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A COMPREHENSIVE MORPHOLOGICAL AND MORPHOMETRIC STUDY OF THE SPINOGLENOID NOTCH AND LIGAMENT/ MEMBRANE: POSSIBLE CLINICAL RELEVANCE OF SUPRASCAPULAR NERVE ENTRAPMENT

SPİNOGLENOİD ÇENTİK VE LİGAMENT/MEMBRAN ÜZERİNE KAPSAMLI MORFOLOJİK VE MORFOMETRİK BİR ÇALIŞMA: SUPRASKAPULAR SİNİR BASISI AÇISINDAN OLASI KLİNİK ÖNEMİ

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ABSTRACT

Objective: This study aimed to determine the anatomical features and clinical significance of the spinoglenoid notch and spinoglenoid ligament-membrane as well as the branches of the suprascapular nerve to the infraspinatus muscle as these structures may cause compression of this nerve.

Material and Methods: Fifty sides (25 right and 25 left) were studied on 26 fixed cadavers belonging to the Department of Anatomy, İstanbul University, İstanbul Faculty of Medicine. The suprascapular nerve branches to the infraspinatus muscle and spinoglenoid ligament-membrane were examined in cadavers, and the spinoglenoid notch was investigated in 50 dry scapulae.

Result: The suprascapular nerve had two branches to the infraspinatus muscle in 22 cadavers on 37 sides (74%) and three branches to this muscle in 11 cadavers on 13 sides (26%). On 31 sides the spinoglenoid membrane and on 19 sides the spino-

ÖZET

Amaç: Bu çalışmada, spinoglenoid çentik ve spinoglenoid ligament-membran ile supraskapular sinirin infraspinatus kasına giden dallarının anatomik özellikleri ve klinik öneminin belirlenmesi amaçlanmıştır, çünkü bu yapılar bu sinirin sıkışmasına neden olabilir.

Gereç ve Yöntem: İstanbul Üniversitesi İstanbul Tıp Fakültesi Anatomi Anabilim Dalı'na ait 26 fikse kadavra üzerinde elli taraf (25 sağ ve 25 sol) çalışıldı. Kadavralarda infraspinatus kasına giden supraskapular sinir dalları ve spinoglenoid ligament-membran incelendi ve 50 kuru skapulada spinoglenoid çentik araştırıldı.

Bulgular: Supraskapular sinir, 37 taraftaki 22 kadavrada (%74) infraspinatus kasına iki dal, 13 taraftaki 11 kadavrada (%26) ise bu kasa üç dal verdi. 31 tarafta spinoglenoid membran ve 19 tarafta spinoglenoid ligament gözlendi. Spinoglenoid çentik ile ilgili

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glenoid ligament were observed. Related to the spinoglenoid notch, the mean width was 17.17±2.17 mm, and the mean depth was 17.45±2.03 mm in calliper measurements on dry bones, while the mean width was 16.99±1.88 mm, the mean depth was 17.73±2 mm and the mean area was 282.04±55.27 mm² in computed tomography measurements.

Conclusion: The presented data regarding the spinoglenoid notch in which the suprascapular nerve is frequently compressed and the branches of the suprascapular nerve to the infraspinatus muscle may guide the surgical treatment of the related entrapment syndrome.

Keywords: Spinoglenoid notch, spinoglenoidal ligament, spinoglenoidal membrane, suprascapular nerve, infraspinatus muscle

olarak kuru kemik üzerinde yapılan dijital kaliper ölçümlerinde ortalama genişlik 17,17±2,17 mm, ortalama derinlik 17,45±2,03 mm iken, bilgisayarlı tomografi ölçümlerinde ortalama genişlik 16,99±1,88 mm, ortalama derinlik 17,73±2 mm ve ortalama alan 282,04±55,27 mm² olarak bulundu.

Sonuç: Supraskapular sinirin sıklıkla sıkıştığı spinoglenoid çentik ve supraskapular sinirin infraspinatus kasına giden dalları ile ilgili sunulan veriler, ilgili tuzak sendromunun cerrahi tedavisine rehberlik edebilir.

Anahtar Kelimeler: Spinoglenoid çentik, spinoglenoid ligament, spinoglenoid membrane, supraskapular sinir, infraspinatus kası

INTRODUCTION

Due to the complex structure of the shoulder region, anatomical and clinical research is important for a better understanding of the pathologies in this region (1). The suprascapular nerve (SN) is a complex nerve that originates lateral to the superior trunk of the brachial plexus and provides motor and, in some conditions, sensory innervation (2). This nerve passes deep to the omohyoideus and trapezius muscles and extends from the posterior triangle of the neck to the suprascapular notch (SsN). It passes under the superior transverse scapular ligament (STSL) to the supraspinous fossa, and from there, it reaches the infraspinous fossa through the spinoglenoid notch (SGN) located on the outer side of the scapular spine (3-6). During this course, the SN and the accompanying vessels are at risk of compression (7-12). The motor component of the SN innervates the supraspinatus and infraspinatus muscles and the articular rami, from which branches reach the shoulder and acromioclavicular joint (4). The suprascapular nerve may rarely have a sensory branch (4). When present, it pierces the deltoid muscle and receives the sensation of the proximal third of the arm. The most common lesion of the suprascapular nerve is neuralgic amyotrophy (4).

Entrapment neuropathy may occur in the scapular notch or because of injury to the SN by trauma to the scapula or shoulder region. Injury to the SN can cause shoulder pain, weakness in the abduction and external rotation, and atrophy of the supraspinatus and infraspinatus muscles. Compression of the SN is a common condition that usually requires surgical intervention, and the treatment of this condition varies according to the site of nerve compression. Injuries of the SN may cause shoulder pain, weakness in the abduction and external rotation of the upper extremity, and atrophy of the supraspinatus and infraspinatus muscles (9, 10). There are several possible causes, but nerve compression is the most common one, and it can be surgically treated. Shah et al. reported that 71% of their patients reported pain relief after decompression surgery with a follow-up of 22.5 months in a series of 24 patients with impingement syndrome of SN (11). Other causes include trauma, traction injuries, scapula fractures, ganglion cysts, repetitive overuse, and compressive mass (9, 11-14). The SN is also at risk of iatrogenic damage during shoulder surgery, mainly in case of an anterosuperior or posterior approach, repair of massive rotator cuff tears, and arthroscopic procedures for anterior glenohumeral instability repair (9, 15-17).

