ANATOMICAL RELATIONS OF SUPRASCAPULAR NERVE: CAUSES OF NERVE ENTRAPMENT

PHONGPAN TANTIPOON

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE (ANATOMY)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2009

Thesis
Entitled

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Phongpan Tantipoon
.....
Miss Phongpan Tantipoon
Candidate

Sitha Piyawinijwong
.....
Assoc. Prof. Sitha Piyawinijwong,
Ph.D. (Anatomy)
Major-Advisor

Jantima Roongruangchai
.....
Assoc. Prof. Jantima Roongruangchai,
D.D.S., Ph.D. (Anatomy)
Co-Advisor

Nopparatn Sirisathira
.....
Asst. Prof. Nopparatn Sirisathira,
Ph.D. (Anatomy)
Co-Advisor

Sirinush Sricharoenvej
.....
Assoc. Prof. Sirinush Sricharoenvej,
Ph.D. (Anatomy)
Co-Advisor

B. Mahaisavariya
.....
Prof. Banchong Mahaisavariya,
M.D.
Dean
Faculty of Graduate Studies
Mahidol University

Jantima Roongruangchai
.....
Assoc. Prof. Jantima Roongruangchai,
D.D.S., Ph.D. (Anatomy)
Chair
Master of Science Programme in
Anatomy
Faculty of Medicine Siriraj Hospital
Mahidol University

Thesis
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was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Anatomy)
on
April 27, 2009

Phongpan Tantipoon
Miss Phongpan Tantipoon
Candidate

Kosum Chinsethagij
Asst. Prof. Col. Kosum Chinsethagij,
Ph.D. (Anatomy)
Chair

Sitha Piyawinijwong
Assoc. Prof. Sitha Piyawinijwong,
Ph.D. (Anatomy)
Member

Jantima Roongruangchai
Assoc. Prof. Jantima Roongruangchai,
D.D.S., Ph.D. (Anatomy)
Member

Sirinush Sricharoenvej
Assoc. Prof. Sirinush Sricharoenvej,
Ph.D. (Anatomy)
Member

Nopparatn Sirisathira
Asst. Prof. Nopparatn Sirisathira,
Ph.D. (Anatomy)
Member

B. Mahaisavariya
Prof. Banchong Mahaisavariya,
M.D.
Dean
Faculty of Graduate Studies
Mahidol University

T. Kulthanan
Clin. Prof. Teerawat Kulthanan,
M.D.
Dean
Faculty of Medicine Siriraj Hospital
Mahidol University

ACKNOWLEDGEMENTS

The successful completion of this thesis can be attributed to the kindness and assistance of many people. I would like to respectfully express my gratitude to my major advisor, Assoc. Prof. Dr. Sitha Piyawinijwong for her kindness, valuable instructive advice, guidance and assistance which has made possible me to perform the study successfully. I am very grateful to my co-advisor, Assoc. Prof. Dr. Jantima Roongruangchai, Asst. Prof. Dr. Nopparatn Sirisathira and Assoc. Prof. Dr. Sirinush Sricharoenvej for their valuable comments, suggestions and consultations in this study.

I would like to extend my sincere gratitude to Asst. Prof. Col. Kosum Chinsethagij, who was the chair and external examiner of the thesis defense for her constructive comments and suggestions.

I am grateful to Mr. Kaseam Keudpeud and Mr. Choochai Hunjang for their valuable advice, kindness and helpfulness in histological laboratory technique. Furthermore, I would like to thank all staffs of the Anatomy Department, Faculty of Medicine Siriraj Hospital for their kindness and helpfulness in supporting some materials that used in this study.

I would also extend my appreciation to Miss Sirisombat Sunont and my friends from graduate study in Department of Anatomy, Faculty of Medicine Siriraj Hospital for their help and friendship.

Finally, I wish to express my deepest gratitude and appreciations to my parents and my sister and brother for their love and understanding, counseling, encouragement and invaluable support.

This research was supported by Siriraj Graduate Scholarship to Tantipoon P.

Phongpan Tantipoon

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PHONGPAN TANTIPOON 4936495 SIAN/M

M.Sc. (ANATOMY)

THESIS ADVISORY COMMITTEE: SITHA PIYAWINIJWONG, Ph.D. (ANATOMY), JANTIMA ROONGRUANGCHAI, D.D.S., Ph.D. (ANATOMY), NOPPARATN SIRISATHIRA, Ph.D. (ANATOMY), SIRINUSH SRICHAROENVEJ, Ph.D. (ANATOMY).

ABSTRACT

This study aimed to investigate the anatomical relations of suprascapular nerve that may cause nerve entrapment in Thais. It was done by carefully dissecting the bilateral limbs of cadaveric specimens to explore and scrutinize the relationship of the thorough course of the suprascapular nerve and its related structures. The dimension of superior transverse scapular, anterior coracoscapular and spinoglenoid ligaments was measured. A photograph of the suprascapular notch was taken and the area of suprascapular foramen was estimated. The anterior coracoscapular ligament was randomly taken out and processed under a standard histological technique for further microscopic study. One hundred and thirty-four limbs from 67 cadaveric specimens (34 male and 33 female, with an average age of 68.06 years) and 238 bony scapulae specimens were used in this study. On the bony structure aspect, the morphology of the suprascapular notch and the area of the suprascapular foramen were varied in size and shape. The results showed that a small V-shaped notch was the most risky type, corresponding to the triangular area of the suprascapular foramen, which yielded the least area and was most likely to cause nerve entrapment neuropathy. For related ligaments, the superior transverse scapular ligament which stretched out between the banks of the suprascapular notch was a single band and occasionally ossified, so could affect the nerve entrapment. Considering the relationship between the structures, the accompanying suprascapular artery traversed underneath the superior transverse scapular ligament together with the nerve could cause nerve entrapment, particularly if it coincided with the small V-shaped notch. Additionally, the existence of the anterior coracoscapular ligament located below the superior transverse scapular ligament and narrowed suprascapular foramen was another cause of nerve compression. Furthermore, the spinoglenoid ligament partly attached to the capsule of the shoulder joint could be an irritative cause of suprascapular nerve entrapment during joint motion.

In conclusion, the results suggested that there were several factors likely to cause suprascapular nerve compression, due to its long course. The anatomic variation of the related structures along the nerve course can be predisposing causes of suprascapular nerve entrapment. This thesis therefore provides fundamental knowledge for further clinical diagnosis and treatment for suprascapular nerve entrapment syndrome.

KEY WORDS: SUPRASCAPULAR NERVE/ ANATOMICAL RELATION/ NERVE ENTRAPMENT

67 pages.

ความสัมพันธ์ทางกายวิภาคศาสตร์ของเส้นประสาทซูปราสแคปปูลาร์ อันเป็นสาเหตุให้เกิดการกดทับต่อเส้นประสาท

ANATOMICAL RELATIONS OF SUPRASCAPULAR NERVE: CAUSES OF NERVE ENTRAPMENT

ผ่องพรรณ ตันติพูล 4936495 SIAN/M

วท.ม. (กายวิภาคศาสตร์)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์: สิทธา ปิยะวินิจวงศ์, Ph.D. (กายวิภาคศาสตร์), จันทิมา รุ่งเรืองชัย, D.D.S., Ph.D. (กายวิภาคศาสตร์), นพรัตน์ สิริสถิระ, Ph.D. (กายวิภาคศาสตร์), ศิรินุช ศรีเจริญเวช, Ph.D. (กายวิภาคศาสตร์)

