL in SSN compression (Plancher et al., 2007; Kharay et al., 2010; Labetowicz et al., 2017). Anterior coracoscapular ligament as a predisposing factor has also been proposed as a new etiologic factor (Polguj et al., 2013a; Labetowicz et al., 2017). In addition to the above, other constrictive lesions in the suprascapular region, such as thickening of supraspinatus fascia, may play a role in SSN entrapment along its course in the supraspinous fossa, involving it in a tunnel syndrome (Duparc et al., 2010). Immunohistochemical analysis of SSN in presence of ossified STSL, revealed signs of neural degeneration. In all samples, the SSN was grossly compressed (10-20%) at and distal to the ossified STSL. The authors proposed that even in absence of symptoms, gross compression of SSN exists in case of an ossified ligament resulting in neural degeneration (Tubbs et al., 2013).

In the present study, the incidence of ossified STSL is 9.7%. Its incidence is reported as 1.5% to 12.5% in the world population and in the North Indian population as 1.96% to 12.6% (Kannan et al., 2014). The bony suprascapular foramen formed due to ossified STSL is classified by previous authors as type IV or type VI (Rengachary et al., 1979; Natsis et al., 2007). A study classifies STSL into four types, describing ossified STSL as type 4, found in two cadavers bilaterally (Bayramoglu et al., 2003). Another study proposed a new classification of STSL into three types- fan shaped, band shape and bifid type (Polguj et al., 2013b). The basis of their classification is medial and lateral width of the STSL. The ossified STSL in their study is in 5(5.8%) cadaveric specimens. They do not

Table 1. Measurements of ossified scapular ligaments, n= 26 STSL, 1 SGL, 2 bony tunnels.

	Ossified STSL (14 Right, 12 Left)	Ossified SGL (1 Left)	Bony tunnel (1 Right, 1 Left)
Length	1.69 (0.17) RIGHT 1.54 (0.23) LEFT	2.31	1.28 RIGHT 1.13 LEFT
Width#	0.51 (0.12) RIGHT 0.40 (0.10) LEFT	0.90 (Lateral) 1.12 (Medial)	mentioned in text

All measurements are in centimeters. The standard deviation is mentioned in round brackets along with mean values. #Width of ossified STSL is measured at lateral edge & width of ossified SGL is measured at both ends- lateral and medial.

Table 2. Distances from ossified scapular ligaments to Coracoid and Glenoid.

	Ossified STSL (14 Right, 12 Left)	Ossified SGL (1 Left)	Bony tunnel (1 Right, 1 Left)
CT-LE	4.23 (0.19) RIGHT 4.07 (0.15) LEFT	4.42	3.63 RIGHT 3.84 LEFT
SG-LE	2.76 (0.25) RIGHT 2.63 (0.21) LEFT	1.37	2.52 RIGHT 2.59 LEFT

CT-LE: coracoid tip to lateral edge of ossified ligament; SG-LE: Supraglenoid tubercle to lateral edge of ossified ligament. All measurements are in centimeters. The standard deviation is mentioned in round brackets along with mean values.

Table 3. Distances from ossified scapular ligaments to Acromion

	Ossified STSL (14 Right, 12 Left)	Ossified SGL (1 Left)	Bony tunnel (1 Right, 1 Left)
AT-LE	5.52 (0.40) RIGHT 5.44 (0.53) LEFT	4.43	5.05 RIGHT 5.13 LEFT
ACIM-LE	4.00 (0.35) RIGHT 4.03 (0.28) LEFT	2.28	3.42 RIGHT 3.43 LEFT
ACMM-LE	4.19 (0.35) RIGHT 4.03 (0.28) LEFT	2.45	3.76 RIGHT 3.74 LEFT

AT-LE: Anterolateral Acromion tip to lateral edge of ossified ligament; ACIM-LE: Acromio-clavicular joint facet middle of inferior margin to lateral edge; ACMM-LE: Acromio-clavicular joint facet medial margin to lateral edge. All measurements are in centimeters. The standard deviation is mentioned in round brackets along with mean values.

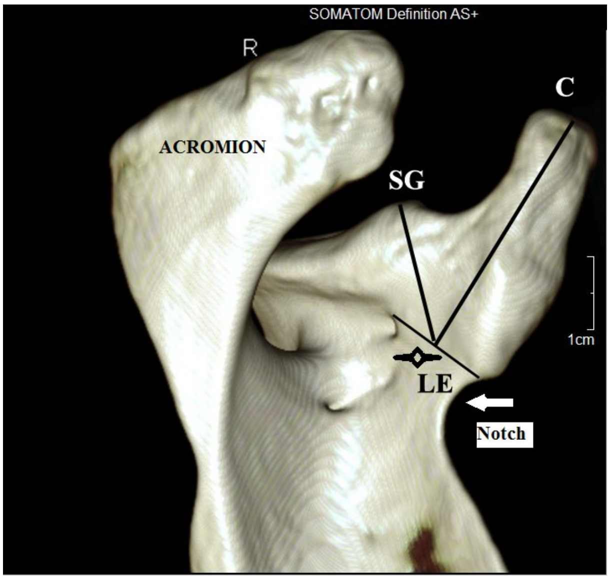

Fig 6. 3D CT reformatted image of left scapula from superior view, showing points designated for lateral edge (LE) of bony bridge, tip of coracoid (C) and superior aspect of Glenoid (SG). Suprascapular notch is marked with an arrow.

consider ossified STSL as a separate type. In a separate study, authors undertook morphological and radiological estimation of suprascapular foramen formed by ossified STSL on a large population sample (Polguj et al., 2014). According to their study, band-shaped ossified STSL should be considered a potential risk for SSN entrapment, as the space below the bony bridge is significantly reduced compared to fan-shaped one. In contrast, a recent report considers fan-shaped ossified STSL potential risk for increased SSN entrapment (Kharay et al., 2016).