The prevalence of the entrapment of the SN is unknown. However, the importance of its entrapment and dysfunction as a pain generator has been approved (11). Entrapment of the SN can occur in two locations: in the SsN (superior compression of the SN) and in the SGN (inferior compression of the SN) (9, 18, 19). Infraspinatus denervation with the preservation of the supraspinatus muscle is considered inferior compression around the SGN (20). The surgical treatment regimen for the entrapment of the SN at the SsN differs from the approach for the entrapment of the same nerve at the SGN. Therefore, the underlying pathological condition and location of the nerve entrapment should be well understood preoperatively (21). An original arthroscopic portal has also been described to reveal both sites where the SN is most commonly compressed (9). While the SN entrapment syndrome was first described by Kopell and Thompson in 1959, Ganzhorn et al. described the entrapment syndrome of the SN in the SGN to be causing shoulder pain, weakness in external rotation, and isolated infraspinatus atrophy in 1981 (22-25). A hypertrophic SGN is also among the possible causes in addition to trauma, ganglion cysts, paralabrax paralabral cysts, and varicose veins in the SGN (3, 5, 10, 18). Moreover, in the scapular region, as the infraspinatus muscle is the most frequently involved area in myofascial pain syndrome, the branches of the SN innervating this muscle are being explored in order to apply an accurate injection site (26). The spinoglenoid ligament (SGL) is a bilaminar structure that starts from the scapular spine and attaches to the scapular neck. It is affected by the shoulder position and is exposed to maximum pressure when the arm is in full adduction and internal rotation

(27, 28). Bektaş et al. found a prominent ligament structure (SGL) in 16% of cadaveric shoulders and named this structure the spinoglenoid membrane (SGM) in the other cases (29). Won et al. classified this structure as ligament, membrane, or both (30). While the suprascapular artery, vein, and nerve (SN) pass under the SGL/SGM, Aktekin et al. reported that this structure forms a fibroosseous foramen consisting of the scapular spine and the SGL/SGM, where the suprascapular artery occupies 68.5% and the nerve 31.5% (31).

This study investigated the anatomical features of the suprascapular nerve in the SGN region and to complete the limited information in the literature. In line with this aim, morphological and morphometric variations of the SGL/SGM structure significantly affect the suprascapular nerve compression.

MATERIAL AND METHODS

In our study, 50 sides (25 right and 25 left sides) were dissected in 5 female and 21 male cadavers aged between 49 and 88 years, fixed with a mixture of formaldehyde-phenol-ethyl alcohol-glycerine-water, which were used in medical education in the Department of Anatomy, İstanbul Faculty of Medicine.

The skin and subcutaneous tissue of all cadavers were formerly dissected as they had been used in student practices already. The trapezius muscle was separated from the clavicle, acromion, and spine of the scapula. Afterwards, the trapezius and deltoid (spinal part) muscles were removed, exposing the supraspinatus and infraspinatus muscles. The supraspinatus muscle was released from the supraspinous fossa medially, revealing the superior border of the scapulae. We examined the presence of a motor branch to the infraspinatus muscle either directly or by piercing the spinoglenoid ligament. Combining the classifications of Bektaş et al. (SGL, spinoglenoid septum) and Won et al. [SGL, spinoglenoid membrane (SGM), combination of SGL and SGM)], we identified a SGL or spinoglenoid membrane (SGM) (29, 30). A digital calliper (INSIZE Co., Ltd., Taiwan) was used in all measurements, and a digital camera was used for the visualisation of the specific cases.

The presence of either SGL or SGM was first examined macroscopically in SGN. To evaluate the microscopic difference in the macroscopic ligament or membrane, one sample from each macroscopically differentiated type was aimed to be histologically assessed. The specimens were fixed in a 10% phosphate-buffered formaldehyde solution and then dehydrated in ascending grades of ethanol (70%, 90%, 96%, and 100%, respectively) for 24 h before performing the light microscopic examination. They were then kept in 100% ethanol twice for 30 min and clarified in toluol (Merck 1.08323.2500) for 1 h. Subsequently, they were placed in liquid paraffin (Merck 1.07337.1000) in an oven (Heraeus) at 56°C for 1 h two times and embedded in paraffin blocks. 4 µm thick sections were taken from these blocks with a microtome (LEICA, RM 2255). Masson Trichrome Stain was applied to the sections. Paraffin sections were removed from the paraffin by soaking in toluol for 30 min and then rehydrated by passing through a series of decreasing alcohols (100%, 96%, 90%, and 70%, respectively) in distilled water. Sections were stained in haematoxylin for 4 min and allowed to bruise in tap water for 10 min. They were stained with Ponceau xylidine-acid fuchsin solution for 5 min and were quickly passed through 1% acetic acid. The sections were stained with Orange G for 10 min, promptly passed through 1% acetic acid, stained with light green for 7 min, and again quickly passed through 1% acetic acid. The sections were then passed through 100% ethanol three times, made transparent with toluol, covered with Canadian balsam, and evaluated under a light microscope to determine the changes in the connective tissue elements.

Fifty (25 right and 25 left) dry scapulae were used for morphometric evaluation of the SGN, where the SN is most frequently compressed. We used two methods (manual measurement with a digital calliper and computed tomography).

For manual measurement with a digital calliper, we determined the anterior and posterior points of the glenoid cavity and the projection of the posterior point on the acromion with the help of a fixed metal needle in a designed plane passing through the spine of the scapula. The distance between the most posterior point of the glenoid cavity and its projection on the acromion was considered the width of the SGN. The shortest distance extending from this width line to the deepest point of the SGN at a perpendicular angle was considered the depth of the SGN. In order to understand the structure of SGN better, the width/depth ratio was calculated (Figure 1).