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ทางกายวิภาคศาสตร์ของเส้นประสาทซูปราสแคปปูลาร์ อันเป็นสาเหตุให้เกิดการกดทับต่อเส้นประสาทในคนไทย โดยการชำแหละบริเวณสะบักอาจารย์ใหญ่อย่างระมัดระวังเพื่อเผยให้เห็นถึงเส้นทางของเส้นประสาทและโครงสร้างต่างๆ ที่สัมพันธ์อยู่กับเส้นประสาทตลอดเส้นทาง ทำการวัดมิติของเอ็น ทรานสเวิร์สแคปปูลาร์ชิ้นบน, โคราโคสแคปปูลาร์ชิ้นหน้า และสไปโนกลีนอยด์ จากนั้นทำการถ่ายภาพรูปร่างของแอ่งซูปราสแคปปูลาร์ นำภาพที่ได้ไปวิเคราะห์หาพื้นที่ของแอ่งด้วยโปรแกรมคอมพิวเตอร์ สุ่มเลือกและเฉาะชิ้นเนื้อของเอ็น โคราโคสแคปปูลาร์ชิ้นหน้าออกและนำไปผ่านขั้นตอนทางจุลกายวิภาคศาสตร์เพื่อศึกษาโครงสร้างเนื้อเยื่อ ศึกษาใน 134 แขนจาก 67 ร่างอาจารย์ใหญ่ แยกเป็นเพศชาย 34 หญิง 33 อายุเฉลี่ย 68.06 ปี และกระดูกสะบักจำนวน 238 ชิ้น เมื่อพิจารณาโครงสร้างกระดูกสะบักพบความผันแปรของลักษณะรูปร่างและขนาดของแอ่งซูปราสแคปปูลาร์และรูซูปราสแคปปูลาร์ โดยลักษณะของแอ่งแบบตัววีก้นแหลมขนาดเล็กหรือรูรูปสามเหลี่ยมนั้นเป็นปัจจัยเสี่ยงต่อการเกิดการกดทับต่อเส้นประสาทมากที่สุดเนื่องจากมีพื้นที่สำหรับให้เส้นประสาททอดผ่านน้อยที่สุด ผลการศึกษาเอ็นทรานสเวิร์สแคปปูลาร์ชิ้นบนที่ขึงอยู่ระหว่างขอบทั้งสองด้านของแอ่งซูปราสแคปปูลาร์พบว่ามีลักษณะเป็นแถบเดี่ยวและมีการก่อตัวกลายเป็นกระดูกขึ้นภายในเอ็นซึ่งจะมีผลรบกวนต่อเส้นประสาทได้ จากการพินิจความสัมพันธ์ระหว่างโครงสร้างต่างๆ บริเวณแอ่งซูปราสแคปปูลาร์พบความผันแปรในลักษณะที่หลอดเลือดแดงซูปราสแคปปูลาร์ลอดผ่านรูซูปราสแคปปูลาร์ไปพร้อมกับเส้นประสาท อีกทั้งยังพบการปรากฏของเอ็นโคราโคสแคปปูลาร์ชิ้นหน้าที่บริเวณด้านหน้าของแอ่ง ล่างต่อเอ็นทรานสเวิร์สแคปปูลาร์ชิ้นบน สองปัจจัยนี้มีผลทำให้พื้นที่บริเวณดังกล่าวแคบลง เป็นผลต่อการกดทับต่อเส้นประสาทได้ นอกจากนี้จากตำแหน่งการเกาะของเอ็นสไปโนกลีนอยด์ที่สัมพันธ์อยู่กับข้อไหล่น่าจะมีผลต่อการเกิดการรบกวนต่อเส้นประสาทขณะที่มีการเคลื่อนไหวข้อไหล่ได้

ผลจากการศึกษานี้ แสดงให้เห็นว่า สาเหตุของการกดทับประสาทซูปราสแคปปูลาร์นั้นมีหลายปัจจัย เนื่องจากเป็นประสาทที่ทอดยาว ความแปรผันทางกายวิภาคของโครงสร้างที่สัมพันธ์ตลอดเส้นทางของประสาทสามารถเป็นเหตุชักนำให้เกิดการกดทับของประสาทซูปราสแคปปูลาร์ การศึกษาในครั้งนี้จะเป็นความรู้พื้นฐานและเป็นประโยชน์ต่อการวินิจฉัยและรักษาอาการที่เกิดจากการกดทับต่อเส้นประสาทนี้ต่อไปได้

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LIST OF ABBREVIATIONS

%	Percent
º	Degree
mm	Millimeter
cm^2	Square centimeter
L	Length
W	Width
T	Thickness
π	Pi
r	Radius
SD	Standard diviation
p-value	Probability of obtaining a result at least as "impressive" as that obtained

CHAPTER I
INTRODUCTION

Suprascapular nerve entrapment syndrome has become increasingly recognized as a cause of shoulder pain and dysfunction in the orthopedics. Clinically, sign and symptom of suprascapular nerve entrapment are pain on the posterolateral aspect of the shoulder, characterized as deep, dull and diffuse aching which exacerbated by overhead activities or cross-body adduction of the extended arm, weakness of the external rotators and abductions of the shoulder. Depending on the duration of the manifestations, atrophy of either or both supraspinatus muscle or infraspinatus muscle can ensure (1-3).

The suprascapular nerve is a mixed peripheral nerve, containing motor and sensory components which derived from ventral rami of 4^{th} (variable), 5^{th}, 6^{th} and 7^{th} (variable) cervical spinal nerves (4-11). After branching from the upper trunk of the brachial plexus, the nerve traverses the posterior triangle of the neck parallel to the inferior belly of the omohyoid muscle and deep to the anterior border of the trapezius muscle. Then, it courses toward the superior border of the scapula, passes through the suprascapular notch beneath the superior transverse scapular ligament and enters the supraspinus fossa. After entering the fossa, the nerve gives off motor branches to the supraspinatus muscle and sensory fibers to the acromioclavicular and glenohumeral joints, and finally gives off motor branches to the infraspinatus muscle through the spinoglenoid notch (1,2,4,5).

Previous studies on the mechanism of the suprascapular nerve injury reported that acute traumatic accident was a common cause of the nerve injury. The acute traumatic causes that mostly mentioned were anterior glenohumeral joint dislocation, fracture of the proximal humerus, scapular fracture and direct trauma at the root of neck or posterior aspect of shoulder (12-15).

Furthermore, nontraumatic causes of suprascapular nerve injury were also reported. There were compression by soft tissue mass lesion such as ganglion cyst or

lipoma (16-20) or compression by various anatomic structures; such as the narrowing suprascapular notch, anomaly of superior transverse scapular ligament or the presence of the anterior coracoscapular ligament together with variation of spinoglenoid ligament at the spinoglenoid notch and tearing of rotator cuff tendon (2,21-35).

In addition, the suprascapular nerve entrapment has been recently reported in throwing athletes, who exposed to repetitive overuse or violent overhead activities, such as volleyball, baseball, tennis, weight lifting or swimming. All of these are vigorous and repetitive activities together with sporadic prolong positioning and traction which can be irritative and distinctive (36-43).

According to the anatomy of suprascapular nerve, it has a long course and related to the bony structures. Thus, it's vulnerable to be compressed and injuried. Most previous anatomical studies have been done to find out the vulnerable anatomical location where the suprascapular nerve might be endangered during surgical procedure or where the neuropathy might evolve.

However, the knowledge about the suprascapular nerve entrapment syndrome is insufficient. The incident of suprascapular nerve entrapment is less than 2% of all shoulder disorder. This rather low figure of the incident can be overlooked by other clinical problem, such as cervical disc disease, tendonitis, a tear of the rotator cuff or adhesive capsulitis (44-47).

The present study intends to find out anatomical relations of suprascapular nerve that may cause suprascapular nerve entrapment. In this regard, the course of suprascapular nerve from origin to termination and its related structures, the associated ligaments as well as the morphology of bony scapular notch from normal Thai cadavers have been investigated. This will provide the fundamental knowledge for further clinical diagnosis and treatment.

CHAPTER II
OBJECTIVES

The present study was intended to investigate the anatomical relations of the suprascapular nerve that may cause suprascapular nerve entrapment in Thais by:

1. Examining the course of the suprascapular nerve from origin to its termination and its related structures which may cause nerve entrapment.
2. Examining the anomaly of superior transverse scapular ligament at the suprascapular notch and estimating the dimension of this ligament.
3. Observing the presentation of spinoglenoid ligament at the spinoglenoid notch and examining the morphology of the ligament.
4. Examining the form of the suprascapular notch and the area of the suprascapular foramen was determined.

CHAPTER III
LITERATURE REVIEW

1. Suprascapular nerve entrapment syndrome

Suprascapular nerve entrapment syndrome is an unusual nerve entrapment syndrome that caused by compression or injury of the suprascapular nerve at the top or posterior aspect of the shoulder, resulting in shoulder pain and dysfunction.