Table 4 depicts the comparison of studies investigating morphometry of STSL.

The incidence of ossified SGL in our study is 0.37%. Though cadaveric studies investigating SGL have found the ligament in 3 to 100% of cadavers (Boykin et al., 2010), there is a single published report of ossified SGL in the literature in a scapula (Kharay and Sharma, 2010). One study reports distance between the supraglenoid tubercle and the base of the spine of the scapula in cadaveric shoulders as 2.5 cm, range 1.9-3.2 cm (Bigliani et al., 1990). Other authors report the length of unossified SGL in 58 cadaveric shoulders as 13.63-17.78 mm (Plancher et al., 2005). Our measurement of bony SGL (extending between the base of spine medially to the superior aspect of Glenoid laterally) as 2.31 cm, concurs with the result of Bigliani et al. (1990). The width of ossified SGL is 0.9 cm laterally and 1.12 cm medially, in present study. Earlier reports define a width of unossified SGL as 10.92 to 16.25 mm laterally and 11.3 to 17.04 mm medially (Plancher et al., 2005). This difference in lateral width of ossified SGL in our study could be due to partial ossification of the glenoidal insertion of the SGL. The lateral edge of ossified SGL is closer to Glenoid and acromion as compared to ossified STSL (Table 2). Additionally, in our study we determined the distances from anatomical landmarks for ossified SGL. The data obtained could not be compared as no such work is done earlier.

The lateral edge of ossified suprascapular ligaments is the reference point used to determine their distance from palpable landmarks. This is presumed to be more useful than the medial edge as the various portals used in arthroscopy use the acromion as a reference point. These distances are more relevant as the lateral, posterior and subacromial arthroscopic portals are preferred for release of STSL causing SSN compression (Yamakado, 2015). Other arthroscopic surgeons use a modified Nevasier portal, to which the study will be important (Lafosse et al., 2007).

The distance between the lateral edge of ossified STSL and the tip of the coracoid is more than the distance from the Glenoid (Table 2). In the present study, we find that the distance from the Glenoid is 2.76 cm on right side and 2.63 cm on left side. A previous study reports a measurement of 2.5 to 3.9 cm for distance from lateral edge of suprascapular notch to superior edge of the Glenoid (Bigliani et al., 1990). A review of techniques for SSN decompression state that SSN runs 2.5 -3 cm medial to superior aspect of Glenoid (Millet et al., 2006).

The distance between the anterolateral tip of the acromion and ossified STSL is >5cm in all specimens (Table 3). A similar distance in cadavers in unossified STSL is reported as 6.1 cm (5.7-6.8 cm) in 16 cadaveric shoulders between the anterolateral tip of the acromion to the suprascapular notch (Terra et al., 2010). The distance is 4cm between ossified STSL and the acromial facet for lateral end of clavicle in present study. The corresponding measurements in unossified STSL are 3.6 cm (Knudsen et al., 2016). Our findings are in conformation with their measurements, taken via the anterolateral arthroscopic portal in cadavers.

The morphometry of anomalous bony tunnels in the present work is a unique feature. The bony tunnel may involve SSN in a condition called tunnel syndrome (Duparc et al., 2010) in reference to thickened supraspinatus fascia. We could not find published literature to compare the relationship of bony tunnels. The ethnicity of the sample adds a new dimension to the interpretation and application of study results. The difference in results between present and previous studies can also be explained on the basis of the three-dimensional nature of the imaging study and racial differences between the studied population groups.

CONCLUSION

Our study reports the 3D CT relationship of ossified STSL and ossified SGL with surgically im-

Table 4. Comparative data for ossified STSL and unossified STSL by different authors

	Ossified STSL (n=26) in cm	Ossified STSL (n=52) in mm	STSL (n=83, out of which 5 ossified STSL) in mm
Measurement modality	**3D CT**	**Vernier caliper**	**Digital photographic measurement**
Length	1.69 (0.17) RIGHT 1.54 (0.23) LEFT	N.A.	13.8 (2.6) Fan-shaped 10.8 (2.6) Band-shaped
Width#	0.51 (0.12) RIGHT 0.40 (0.10) LEFT	5.78 (3.56)	3.9 (2.4) Fan-shaped 5.0 (1.8) Band-shaped
	Present study	Agrawal et al. 2015 [22]	Polguj et al. 2013 [20]

portant anatomical landmarks. Detailed morphometric documentation of bony tunnels is another unique feature. Its knowledge will assist the differentiation of various types of tunnel syndromes causing SSN entrapment.

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