The computed tomography (CT) scans were performed at the Radiology Clinic using the 16-detector CT acquisition protocol (Somatom Emotion 16, Siemens, AG, Erlanger, Germany). The acquisition parameters were 16x0.75 mm detector collimation, 0.5 s gantry rotation time, and 5 mm slice thickness. The tube voltage was 130 kVp, and the current was 50 mAs. For evaluation, the 5-mm section thickness images were electronically transferred to a workstation (Leonardo, Siemens AG, Erlanger, Germany). At the workstation, reconstruction (MPR: Multiplanar Reconstruction) images were created from these images in axial, coronal, and sagittal planes with 0.75 mm thickness and 0.2 mm reconstruction interval. To evaluate the SGN, images were obtained in the plane passing through the spine of the scapula. In this plane, we determined the most anterior and posterior edges of the glenoid cavity and the projection of the posterior edge on the acromion. The distance between the posterior border and its projection was considered the width of the SGN, and the perpendicular line drawn from this line to the deepest point of the SGN was regarded as the depth (Figure 1). In addition, we calculated the area under the width of the SGN to determine whether the neurovascular structures passing through the region would affect SN compression. All images were evaluated, and an expert radiologist performed the measurements.

The Clinical Research Ethical Committee of İstanbul Faculty of Medicine approved the study (Date: 08.10.2021, No: 18).

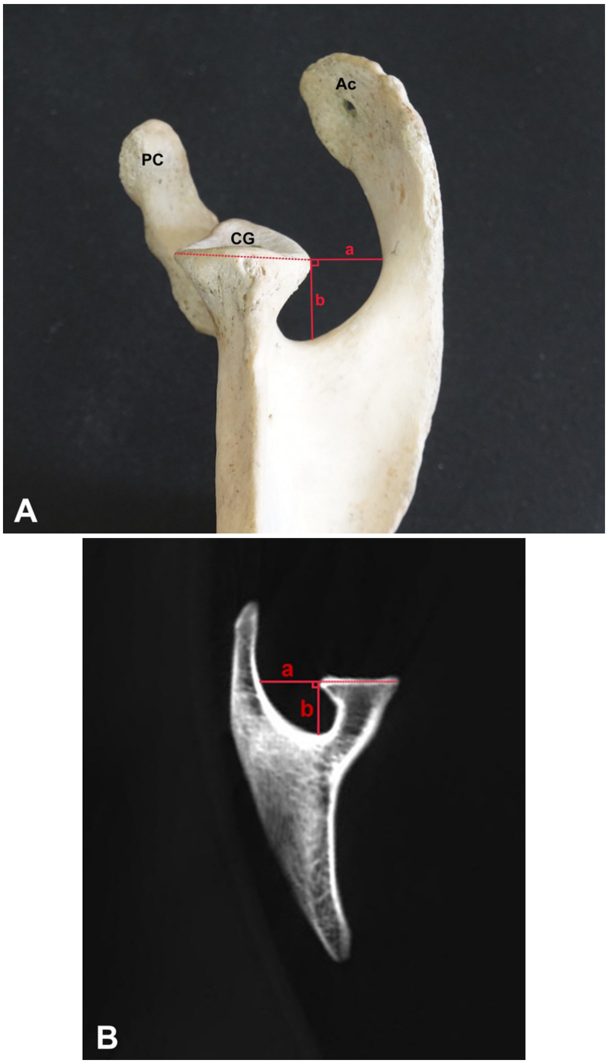

Figure 1: Morphometric measurements of the incisura spinoglenoidale. **A** Manual measurements, **B** Measurements on computed tomography
a: Width, b: Depth, Ac: Acromion, CG: Cavitas glenoidalis, PC: Processus coracoideus

RESULTS

Related to the branches of SN to the infraspinatus muscle, 22 cadavers on 37 sides (74%) had two motor branches and 11 cadavers with 13 sides (26%) had three motor branches (Figure 2). All measurements and evaluations performed on cadavers are shown in Table 1.

In SGN, SGL was macroscopically observed on 19 sides (38%) in 11 cadavers, and SGM was observed on 31 sides (62%) in 18 cadavers (Figure 3). Tight connective tissue arrangement, sparse fibroblasts in between, and the typical corrugated structure seen in the compact connective tissue structure were observed in the sections taken from the specimens macroscopically evaluated as ligaments.

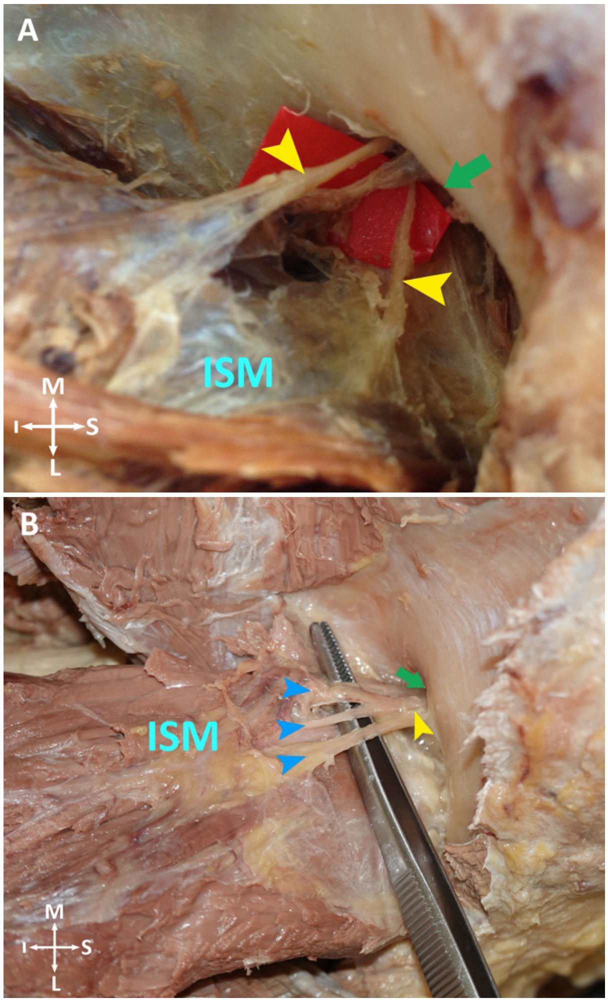

Figure 2: Motor branches to the infraspinatus muscle **A** 2 motor branches to the infraspinatus muscle **B** 3 motor branches to the infraspinatus muscle: infraspinatus muscle (ISM), medial (M), lateral (L), superior (S), inferior (I). Yellow arrows show the motor branches to the infraspinatus muscle. The green arrow shows the spinoglenoid notch. Blue arrows show the motor branches to the infraspinatus muscle