Typically, most patients presented with suprascapular nerve entrapment have a similar history. They usually aged between twenty to fifty years often involved in the dominant limb. The most common complaint symptoms are pain, characterized as a dull and diffuse aching, located in the posterolateral aspect of the shoulder that exacerbated by cross-body adduction of the extended arm or overhead activities. In addition, they also have weakness of the affected shoulder. (1-2,44,48-49)

1.1) Etiology

The suprascapular nerve is susceptible to compression or injury because it has a long course, its relatively fixed position under the rotator cuff tendon and ligaments and its relation related to the bony foramen. According to previous studies, the cause of suprascapular nerve entrapment is divided into two groups, acute traumatic causes and nontraumatic causes (1).

For acute traumatic causes, the nerve may be compressed or injuried following anterior glenohumeral joint dislocation, proximal humerus fracture, clavicle fracture or scapular fracture. In these, the affected traction on the nerve induced injury to the nerve between its origin from upper trunk of brachial plexus and its anchoring part at the suprascapular notch (12-14). Furthermore, direct trauma at the root of neck or posterior aspect of the shoulder also cause damage to suprascapular nerve (15,50).

On the other hand, the nontraumatic causes were soft tissue mass lesion and hypertrophic muscle mass; such as ganglion cyst, lipomas, tumor or hematomas. The ganglion cyst occurred as a result of macrotrauma or repetitive microtrauma of the

posterior capsule-labral complex of the shoulder, and in consequence of capsular tearing which allowed synovial fluid leaking out to form a cyst that located close to the joint capsule. The ganglion cyst compression of the suprascapular nerve could be at the suprascapular notch or extend into the supraspinous or infraspinous fossa but most frequently reported ganglion cyst compression was at the spinoglenoid notch (16-20,46,51-53)

In addition, variation of the suprascapular notch configuration and abnormality of the superior transverse scapular ligament which attached between the superior margin of the scapula and the root of coracoid process to form a fibro-osseous tunnel for the suprascapular nerve, can also be the cause of nerve entrapment (21-23,30-34). Furthermore, entrapment of the suprascapular nerve can result from a complication after rotator cuff tear (24,29), or by pathologic condition around the spinoglenoid notch (26-28,35).

1.2) Clinical Evaluation

- **History**

Regardless of the numerous causes of suprascapular nerve injury, most patients presented with a similar history. Typically, patients were between the ages of 20-50 years with involvement of the dominant upper extremity. Frequently, the patient complained of poorly localized but constant dull-aching pain over the posterior and lateral aspects of the shoulder or sometime radiated into the radial side of the ipsilateral upper extremity and may also be referred to the neck or the upper anterior chest wall. The pain was severe in the early weeks and then became mild to moderate. Although the onset of the pain might relate with a specific acute trauma or change in activity level, most patients reported an insidious onset. Activities involving repetitive overhead motion also exacerbated the symptoms. According to the high origin of the nerve fibers, pain and weakness in the affected shoulder tended to be more extensive in patients with a proximal nerve lesion. While, patients with a distal lesion always complained only of weakness and might report minimal or no pain (1,3,54-59).

- **Physical examination**

Physical examination should be composed of a though shoulder, cervical spine examination and neurological evaluation to exclude other causes of symptom such as cervical spine disease, brachial plexopathy, rotator cuff tendinitis or intraarticular glenohumeral pathology.

During the early stages of suprascapular nerve injury, the examination may only yield non-specific findings. On the other hand, a common finding in chronic nerve injury may reveal atrophy of the supraspinatus or/and infraspinatus muscles that depends on the site of compression. Due to the overlying trapezius muscle, atrophy of the supraspinatus muscle may be difficult to detect in some patients. Atrophy of the infraspinatus muscle is rather readily apparent as it situates underneath the skin. Palpation along the course of the nerve can reveal focal tenderness at the site of compression.

The physical assessment also reveals mild to moderate loss of strength in shoulder abduction (0º- 20º initial range) and external rotation. Weakness of shoulder abduction will occur only with lesions involving the supraspinatus muscle (the nerve is compressed at the proximal part, at the suprascapular notch) and is compensated by deltoid muscle to elevate and further abduct the humerus. Involvement of infraspinatus muscle, results in weakness of shoulder external rotation. However, it does not always exhibit impairment of external rotation as some patients can compensate with the teres minor and posterior part of the deltoid muscle (1-2,46-64).

Furthermore, the cross-body adduction test is a provocative test for suprascapular neuropathy, the positive pain is produced by passive adduction of the extended arm across the chest because at this position the nerve is under increasing tension particularly at the superior transverse scapular ligament. In addition, patients whose symptoms are suspicious for a suprascapular nerve lesion, a diagnostic injection test can be considered. The nerve block with a local anesthetic agent injected into the suprascapular notch and the test is considered positive if the pain is relieved (54,57).

- **Diagnostic study**

Diagnostic study is the further step for investigation after the previous physical examination remained some doubt. There are various methods such as,

electrodiagnosis study and imaging study which can provide essential information in the diagnosis and treatment of suprascapular nerve entrapment (1,54-55,57,60-61,63,65-66).

- ***Electrodiagnosis study***

In order to confirm and localize the lesion of the suprascapular nerve entrapment, the electrodiagnosis study including nerve conduction velocity study and electromyography was used.

The nerve conduction velocity study is commonly used to evaluate nerve function, especially the ability of electrical conduction, of the motor and sensory nerves. The nerve conduction velocity method can be very useful in detecting the demyelination and axonal degeneration in a nerve and able to quantify the degree of nerve injury (65). According to Kraft (1972) who studied the latency from Erb's point (which located on the posterior border of the sternocleidomastoid muscle at midway between its attachments 2-3 centimeters above the clavicle.) to the fixed locations in the supraspinatus and infraspinatus muscles, found that the mean normal latency was between the 2.7±0.5 and 3.3±0.5 milliseconds, respectively. Any pathologic condition of the nerve, the conduction velocities showed prolonged motor latencies from Erb's point to the supraspinatus or infraspinatus, depending on the level of the pathology (66-67).

An electromyography (alternative names are EMG or myogram) is usually in combination with a nerve conduction velocity test to assess the physical condition of the muscle and condition of the nerve controlling the muscle. Performing the test, a needle electrode is inserted through the skin into the muscle and the electrical activity is detected by this electrode (68). When the suprascapular nerve was injuried, the EMG demonstrated an increasing spontaneous activity, fibrillations and positive sharp waves which indicated the denervated muscles. In additional, the changes of myogram including polyphasic activity and diminished in the amplitude of evoked potentials were also detected (1,54,65).

- ***Imaging studies***

Several imaging modalities can be utilized to identify the possible sites of nerve injury which are an important part of the evaluation of the suprascapular nerve entrapment. Regularly, standard radiographs of the cervical spine and the shoulder are

selected to be the first choice but it usually demonstrates not much pathologic change of the soft tissue.

In plain film, the x-ray beam was directed 15 to 30 degrees caudally toward the suprascapular notch to determine its size. This projection avoids the superimposition of the clavicle, the scapular spine and the ribs. Radiographs are particularly useful for patients with a suspected fracture after trauma to this area. In the acute stage, fracture lines may be observed near the anatomically sensitive regions whereas in more chronic cases, callous or fibrous tissue may compress or entrap the nerve (54-55).

A computed tomography (CT) scan can demonstrate osseous abnormalities affecting the nerve. However, similar to the radiographs, CT scan is often provided little additional diagnosis value (54-55,63,69-70).

In addition, magnetic resonance imaging (MRI) is the best modality for assessment of the possible sites of the suprascapular nerve entrapment. This modality is useful in identification the course of the nerve and demonstration of various intraarticular and extraarticular soft-tissue masses that may affect the nerve. Ganglion cysts, for example, are clearly visible on the MRI (1,51,54,70-73). Furthermore, MRI technique is also able to demonstrate denervative changes in the supraspinatus and infraspinatus muscles (74).

1.3) Treatment

The treatment of the suprascapular nerve entrapment depends on the duration of the symptoms, the location and etiology of the entrapment. Typically, it is divided into two methods, conservative treatment and operative treatment (1-2,47,49,54-55,57,63-64,66,75-76).