Table 1: Measurements on the cadavers

Cadaver No	Spinoglenoid lig./septum	Branches of SN to the infraspinatus muscle	Cadaver No	Spinoglenoid lig./septum	Branches of SN to the infraspinatus muscle
1-Left	S	3+S	14-Left	S	2
1-Right	S	3	14-Right	S	2
2-Left	L	3	15-Left	S	2
2-Right	L	3	15-Right	S	2
3-Left	S	2	16-Left	L	2
3-Right	S	3	16-Right	L	3
4-Left	S	2	17-Left	L	2
4-Right	S	2	17-Right	S	2
5-Left	L	2	18-Left	S	2
5-Right	L	3	18-Right	S	2
6-Left	S	2	19-Left	S	2
6-Right	L	2	19-Right	S	2
7-Left	S	3	20-Left	S	2
7-Right	S	2	20-Right	S	2
8-Left	S	2	21-Left	S	2
8-Right	S	3	21-Right	S	2
9-Left	L	2	22-Left	L	2
9-Right	L	2	22-Right	L	2
10-Left	L	2	23-Left	L	2
10-Right	L	2	23-Right	L	2
11-Left	L	2	24-Left	S	2
11-Right	L	2	24-Right	S	2
12-Left	S	3	25-Right	S	3
12-Right	L	2	26-Left	S	3
13-Left	S	3			
13-Right	S	2			

S: Spinoglenoid septum **L:** Spinoglenoid ligament

In the sections taken from the specimens macroscopically evaluated as membrane, connective tissue, muscle tissue, and dense fibroblast structures were observed (Figure 3).

The results of the osteometric measurements related to SGN were prepared as the value + standard deviation (minimum value, maximum values).

Related to the spinoglenoid notch; the mean width was 16.91±2.04 mm (13.2, 21.2 mm), and the mean depth was 17.2±2.04 mm (12.6, 20.7 mm) in the 25 right scapula, while the mean width was 17.43±2.3 mm (13.5, 23.5 mm) and the mean depth was 17.71±2.02 mm (14.1, 22.9 mm) in the 25 left scapula. The mean width was 17.17±2.17 mm, and the mean depth was 17.45±2.03 mm regardless of the side. The mean width/depth ratios were 0.98±0.09 (0.79, 1.17) in 25 right scapula, 0.98±0.1 (0.81, 1.32) in 25 left scapula, and 0.98±0.1 total. We collected the data of the manual SGN measurements in a Table (Table 2).

Related to the spinoglenoid notch; the CT evaluation of the same bones (50 scapula) showed that the mean width was 17.26±2.02 mm (14.4, 20.8 mm), the mean depth was 17.66±1.63 mm (14.1, 20.9 mm) and the mean area was 278.04+46.05 mm² (197, 378 mm²) for the right scapula, while the mean width was 16.73±1.74 mm (13.5, 19.7 mm), the mean depth was 17.8±2.35 mm (13.7, 21.4 mm) and the mean area was 286.04±63.9 mm² (201, 375 mm²) for the left scapula. Regardless of the side, the