A trial of conservative or non-operative treatment should be the first choice for all patients with a suprascapular nerve injury (1,47,54,62-63,75-77). The initial treatment includes avoidance of activities or posture that caused trauma and irritation to the nerve. However, these activities or postures vary from patient to patient, but typically involve repetitive overhead motions or cross-body adduction of the extended arm. Furthermore, patients may receive anti-inflamatory injection at the suprascapular notch to relive pain and reduce inflammation of the nerve (75).

In addition, this treatment should be combined with physical therapy which included the electrical stimulation to relive the pain, a rehabilitation program and a self directed home exercise program to enhance flexibility of muscle around the glenohumeral joint and maintain range of motion of this joint. A further strengthening program of the scapular stabilizing muscles to enhance the compensation muscle and regian muscular balance about the shoulder should be recommended. Especially, special attention should be directed toward establishing proper posture with scapular retraction exercise, as well as strengthening of the trapezius, the rhomboids and the serratus muscles. Rehabilitation focused on scapular function is beneficial in recovery and may avoid recurrence of the injury (1,62-63,77). However, during rehabilitation phase, movement such as cross-body adduction, forward flexion or external rotation of the shoulder which irritate to the suprascapular nerve should be carefully monitored (62).

The result of conservative treatment depends on the etiology and location of the nerve lesion. Thus, after 3-6 months rehabilitation program has brought no improvement, the operative procedures such as open surgical technique and arthroscopic technique to release of the entrapped nerve are indicated for the patients (45,48,57,85).

The surgical approach is usually dictated by the location and cause of the lesion. Although an anterior approach to the suprascapular notch has been described, it has not been routinely utilized due to the difficult dissection, increase risk of neurovascular injuried, and poor visualization of the nerve. Therefore, the majority of the surgeons tend to use either the posterior or the superior approaches to the nerve (54).

If the suprascapular nerve entrapment is localized at the suprascapular notch, with no evidence of the mass lesion, the operative treatment is usually performed to release the suprascapular nerve by incising the superior transverse scapular ligament. In contrary, if the entrapment occurred at the spinoglenoid notch, the operative treatment is usually designed to release of the nerve via the spinoglenoid ligament (inferior transverse scapular ligament) (1,47,54,55,57,63-64,76).

2. Anatomy of suprascapular nerve

Suprascapular nerve is a mixed peripheral nerve, containing motor and sensory components, which arises from upper trunk of brachial plexus. It originates from ventral rami of fifth and sixth cervical spinal nerve, occasionally with a contribution from fourth cervical spinal nerve (4-6). In addition, the variation of the origin of the suprascapular nerve such as arises from the union of fourth and fifth directly (8) or originates from formation of fifth, sixth and seventh cervical spinal nerve (10) has been reported.

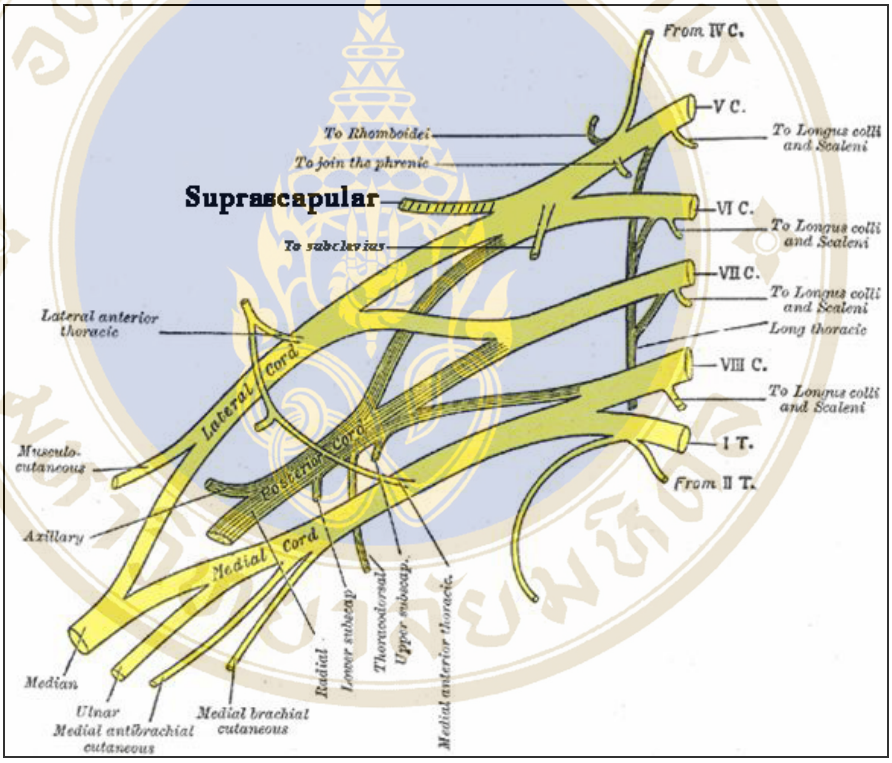


Figure 3.1: Diagram of the brachial plexus showed the suprascapular nerve originating from ventral rami of the 5th and 6th cervical spinal nerve and occasionally with a contribution from 4th cervical spinal nerve. (Adapted from: http://chiropractiehuizen.com/_wsn/page4.html)

After separating from the upper trunk of brachial plexus at the Erb's point or punctum nervosum, the nerve travels laterally across the posterior triangle of neck parallel to the inferior belly of omohyoid muscle, deep to the anterior border of

trapezius muscle. Then, it points towards the superior border of scapula accompanies with the suprascapular artery, a branch from the thyrocervical trunk of subclavian artery.

At the superior border of scapula, the suprascapular nerve enters the supraspinous fossa by passing through a fibro-osseous tunnel which is formed by suprascapular notch and suprascpular ligament (also known as superior transverse scapular ligament). Normally, it's always found that the suprascapular nerve passes beneath the superior transverse scapular ligament, while the suprascapular artery travels above the ligament. However, anatomical variants of the suprascapular artery passes through the suprascapular notch have been described. An anomalous suprascapular artery passing underneath the superior transverse scapular ligament along with the nerve has been reported (78-79).

After crossing the suprascapular notch and traveling in the muscle mass about one centimeter, the suprascapular nerve sends off 1-2 motor branches to innervate the supraspinatus muscle. Furthermore, just proximal or at the superior transverse scapular ligament, the nerve sends off sensory fibers to acromioclavicular joint, coracoclavicular ligament, coracohumeral ligament and subacromial bursa. Afterward the suprascapular nerve travels oblique laterally along the supraspinous fossa under the supraspinatus muscle descends to spinoglenoid notch. There, it sends sensory fibers to posterior part of glenohumeral joint capsule (80-81).

Subsequently, the suprascapular nerve travels around the lateral border of the base of scapular spine, passing through the spinoglenoid notch which is formed by scapular spine and the spinoglenoid ligament (or inferior transverse scapular ligament). Thereafter, it terminates into 3-4 motor branches to innervate the infraspinatus muscle.

The existence of the cutaneous branch of the suprascapular nerve has been neglected and hardly mentioned in the standard textbook except the Gray's Anatomy (5). This possibly, due to the difficulty in routine dissection whereby the nerve was damaged on the hardship to differentiate it from the cutaneous branch of the axillary nerve (82).

However, it has been a few studies that reported the finding of the cutaneous branch of the suprascapular nerve. In 1980, Horiguchi M. reported the presence of the

cutaneous branch in 5 cadavers (4 male, 1 female) from 61 Japanese cadavers (82). Later in 1994, Ajmani reported a cutaneous branch of the supracapular nerve supplying the proximal 1/3 of the lateral aspect of the arm in 5 cadavers from 34 adult cadavers. All of them were found bilaterally in 3 cadavers and unilaterally in 2 cadavers (83).

The description of the course of the cutaneous branch was similar in all reports (82-84). The branch took off from the main trunk, either under or just distal to the superior transverse scapular ligament or from the superior branch of the nerve to supraspinatus muscle. Thereafter, the branch traveled superolaterally along the supraspinatus muscle, passed anterior to the coracoacromial ligament towards the tip of the acromion. Then it pierced the deltoid muscle to become subcutaneous as the cutaneous branches of the suprascapular nerve which innervated skin area of the proximal 1/3 of arm.

3. Patterns of injury of the suprascapular nerve

Considering the anatomy of the suprascapular nerve, it has a long course and relates to various bony structures. Thus, it's vulnerable to be compressed and injuried. Several studies have been done to find out any important anatomical location where the suprascapular nerve might be endangered during the surgical procedure or in the neuropathic condition. The two most vulnerable sites of the suprascapular nerve injury have been documented (1). First, proximal part at the suprascapular notch where the nerve traverses beneath the superior transverse scapular ligament toward the supraspinous fossa. Second, distal part at the spinoglenoid notch where the nerve turns into the infraspinous fossa by traveling through the fibro-osseous tunnel between the spinoglenoid notch and ligament (1,86).

3.1) Injury at the proximal part of the suprascapular nerve

The entrapment of the suprascapular nerve at the suprascapular notch, where the nerve is tethered by the superior transverse scapular ligament was first described by Thompson and Kopell in 1959 (87-89). In which, they proposed a friction-related injury that aroused as a result of the sliding action of the nerve within the suprascapular notch, They reported that abduction or horizontal adduction of the

shoulder exerted traction on the suprascapular nerve, which could lead to its compression against the superior transverse scapular ligament.

In 1979, the mechanism of injury of the suprascapular nerve was first proposed by Rengachary and coworkers whom conducted an extensive anatomical, clinical and comparative studies of the possible etiology of the suprascapular nerve entrapment at the suprascapular notch (21,64). They dissected bilaterally suprascapular regions of 15 cadavers, traced the course of the suprascapular nerve from its origin to the termination in the supraspinatus and infraspinatus muscles. Thereafter, they observed the relation of the nerve to the suprascapular foramen during elevation, depression, protraction and retraction of the shoulder girdle and also abduction, adduction, flexion, extension, internal rotation and external rotation of the arm. The authors found that the nerve had two fixed points, one at the origin in the brachial plexus and the other at its termination in the supraspinatus muscle. During the motion of the arm, these fixed points moved in unison so that independent translational motion did not occur.

Surprisingly, they found that the plane of the origin from upper trunk of the brachial plexus and the plane of the termination of the nerve in the supraspinatus muscle were higher than the plane of the suprascapular foramen. Thus, the nerve was often pressed against to the sharp inferior margin of the superior transverse scapular ligament. This opposition was accentuated during depression and retraction shoulder girdle or hyperabduction of the shoulder joint. Therefore, the mechanism of trauma to the nerve seemed focus on the kinking of the nerve against the ligament at the foramen, which they designated as the “sling effect”.

In addiction, Rengachary and coworkers were examined the variations on morphologic characteristic of the suprascapular notch in 211 adult scapulae and classified into six types that focused on the shape of the suprascapular notch as well as the degree of ossification of the superior transverse scapular ligament as following:

Type I: The suprascapular notch had an entire superior border of the scapula as a wide depression from the medial border of superior angle of the scapula to the base of the coracoid process.

Type II: The suprascapular notch showed a wide, blunted V-shaped notch occupying nearing 1/3 of the superior border of the scapular and the widest point in the notch was along the superior border of the scapula.

Type III: The suprascapular notch was symmetrical U-shaped with nearly parallel lateral margins.

Type IV: The suprascapular notch was very small V-shaped.

Type V: The suprascapular notch was very similar to type III with partial ossification of the medial part of the superior transverse scapular ligament.

Type VI: The ligament was complete ossified, resulting in the bony foramen of variable size located just inferomedial to the base of the coracoid process.

Their conclusion based on the size and shape of the suprascapular foramen came up with the assumption that the type IV of the suprascapular notch was associated with suprascapular nerve entrapment.

In 1998, Ticker and colleagues (22) studied the variations of the anatomical relations of the suprascapular nerve and implications for the treatment of the suprascapular nerve entrapment syndrome. They carried out 79 shoulders dissection from 41 human cadavers and examined the incidence and location of any ganglion cysts, variations in the shape of the suprascapular notch and the degree of ossification of the superior transverse scapular ligament.

They found only one ganglion cyst (1%) in 79 shoulders. It was a 10 x 16 x 25 mm cystic mass, extended medially from the glenohumeral joint into the supraspinous fossa, adjacent to the suprascapular notch thereby the suprascapular nerve at the notch and distal portion could be compressed and altered its course. They classified the suprascapular notch into two types, as a U-shaped notch (77%) and a V-shaped notch (23%). They concluded that the U-shaped notch associated with entrapment less than the V-shaped notch and no other pathologic condition was found.

In reference to the superior transverse scapular ligament, Ticker and colleagues also classified the ligament into three types as following: non-ossified superior transverse scapular ligament (77%), partial ossified superior transverse scapular ligament (18%) and the remaining 5% were completely ossified.

In addition, they reported an anomality of the superior transverse scapular ligament, as multiple bands, in two shoulders. One shoulder had two distinct bands of the superior transverse scapular ligament spanning the suprascapular notch. Both bands took origin from the superolateral corner of the notch, one crossed transversely to superomedial corner of the notch while another pointed inferiorly to attach at a

point just below the superior corner of the notch. The suprascapular nerve was found passing between two distinct bands and entering the supraspinous fossa.

Another shoulder had three bands of superior transverse scapular ligament, consisted of superior and inferior bands which were non-ossified and ossified middle band. The suprascapular nerve traveled beneath the trifid ligament.

They concluded that both of partial-ossified or complete ossified superior transverse scapular ligament and multiple bands of superior transverse scapular ligament might cause an entrapment of the nerve.

In 2002, Avery and his coworkers (25) described an unreported ligament that located anterior to the suprascapular foramen and suggested that it might be a risk factor to suprascapular nerve entrapment.

In their study, 54 shoulders from 27 cadavers (15 male and 12 female, mean age 78 years) were dissected. They found an unreported ligament, which located inferior to the superior transverse scapular ligament and anterior to the suprascapular foramen in 16 cadavers (9 male, 7 female) or 60%. In regard to its location and attachment, they named it as anterior coracoscapular ligament.

Most of the cases (81.25%), the ligament transected the suprascapular foramen that resulted in diminishing the space which the suprascapular nerve passing through. Therefore, they concluded that the anterior coracoscapular ligament could be a possible risk factor in suprascapular nerve entrapment.

Later, in 2003 Bayramuglu and his coworkers (23) studied the anatomical risk factors which could probably be a cause of the suprascapular nerve entrapment. They dissected bilateral 32 shoulders from 16 cadavers (12 male and 4 female, mean age 56.4 years), observed the morphologic characteristics of the superior transverse scapular ligament and suprascapular notch. They also investigated the relationship of the superior fibers of the subscapularis muscle with the suprascapular notch and the suprascapular nerve.

They classified the ligament into four types as following:

Type I: The superior transverse scapular ligament was a uniform fan shaped (53.1%). The anterior and posterior borders of the fan shaped ligament were thicker and the middle portion of the ligament was more like a membrane. The suprascapular nerve passed underneath the fan shaped ligament.

Type II: The presence of the anterior coracoscapular ligament below the superior transverse scapular ligament (18.8%) and the suprascapular nerve in all specimens traveled between two ligaments.

Type III: The bipartite superior transverse scapular ligament (15.6%) which had two bands, as anterior and posterior, but the suprascapular nerve passed beneath both bands of the ligament.

Type IV: Calcified superior transverse scapular ligament (12.5%). The available space for the suprascapular nerve was significantly reduced and the nerve passed beneath the ligament.

Regarding to the relation of the superior fibers of the subscapularis muscle with the suprascapular notch and the suprascapular nerve, the study revealed that the superior part of the subscapularis muscle usually passed below the base of the suprascapular notch. However, they also indicated an abnormal hypertrophy of the subscapularis muscle in 5 shoulders of 16 cadavers (15.6%). The superior part of the muscle covered entire anterior surface of the suprascapular notch and the suprascapular nerve. Thereby, a considerably decrease in the available space for the suprascapular nerve could cause the nerve entrapment (23,90).

Since the subscapularis muscle has its main function as the medial rotation and adduction of the arm and help stabilizing shoulder joint, thus hypertrophy of the muscle may occur in ones who are involved in repetitive overhead activities such as volleyball or baseball. This may be liable to suprascapular nerve entrapment in those individual (90).