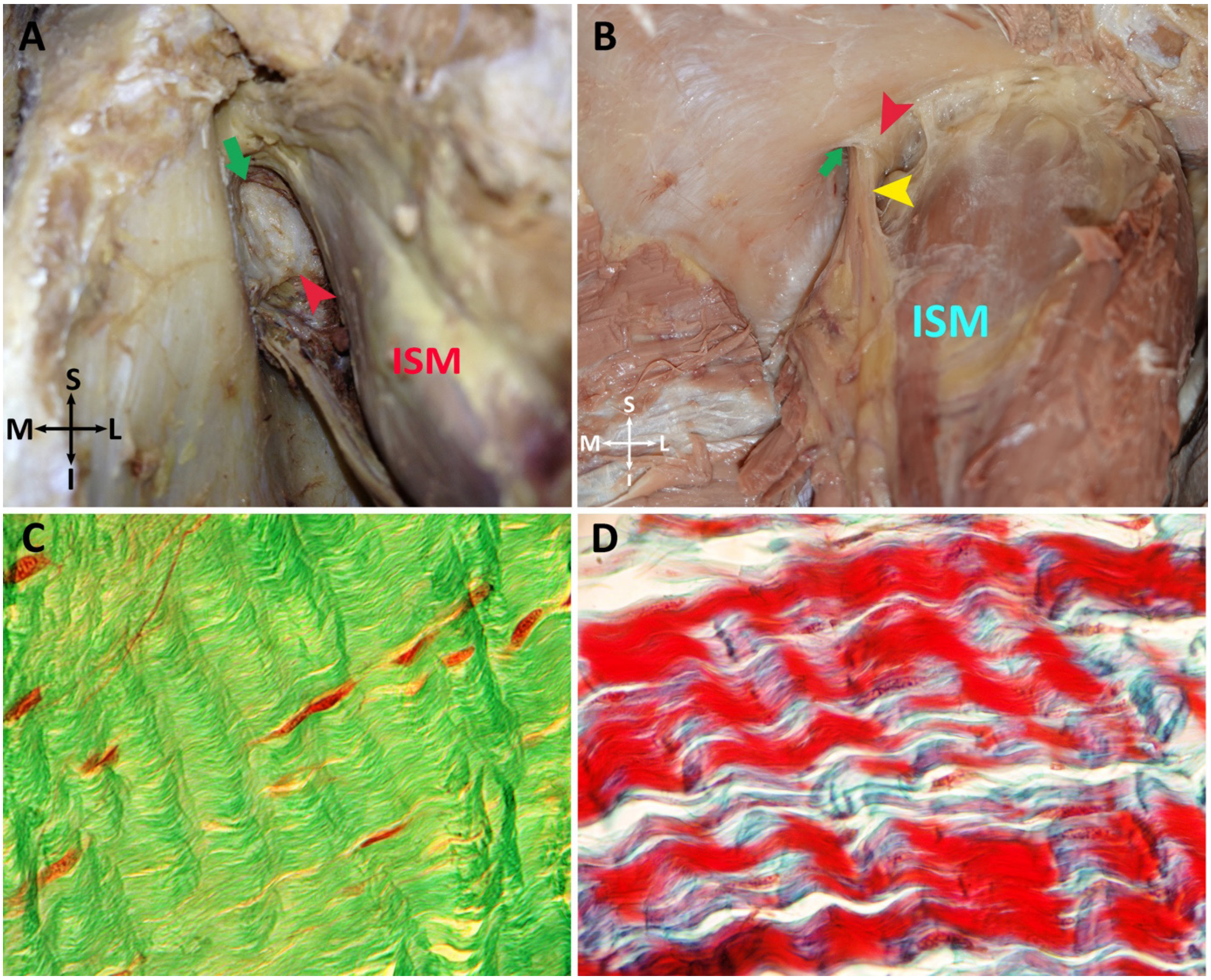

Figure 3: Spinoglenoid ligament and septum, and their histological evaluation **A** Ligament **B** Septum **C** Spinoglenoid ligament (tight connective tissue arrangement, sparse fibroblasts in between, and typical appearance of corrugated structure seen in the compact connective tissue structure) **D** Septum (appearance of connective tissue, muscle tissue, and dense fibroblast structures): infraspinatus muscle (ISM), medial (M), lateral (L), superior (S), inferior (I)

mean width was 16.99±1.88 mm (13.5, 20.8 mm), the mean depth was 17.73±2 mm (13.7, 21.4 mm), and the mean area was 282.04±55.27 mm² (197, 378 mm²). The mean width/depth ratios were 0.98±1.02 (0.10, 1.21) in 25 right scapula, 0.94±0.87 (0.72, 1.16) in 25 left scapula, and 0.96±0.09 totally. The data of the SGN-related measurements performed using CT are shown in a Table (Table 3).

DISCUSSION

The main findings of this study include the number and distribution of the motor branches of the suprascapular nerve to the infraspinatus muscle, macroscopic and microscopic examination of the spinoglenoid ligament (SGL) and spinoglenoid membrane (SGM), and determination of the spinoglenoid notch (SGN) dimensions by manual and CT measurements. These findings are thought to contribute significantly to shoulder surgery, nerve impingement syndromes, and anatomical education.

Morphological and morphometric evaluations

Our study found that the suprascapular nerve gave the infraspinatus muscle two or three motor branches. Two motor branches were observed in 74% (37/50 sides), and three motor branches were observed in 26% (13/50 sides) of the specimens. These findings are consistent with the finding of 70% (14/20) of two branches and 30% (6/20) of three branches reported by Lee et al. (26). However, Warner et al. reported a higher rate by detecting three or four motor branches in 48% (15/31) of the specimens examined (6). These differences may be due to the sample size, methodological differences, or possible anatomical variations. In addition, Warner et al. reported that the branches of the suprascapular nerve to the supraspinatus muscle were fewer, shorter, and smaller (6). Our findings support the existing literature regarding the motor innervation of the infraspinatus muscle and provide important anatomical information regarding nerve preservation during surgical procedures (32-35).

Table 2: Data from manual SGN-related measurements

Spinoglenoid Notch							
Cadaver No	Right (mm)		Cadaver No	Left (mm)		Right	Left
	Width	Depth		Width	Depth	Width/Depth	Width/Depth
1	18.4	17.7	1	18.3	18.6	1.039548	0.983871
2	17.9	18.3	2	19.8	19.7	0.9781421	1.005076
3	13.6	12.6	3	14.3	14.1	1.0793651	1.014184
4	18	18.9	4	18.1	16.9	0.952381	1.071006
5	15	14.9	5	17.1	18.8	1.0067114	0.909574
6	15.2	18.4	6	16.3	16.8	0.826087	0.970238
7	14.9	17.9	7	15.8	19.4	0.8324022	0.814433
8	20.4	19.1	8	15.7	16.4	1.0680628	0.957317
9	13.2	14.4	9	14.4	17.3	0.9166667	0.83237
10	18.4	20.7	10	19.5	20.3	0.8888889	0.960591
11	16.3	15.7	11	17.3	17.2	1.0382166	1.005814
12	14.6	14.1	12	15.3	14.4	1.035461	1.0625
13	15	18.9	13	13.5	16.5	0.7936508	0.818182
14	18.6	16.7	14	16.1	15.8	1.1137725	1.018987
15	16.6	17.1	15	18.4	18.1	0.9707602	1.016575
16	19.1	18.3	16	17.6	20.3	1.0437158	0.866995
17	18.7	18.5	17	21	22.9	1.0108108	0.917031
18	18.3	20.2	18	23.5	17.8	0.9059406	1.320225
19	15.7	15	19	15	14.7	1.0466667	1.020408
20	16.4	17.8	20	17.9	17	0.9213483	1.052941
21	16.1	16.2	21	16.4	16.6	0.9938272	0.987952
22	21.2	19.4	22	20.1	18.8	1.0927835	1.069149
23	18.1	16.8	23	17	18.6	1.077381	0.913978
24	17.4	14.8	24	18.8	19.3	1.1756757	0.974093
25	15.7	17.6	25	18.7	16.5	0.8920455	1.133333

The spinoglenoid ligament (SGL) and spinoglenoid membrane (SGM) were analysed macroscopically and microscopically in our study and compared with the literature (33-35). SGL was detected on 19/50 sides (38%), while SGM was observed on 31/50 sides (62%). The presence of SGL has been reported at different rates in the literature. Although Plancher et al. and Aktekin et al. observed SGL in all their specimens (58 fresh frozen shoulders and 36 cadaver shoulders, respectively), Bektaş et al. found significant SGL in only 16% (5/32) (27-29,31). Demirhan et al. reported the presence of SGL in 60.8% (14/23 shoulders), Aiello et al. in 50% and Duparck et al. in 28/30 cadaver shoulders (18, 36, 37). Although the rates in our study contribute to the wide range of variations in the literature, it is noteworthy as one of the few studies that address the distinction between SGL and SGM at the macroscopic and microscopic levels. We found prominent SGL in 11 cadavers on 19 sides (38%), while we observed SGM in 18 cadavers on 31 sides (62%). The differences in the data presented may be because the SGL-SGM distinction was not made in some studies, and all were accepted as SGL. Moreover, racial disparities and sample size may be responsible for the different results.