3.2) Injury at the distal part of the suprascapular nerve

Consideration to the anatomical relations of the suprascapular nerve, another susceptible site of suprascapular nerve entrapment has been noted at the spinoglenoid notch, where the suprascapular nerve and vessels enter the infraspinous fossa to supply infraspinatus muscle. However, entrapment of the suprascapular nerve at this site is rare and much less common than entrapment at the suprascapular notch (1,26,66).

In 1981, Ganzhorn and coworkers (91) published their first report on the entrapment of the distal part of the suprascapular nerve which resulted from the spinoglenoid ligament or as known as inferior transverse scapular ligament.

In the next year (1982), Aiello and coworkers (92) described a more dynamic mechanism in spinoglenoid notch lesions. They reported that the spinoglenoid ligament which inserts medially on the scapular spine had a variable lateral insertion. The usual site of lateral insertion of the ligament was lateral edge of the scapula, however other site of insertion also reported at the capsule of shoulder joint. In the latter case, movement of the arm could reduce diameter of the spinoglenoid notch and caused repeating focal compression of the suprascapular nerve and finally leaded to nerve entrapment.

Subsequently, several researchers were interested in the spinoglenoid ligament and found out that the presentation of the ligament varies between 14-100% (22,25-27)

In 1991, Demaio and coworkers (93) studied the prevalence of the spinoglenoid ligament in cadavers. They dissected 75 shoulders from 39 cadavers (18 male and 21 female, mean age 77.6 years). The criteria used to indicate the presence of the ligament were based on the medical definition of a ligament and the anatomical definition of the spinoglenoid ligament. The medical definition of a ligament was a band of flexible, tough, dense white fibrous connective tissue connecting the articular margin of the bones and sometimes extended to the joint capsule. The anatomical definition, the spinoglenoid ligament extended from the lateral aspect of the root of the scapular spine to the margin of the glenoid process. Together with the bone, it formed a foramen for the passage of the suprascapular nerve and vessels into the infraspinous fossa. They reported the existence of the spinoglenoid ligament only in one cadaver.

In 1998, Ticker and coworkers (22) dissected in 79 shoulders from 41 cadavers (16 male and 25 female, mean age 77.3 years) to examine the presence of the spinoglenoid ligament. They found that the ligament existed in 11 of 79 shoulders or 14% (9 male and 2 female), which extended from the scapular spine to the posterior glenoid neck, medial to the glenoid rim.

In the same year, Demirhan and coworkers (26) studied the occurrence of the spinoglenoid ligament and its relationship to the posterior capsule of glenohumeral joint by dissecting 23 shoulders (15 male and 8 female) from 19 fresh-frozen cadavers. They found the ligament in 14 shoulders (60.8%), which was four times greater than what found in Ticker's work.

In addition, Demirhan and coworkers described the mechanism and clinical relevance of suprascapular nerve entrapment at the spinoglenoid notch. They suggested that the inferior portion of the spinoglenoid ligament was lengthened during adduction or internal rotation of the humerus, caused the suprascapular nerve stretching underneath the ligament and led to distal suprascapular nerve entrapment.

This mechanism was corresponding to the suggestion from several researches that distal suprascapular nerve entrapment always associated with the overhead athletes such as volleyball player, baseball player or in who had violent repetitive overhead activities (38-43).

In 2003, Junji and coworkers (27) studied the incidence of the spinoglenoid ligament and defined the anatomic characteristic of the ligament. They dissected 115 shoulders from 62 cadavers (38 male and 24 female, mean age 74.4 years) and recorded the feature of the ligament as absent, distinct (ligament-type) or thin (membrane-type). Then, they measured each ligament's width at the mid portion as well as its maximum distance from the ligament to the bone of spinoglenoid notch and to the suprascapular nerve.

They found the spinoglenoid ligament in 94 shoulders (81.7%) and it was classified into two types, as ligamentous type presented in 25 shoulders (21.7%) and membranous type presented in 69 shoulders (60%).

Furthermore, they found a variation in the thickness of the ligament and variation in the distance from the ligament to the bone and to the nerve and suggested that it might associate to the distal suprascapular nerve entrapment.

The same year (2003), Bektas and coworkers (94) reported a new anatomic finding of a spinoglenoid septum. By dissecting 32 shoulders of 16 embalmed cadavers, they found that the spinoglenoid ligament in 5 shoulders was thin, loose and weak structure. They also found an other as a septum-like structure with a thickening of the covering fascia. It originated from lateral margin of the spinoglenoid notch and inserted into the posterior capsule extending between the supraspinatus and infraspinatus tendon. Thus, they named this structure as spinoglenoid septum that could be a cause of entrapment to the suprascapular nerve.

Subsequently, in 2005 Plancher and coworkers (28) studied the anatomy, morphology and histology characteristics of the spinoglenoid ligament. The

spinoglenoid ligament from 58 fresh-frozen shoulders of 30 cadavers (16 male, 14 female, mean age 60 years) was dissected out to evaluate their anatomic dimensions, histological characteristic and relationship to the suprascapular nerve, the posterior part of the capsule and the gleniod rim.

The gross examination revealed that the spinoglenoid ligament existed in all specimens (100%). It presented as an irregular quadrangular shape, the deep fibers of the ligament extended from the lateral aspect of the scapular spine to the posterior part of the glenoid and the superficial fibers blended with the posterior aspect of the shoulder joint capsule.

Histologic study revealed the Sharpey fibers inserting into the bone at the scapular spine and blending with the posterior aspect of the joint capsule to insert into the posterior surface of the glenoid. This finding confirmed the ligamentous nature of this structure.

Recently, in 2007, Plancher and coworkers (95) examined the changing pressure that was created by the spinoglenoid ligament on the distal suprascapular nerve during glenohumeral motion. By dissecting 25 shoulders from 13 fresh frozen cadavers (9 male and 4 female, mean age 60 years), then 10 shoulders were immobilized on a stand in an upright anatomic position for visual observation of variation in the position and tension of the ligament. The remaining 15 shoulders were placed a transducer to sense and record the pressure during glenohumeral motion. They found that the spinoglenoid ligament was affected by the position of the glenohumeral joint, the greater pressure was noted when the arm was full adduction and internal rotation. The changes in combination with repetitive shoulder movement might cause repeated trauma or compression on the distal suprascapular nerve created by a scapular tunnel syndrome.

CHAPTER IV
MATERIALS AND METHODS

Materials

1. Cadaveric specimens

One hundred and thirty-four shoulders taken from 67 Thais cadavers were used in the study. These embalmed cadavers were provided by the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University and dissected previously by the second year medical students in the standard anatomical laboratory course in 2007. There were 34 male and 33 female with a mean age of 68.06 years (range from 28-95 years). Occasionally the fresh cadaver was also dissected to investigate the morphology of the related ligamentous structures.

2. Bony scapular specimens

A total two hundred and thirty-eight bony scapulae from Thais cadavers were obtained from the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University that preserved for anatomical laboratory course during 2006 to 2007 were examined.

3. Instrumentation

3.1 Digital caliper

The digital caliper (Mitutoyo, Kawasaki, Japan) with the accuracy of 0.01 mm was used for measuring the linear parameter (Figure 4.1).

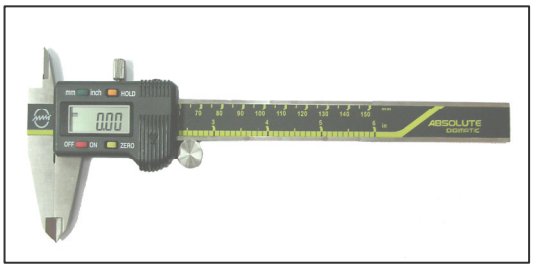


Figure 4.1: The digital caliper (Mitutoyo, Kawasaki, Japan) that was used in this study.

3.2 Digital camera

The digital camera was used to photograph the anatomical relation of the suprascapular nerve and the morphologic characteristic of the suprascapular notch for further image analysis. The scapulae were placed in the pose that the suprascapular notch was in the exact horizontal plane. With the constant distant between the camera's lens and the notch, the photograph of the suprascapular notch was taken in the digital format. All the photos were always taken in conjunction with the ruler in order to calibrate for the actual dimension of the specimens.

3.3 Image analysis program

The area of the suprascapular notch was measured by using the UTHSCSA image tool program (developed by the team from the University of Texas Health Science Center at San Antonio, Texas and available from the internet by anonymous FTA from http://www.maxradb.uthscsa.edu).

Methods

1. Cadaveric dissection

The specimens were obtained from the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University and partially dissected by second year medical students during their anatomy laboratory course. Subsequently, bilateral shoulder regions of these specimens were further carefully dissected to explore the course of the suprascapular nerve and its related structures.

The skin was completely removed from the scapular region. The soft tissue and the fatty subcutaneous layer were dissected out and the trapezius muscle and the deltoid muscle were clearly demonstrated. After that, both of the muscles were removed from their insertion to expose the scapular muscles. Subsequently, the scapular muscles had been carefully detached, the course of suprascapular nerve from its origin at the upper trunk of brachial plexus to its termination at the infraspinatus muscle and the related structures along its course were noted, especially the relation at the suprascapular notch.

The suprascapular notch located at the superior border of the scapula, at the banks of the notch the suprascapular (or superior transverse scapular) ligament was stretched out and formed the fibro-osseous tunnel. The suprascapular nerve passed through the

supraspinous fossa underneath the ligament to supply the supraspinatus muscle. The courses of the suprascapular nerve and vessels were investigated and recorded. The morphologic characteristic of the suprascapular notches were examined and photographed. As well as the anomalies of the superior transverse scapular ligament, the presentation of the anterior carocoscapular ligament and the degree of ossification of the ligament were examined and recorded. Eventually the attached muscles were removed from the scapula and the suprascapular notch area was cleaned. The dimensions of the suprascapular ligament and the anterior coracoscpular ligament were measured and recorded. After the scapula was placed to keep the suprascapular notch in the horizontal plane, the photographs of the suprascapular notch were taken. The calibrated ruler was included in the frame and the center of the lens was kept in line (Figure 4.2).

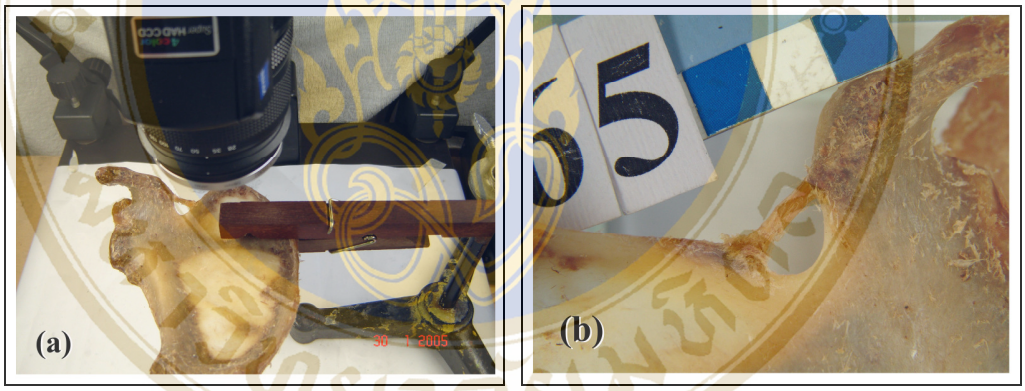


Figure 4.2: Demonstrating the measurement of the area of the suprascapular notch. The scapula was placed to keep the suprascapular notch in the horizontal plane (a), the calibrated ruler was included in the frame and the center of the lens was kept in line and then the photograph of the suprascapular notch was taken (b).

2. Measurements

2.1) Measurement of the dimension of the superior transverse scapular ligament

The dimensions of the superior transverse scapular ligament (LxWxT) were measured by using the digital caliper (Mitutoyo, Kawasaki, Japan)**.** The length (L) was taken from the center of the ligament between both bony attached points. The width (W) was measured at both ends and the average was taken. The thickness (T) was measured at the center of the ligament. In the case of ossified superior transverse scapular ligament was excluded from measurement.

2.2) Measurement of the dimension of the anterior coracoscapular ligament

The dimensions of the anterior coracoscapular ligament (LxWxT) were measured by using the digital caliper. The length (L) of the ligament was measured from the upper border and lower border of the ligament between bony attachments and then the average was taken. The width (W) of the ligament that was measured at both bony attachments and the average was taken. The thickness (T) was taken at the center of the ligament.

2.3) Measurement of the dimension of the spinoglenoid ligament

The dimensions of the spinoglenoid ligament (LxWxT) were measured by using the digital caliper. The length (L) of the ligament was measured from the upper border and lower border of the ligament between bony attachments and then the average was taken. The width (W) of the ligament that was measured at both bony attachments and the average was taken. The thickness (T) was taken at the center of the ligament. In addition, the distance from the spinoglenoid ligament to base of the spinoglenoid notch was measured from the mid-portion of the inferior border of the ligament perpendicular to the base of spinoglenoid notch.

2.4) Measurement of the area of suprascapular notch

The measurement of the area underneath the superior scapular ligament (suprascapular foramen) was carried out on the image tool program. The digital image of the suprascapular foramen was imported into the program, the measurement was taken under the various conditions depended on the shape of the foramen.

If the suprascapular foramen resembled the ellipsoidal shape, the major diameter (a) and minor diameter (b) which crossing the foramen were measured. Then the cross sectional area of the foramen was yielded from the following formula:

Ellipsoid area = π x a/2 x b/2

If the suprascapular foramen resembled the circle, the diameter of the circle was measured and the radius (r) was taken by dividing by 2. The cross sectional area of the foramen was yielded as following:

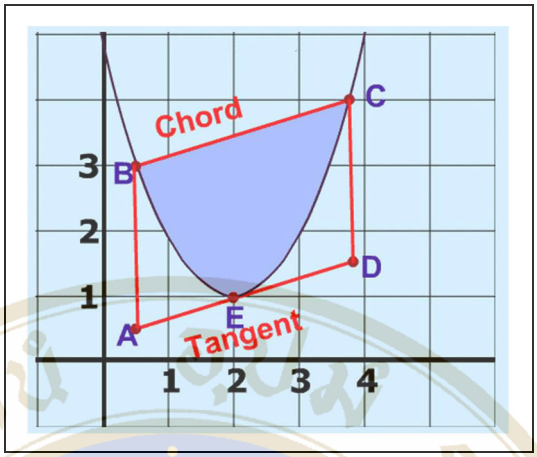
Circular area = πr^2

If the suprascapular foramen resembled the triangular shape, the base of the triangle was measured by drawing the chord line superimposed to the inferior border of the suprascapular ligament and the height was taken by drawing a perpendicular line from middle part of the chord line to the base of the suprascapular notch. Then the cross sectional area of the foramen was yielded from the following formula:

Triangular area = 1/2 x (base x height)

If the suprascapular foramen resembled the area enclosed by parabolic curve, the circumscribed parallelogram was drew, by drawing the chord line superimposed to the inferior border of the suprascapular ligament and the tangent line on the bottom of the notch. The area of the parallelogram was then calculated. Later the parabolic area was yielded as the following:

The area enclosed by chord of parabola = 2/3 area of circumscribed parallelogram formed by the chord of the parabola and a tangent of the parabola.



(from: http://www.mathwarehouse.com/geometry/parabola/area-ofparabola.php)

3. Histological Analysis

The microscopic structure of the anterior coracoscapular ligament was studies by randomly sampling of the ligament from the embalmed cadavers and one fresh cadaver (77 years-old, female). The ligament was dissected out and processed under standard histological technique. The tissues were post-fixed and fixed overnight in 10% formaldehyde, dehydrated in graded alcohol and embedded in paraffin. The tissue blocks were cut at 6 micrometer thick and stained with hematoxylin-eosin. The tissue section was investigated under the light microscope and the photograph was taken.

4. Statistical Analysis

The statistical analysis of the data was performed by using SPSS program (version 13.0 for window). The results were presented in the Mean±SD and the statistical significance for all analysis was set at $p<0.05$.