From the histological point of view, only Plancher et al. reported that they had histologically examined 8 out of their 58 fresh-frozen specimens (27, 28). They mentioned that the SGL was composed of bundles of collagen fibrils having similar orientations. They also observed that Sharpey fibre bundles of collagen fibres extending from the periosteum to the underlying bone were inserted into the scap-

Table 3: Data of measurements of the spinoglenoid notch performed by computed tomography

Scapula (Right)	Depth (mm)	Width (mm)	Area (mm^2)	Scapula (Left)	Depth (mm)	Width (mm)	Area (mm^2)	Width/Depth (Right)	Width/Depth (Left)
1	17.6	18.4	272	1	16.2	15.8	245	1.04545455	0.975309
2	20.9	15.7	309	2	19.1	19.7	359	0.75119617	1.031414
3	18.2	22.2	378	3	18.6	18.9	332	1.21978022	1.016129
4	17.1	17.7	290	4	16.9	16.5	259	1.03508772	0.976331
5	16.2	14.4	208	5	14.2	13.5	204	0.88888889	0.950704
6	19.3	17.1	313	6	14.9	15.6	201	0.88601036	1.04698
7	16.1	16.7	226	7	21.4	19.7	400	1.03726708	0.920561
8	19.4	20.6	334	8	17.9	17.8	288	1.06185567	0.994413
9	19.1	18.1	323	9	17.8	17.9	308	0.94764398	1.005618
10	15.2	15.1	197	10	21.2	18.4	375	0.99342105	0.867925
11	18.3	15.1	240	11	18.5	17.7	277	0.82513661	0.956757
12	15.6	15.1	239	12	20.6	18.2	362	0.96794872	0.883495
13	15.7	15.7	233	13	19.7	17.4	317	1.0	0.883249
14	18.7	17.8	301	14	18.3	16	265	0.95187166	0.874317
15	20.1	19.5	334	15	14.3	14.5	202	0.97014925	1.013986
16	14.1	15.4	201	16	17.1	16.7	266	1.09219858	0.976608
17	18.8	17.6	293	17	14.8	13.7	202	0.93617021	0.925676
18	17.9	15.7	283	18	20.2	17.5	314	0.87709497	0.866337
19	18.2	20.8	312	19	22	16	361	1.14285714	0.727273
20	17	18.6	295	20	13.7	16	212	1.09411765	1.167883
21	19	18.5	321	21	16.3	15.9	242	0.97368421	0.97546
22	16.6	15.4	256	22	16.5	13.5	203	0.92771084	0.818182
23	17.9	15.7	265	23	18	16.3	252	0.87709497	0.905556
24	18	17.4	269	24	17.2	17.2	365	0.96666667	1.0
25	16.7	17.3	259	25	19.6	17.9	340	1.03592814	0.913265

ular spine. Plancher et al. did not define different types of SGL (28). In our study, SGL was classified into two types according to the macroscopic examination: SGL (observed on 19 sides (38%) in 11 cadavers) and SGM (on 31 sides (62%) in 18 cadavers). We examined one specimen from each of these two types. In a microscopic examination of the SGL, a tight connective tissue arrangement, sparse fibroblasts in between, and the typical corrugated structure seen in the compact connective tissue structure were observed, and in the sections taken from the SGM, connective tissue, muscle tissue, and dense fibroblast structures were observed. In the literature, we could only reach the study of Plancher et al. to examine the SGL histologically (28). Consequently, we believe that we have provided supplemental microscopic data for types of SGL.

In our study, the mean width of the SGN by the manual measurement method was found to be 17.17±2.17 mm, the mean depth was 17.45±2.03 mm, and the mean width/depth ratio was 0.98±0.1. From the results of the CT measurements, the mean width of the SGN was determined as 16.99±1.88 mm (13.5, 20.8 mm), the mean depth as 17.73±2 mm (13.7, 21.4 mm), the mean area as 282.04±55.27 mm² (197, 378 mm²) and the mean width/depth ratio as 0.96±0.09. Yang et al., in their study of 478 patients (266 males, 212 females, 236 left-side and 242 right-side were examined) with thin-section CT, reported that the mean width (AP-the distance between the nadir of the SGN and of the SGN) was 14.63±7.07 mm in males and 13.42±1.89 mm in females while the mean depth on the left side was 13.89±2.19 mm and 12.43±2.03 mm on the right side (38). In their bony study, which was performed by digital callipers on 70 scapulae (58 non-articulated, 12 articulated), Kannapan et al. defined the acromioglenoid (anteroposterior) diameter to be between the supraglenoid tubercle and the highest concavity of the acromion and the lateral diameter (mediolateral) to be located between the posterior rim of the glenoid cavity and the centre of the lateral border of the spine of the scapula. They determined that the anteroposterior and mediolateral diameters of the spinoglenoid notch were found meanly as 3.01±0.4 cm (ranging from 2 to 3.5 cm) and 1.4±0.1 cm (ranging from 1.2 to 1.6 cm), respectively (39). The studies of Yang et al., Kannapan et al., and ours are the only studies we could reach to report both the width and depth of SGN, while there are other studies mentioning their results related to the width of SGN (38, 39). We believe that the difference in the results of these three studies may be due to different measurement methods, different points of measurement, and racial differences, including body size and type.

Defining the acromioglenoid diameter as the distance between the tip of the acromion process and the supraglenoid tubercle, Vinay et al. reported that the acromioglenoid diameter was found meanly as 29.79±4.04 mm and 30.36±4.1mm, on the right and left sides, respectively, and Dhindsa et al. reported that this diameter was measured meanly as 30.03±3.66mm and 30.27±4.61 mm on the right and left sides, respectively (40, 41). Mansur et al. defined the acromioglenoid diameter as the distance from the tip of the acromion process to the uppermost point of the glenoid cavity, and they determined that they measured the acromioglenoid diameter meanly as 31.83±3.66mm and 31.97±3.96mm, on the right and left sides, respectively (42). We have identified our width differently from other studies as the distance between the most posterior point of the glenoid cavity and its projection on the acromion. We believe that our defining points for the width and the depth may better identify the area where the SN may be impinged.

Bigliani et al., in their cadaver study including 90 (in some measurements, they used 15 cadavers more) cadavers, reported that the suprascapular nerve passed through the spinoglenoid notch approximately 18 mm from the posterior glenoid rim (range: 14–25 mm) (15). Moreover, Bigliani et al. described a safe zone of the posterior glenoid neck. According to them, the safe zone measured 2 cm at the level of the supraglenoid tubercle and decreased to 1 cm at the level of the scapular spine (15). Warner et al. dissected 31 shoulders in 18 cadavers and determined that the palpable posterolateral tip of the acromion to the base of the scapular spine was 4.5 centimeters±4 millimetres, adding that this distance might be an appropriate reference point for the location of SN. Warner et al. suggested a posterior incision along the scapular spine just medial to allow dissection in the medial safe zone (6). Because of the narrow passage, even small cysts (0.5–10 mm) may be responsible for causing entrapment (15, 21).

The findings of our study provide comprehensive data on the distribution of the motor branches of the suprascapular nerve, the structural features of the SGL and SGM, and the dimensions of the SGN. This information may contribute to optimising the surgical approach in nerve preservation and decompression procedures in shoulder surgery. It also provides an anatomical basis for understanding the pathophysiology of SN impingement syndromes.

CONCLUSION

This study provided comprehensive data on the anatomy of the suprascapular nerve, the distribution of its motor branches, the macroscopic and microscopic structure of the spinoglenoid ligament and membrane, and the dimensions of the spinoglenoid notch. The failure to detect the cutaneous branch may be because the cadavers were previously used in student practice. Future studies with less damaged cadavers may better reveal the anatomical features of this branch. Our study is an essential anatomical guide for shoulder surgery and nerve decompression operations. We believe our findings significantly contribute to the existing literature both clinically and academically.

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REFERENCES

1. Chan CW, Peng PW. Suprascapular nerve block: a narrative review. Reg Anesth Pain Med 2011;36(4):358-73. [CrossRef]
2. Yang HJ, Gil YC, Jin JD, Ahn SV, Lee HY. Topographical anatomy of the suprascapular nerve and vessels at the suprascapular notch. Clin Anat 2012;25(3):359-65. [CrossRef]
3. Demirhan M, Imhoff AB, Debski RE, Patel PR, Fu FH, Woo SL. The spinoglenoid ligament and its relationship to the suprascapular nerve. J Shoulder Elbow Surg 1998;7(3):238-43. [CrossRef]
4. Standring S, editor. Gray's Anatomy. The Anatomical Basis of Clinical Practice. 41st ed. London: Elsevier; 2016.p.803-4.
5. Titelbaum AR, Ibarra Asencios B, McNeil BE. A circular depression at the spinoglenoid notch of a prehistoric Andean scapula: Plausible evidence of suprascapular nerve entrapment by a paralabral cyst. Int J Paleopathol 2019;24:19-24. [CrossRef]
6. Warner JP, Krushell RJ, Masquelet A, Gerber C. Anatomy and relationships of the suprascapular nerve: anatomical constraints to mobilization of the supraspinatus and infraspinatus muscles in the management of massive rotator-cuff tears. J Bone Joint Surg Am 1992;74(1):36-45. [CrossRef]
7. Callahan JD, Scully TB, Shapiro SA, Worth RM. Suprascapular nerve entrapment. A series of 27 cases. J Neurosurg 1991;74(6):893-6. [CrossRef]
8. Cummins CA, Messer TM, Nuber GW. Suprascapular nerve entrapment. J Bone Joint Surg Am 2000;82(3):415-24. [CrossRef]
9. Soubeyrand M, Bauer T, Billot N, Lortat-Jacob A, Gicquelet R, Hardy P. Original portals for arthroscopic decompression of the suprascapular nerve: an anatomic study. J Shoulder Elbow Surg 2008;17(4):616-23. [CrossRef]
10. Van Meir N, Fourneau I, Debeer P. Varicose veins at the spinoglenoidal notch: an unusual cause of suprascapular nerve compression. J Shoulder Elbow Surg 2011;20(7):e21-4. [CrossRef]
11. Shah AA, Butler RB, Sung SY, Wells JH, Higgins LD, Warner JJ. Clinical outcomes of suprascapular nerve decompression. J Shoulder Elbow Surg 2011;20(6):975-82. [CrossRef]
12. Gosk J, Urban M, Rutowski R. Entrapment of the suprascapular nerve: anatomy, etiology, diagnosis, treatment. Ortop Traumatol Rehabil 2007;9(1):68-74.
13. Natsis K, Totlis T, Tsikaras P, Appell HJ, Skandalakis P, Koebke J. Proposal for classification of the suprascapular notch: a study on 423 dried scapulas. Clin Anat 2007;20(2):135-9. [CrossRef]
14. Steinwachs MR, Haag M, Krug C, Erggelet C, Reichelt A. A ganglion of the spinoglenoid notch. J Shoulder Elbow Surg 1998;7(5):550-4. [CrossRef]
15. Bigliani LU, Dalsey RM, McCann PD, April EW. An anatomical study of the suprascapular nerve. Arthroscopy 1990;6(4):301-5. [CrossRef]
16. Ebraheim NA, Whitehead JL, Alla SR, Moral MZ, Castillo S, McCollough AL, et al. The suprascapular nerve and its articular branch to the acromioclavicular joint: an anatomic study. J Shoulder Elbow Surg 2011;20(2):e13-7. [CrossRef]
17. Vorster W, Lange CP, Briët RJ, Labuschagne BC, du Toit DF, Muller CJ, et al. The sensory branch distribution of the suprascapular nerve: an anatomic study. J Shoulder Elbow Surg 2008;17(3):500-2. [CrossRef]
18. Demirkan AF, Sargon MF, Erkula G, Kiter E. The spinoglenoid ligament: an anatomic study. Clin Anat 2003;16(6):511-3. [CrossRef]
19. Lichtenberg S, Habermeyer P. Nervenkompressionssyndrome der Schulter : Arthroskopische Dekompressionsverfahren [Nerve compression syndrome of the shoulder: Arthroscopic decompression procedures]. Orthopade 2011;40(1):70-8. [CrossRef]
20. Ferretti A, De Carli A, Fontana M. Injury of the suprascapular nerve at the spinoglenoid notch. The natural history of infraspinatus atrophy in volleyball players. Am J Sports Med 1998;26(6):759-63. [CrossRef]
21. Moore TP, Hunter RE. Suprascapular nerve entrapment. Oper Tech Sports Med 1996;4(1):8-14. [CrossRef]
22. Buyukdogan K, Altintas B, Koyuncu Ö, Eren İ, Birsel O, Fox M, et al. Ultrasound-Guided intralesional methylene blue injection for the arthroscopic decompression of spinoglenoid notch cyst causing suprascapular neuropathy. Arthrosc Tech 2020;9(11):e1785-9. [CrossRef]
23. Ganzhorn RW, Hocker JT, Horowitz M, Switzer HE. Suprascapular-nerve entrapment. J Bone Joint Surg Am 1981;63(3):492-4. [CrossRef]
24. Kopell HP, Thompson WA. Pain and the frozen shoulder. Surg Gynecol Obstet 1959;109(1):92-6.
25. Pillai G, Baynes JR, Gladstone J, Flatow EL. Greater strength increase with cyst decompression and SLAP repair than SLAP repair alone. Clin Orthop Relat Res 2011;469(4):1056-60. [CrossRef]
26. Lee HJ, Lee JH, Yi KH, Kim HJ. Anatomical analysis of the motor endplate zones of the suprascapular nerve to the infraspinatus muscle and its clinical significance in managing pain disorder. J Anat 2023;243(3):467-74. [CrossRef]
27. Plancher KD, Luke TA, Peterson RK, Yacoubian SV. Posterior shoulder pain: a dynamic study of the spinoglenoid ligament and treatment with arthroscopic release of the scapular tunnel. Arthroscopy 2007;23(9):991-8. [CrossRef]

28. Plancher KD, Peterson RK, Johnston JC, Luke TA. The spinoglenoid ligament. Anatomy, morphology, and histological findings. J Bone Joint Surg Am 2005;87(2):361-5. [CrossRef]
29. Bektas U, Ay S, Yilmaz C, Tekdemir I, Elhan A. Spinoglenoid septum: a new anatomic finding. J Shoulder Elbow Surg 2003;12(5):491-2. [CrossRef]
30. Won HJ, Won HS, Oh CS, Han SH, Chung IH, Yoon YC. Morphological study of the inferior transverse scapular ligament. Clin Anat 2014;27(5):707-11. [CrossRef]
31. Aktekin M, Demiryurek D, Bayramoglu A, Tuccar E. The significance of the neurovascular structures passing through the spinoglenoid notch. Neurosciences (Riyadh) 2003;8(4):222-4.
32. Ajmani ML. The cutaneous branch of the human suprascapular nerve. J Anat 1994;185(Pt 2)(Pt 2):439-42.
33. Cummins CA, Anderson K, Bowen M, Nuber G, Roth SI. Anatomy and histological characteristics of the spinoglenoid ligament. J Bone Joint Surg Am 1998;80(11):1622-5. [CrossRef]
34. Horiguchi M. The cutaneous branch of some human suprascapular nerves. J Anat 1980;130(Pt 1):191-5
35. Harbaugh KS, Swenson R, Saunders RL. Shoulder numbness in a patient with suprascapular nerve entrapment syndrome: cutaneous branch of the suprascapular nerve: case report. Neurosurgery 2000;47(6):1452-5. [CrossRef]
36. Aiello I, Serra G, Traina GC, Tugnoli V. Entrapment of the suprascapular nerve at the spinoglenoid notch. Ann Neurol 1982;12(3):314-6. [CrossRef]
37. Duparc F, Coquerel D, Ozeel J, Noyon M, Gerometta A, Michot C. Anatomical basis of the suprascapular nerve entrapment, and clinical relevance of the supraspinatus fascia. Surg Radiol Anat 2010;32(3):277-84. [CrossRef]
38. Yang J, Feng Q, Wen YL, Fan QH, Luo B, Jia WL, et al. Morphological measurements and classification of the spinoglenoid notch: A three-dimensional reconstruction of computed tomography in the Chinese population. Ann Anat 2019;226:10-5. [CrossRef]
39. Kannappan SGP, Bagoji IB, Kumar S. A morphometric study of spinoglenoid notch, subcoracoacromial arch, and spinous process of the scapula on shoulder impingement. MGM Journal of Medical Sciences 2022;9(4):459-64. [CrossRef]
40. Dhindsa G, Gupta V. Morphometric study of the acromion process and its clinical relevance. Asian J Med Res 2019;8(3):2. [CrossRef]
41. Vinay G, Sivan S. Morphometric study of the acromion process of scapula and its clinical importance in South Indian population. Int J Anat Res 2017;5(3.3):4361-4. [CrossRef]
42. Mansur DI, Khanal K, Haque MK, Sharma K. Morphometry of acromion process of human scapulae and its clinical importance amongst Nepalese population. Kathmandu Univ Med J (KUMJ) 2012;10(38):33-6. [CrossRef]