CHAPTER V
RESULTS

1. Anatomical relations of the suprascapular nerve

One hundred and thirty- four limbs from 67 Thai embalmed cadavers (34 male, 33 female) with an average age of 68.06 years (range from 28-95 years, SD=15.26) were dissected. The course of the suprascapular nerve from its origin at the upper trunk of the brachial plexus to its termination at the infraspinatus muscle and its related structures along its course was carefully observed on the 127 limbs. The remaining 7 limbs were excluded because of the incomplete nerve course due to the damage of the suprascapular nerve during routine anatomical laboratory course.

The suprascapular nerve of all limbs arose from upper trunk of the brachial plexus which corresponded to what was mentioned in the standard textbook. After arising from the upper trunk of the brachial plexus (Figure 5.1), it lay superior to the trunk and passed inferolaterally across the posterior triangle of neck, parallel to the inferior belly of the omohyoid muscle and deep to the anterior border of the trapezius muscle. Subsequently, the suprascapular nerve was joined and accompanied by the suprascapular artery which branched from the thyrocervical trunk of the subclavian artery and pointed toward the suprascapular notch (Figure 5.2).

The suprascapular notch was located on the superior border of the scapula, between the banks of the notch the suprascapular (or superior transverse scapular) ligament was stretched out and formed the fibro-osseous tunnel. The present study did not found any soft tissue mass lesion around the suprascapular notch. While the relationship between the suprascapular nerve, the suprascapular artery and the suprascapular notch was categorized into 2 types (Table 5.1). One fell in with the previously mentioned in the standard textbooks, the suprascapular nerve passed beneath the superior transverse scapular ligament while the suprascapular artery traveled above the ligament. There was found in 97 limbs (76.38%), in which 66.14%

was bilateral (84 limbs) and 10.24% was unilateral (13 limbs, 6 of the left, 7 of the right).

The other was considered as a variation subligamentous course of the suprascapular artery that passing underneath the superior transverse scapular ligament together with the suprascapular nerve (Figure 5.3). There was found in 30 limbs (23.62%), in which 12.60% was bilateral and 11.02% was unilateral (14 limbs, 8 of the left, 6 of the right).

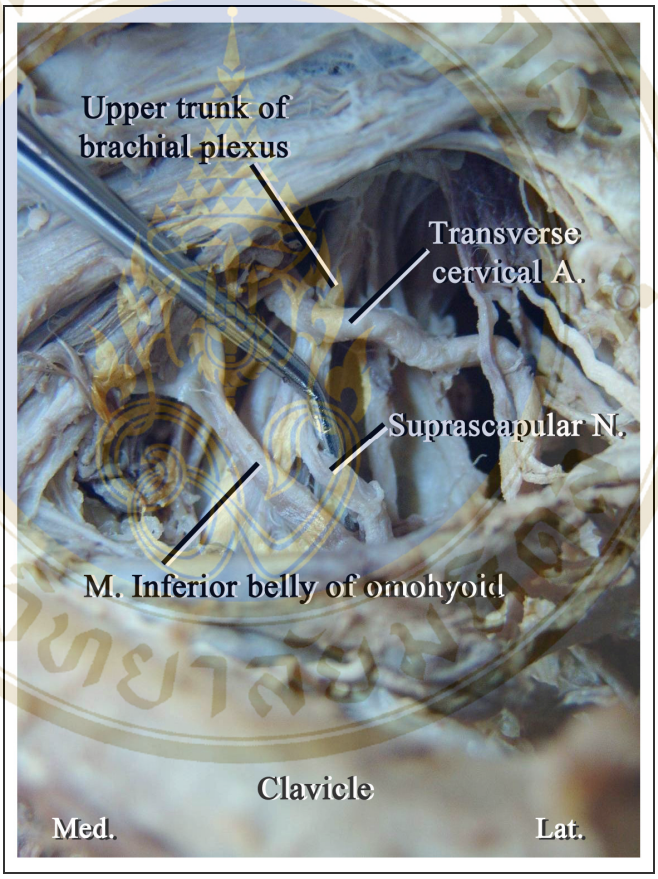


Figure 5.1: Photograph of the anterior view of suprascapular region of the left shoulder demonstrating the suprascapular nerve (hooked by probe) arises from upper trunk of brachial plexus and travels laterally across the posterior triangle of neck parallel to the inferior belly of the omohyoid muscle.

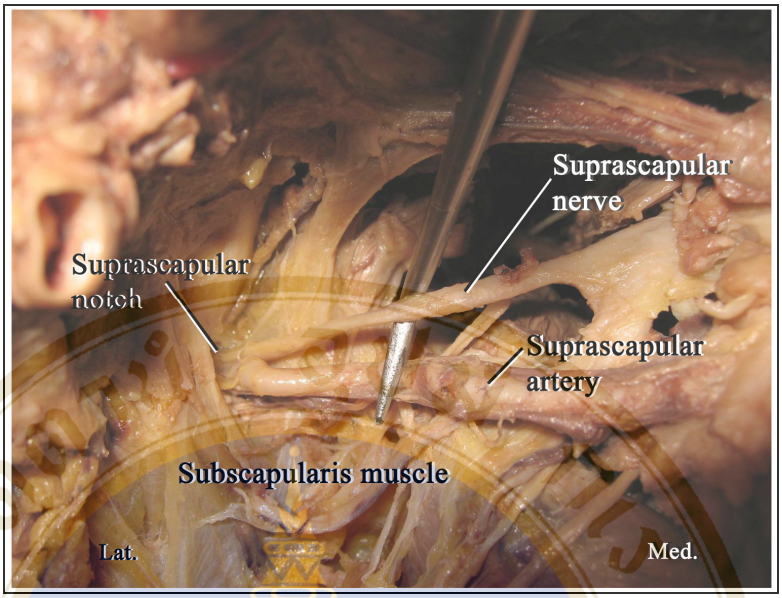


Figure 5.2: Photograph of the anterior view of right scapula demonstrating the suprascapular nerve accompanying by the suprascapular artery, both are pointing toward the suprascapular notch at the superior border of scapula.

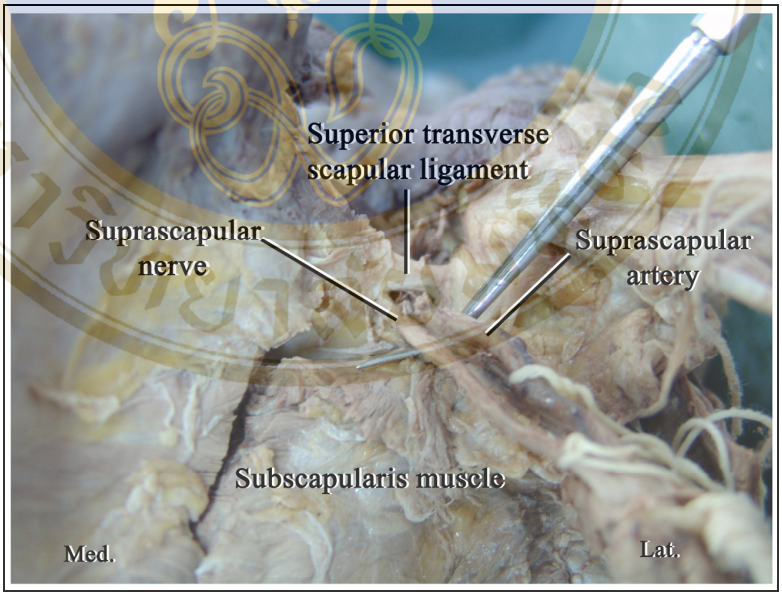


Figure 5.3: Photograph of the anterior view of left scapula demonstrating the relation between the suprascapular nerve and artery (hooked by probe) that passing underneath the superior transverse scapular ligament.

Table 5.1: The distribution of specimen in each category between subligamentous suprascapular artery and conventional suprascapular artery (n=127 limbs)

Side		Passing above the ligament	Passing below the ligament
Unilateral	Left	6 (4.72%)	8 (6.30%)
	Right	7 (5.52%)	6 (4.72%)
Bilateral		42 (66.14%)	8 (12.60%)

During the dissection, a ligamentous structure was found on the vicinity of the suprascapular notch. This structure was similar to the work of Avery (2002), which was defined by the author as the anterior coracoscapular ligament. The ligament was located anterior to the suprascapular notch and inferior to the superior transverse scapular ligament. It attached proximally to anteromedial surface of the root of coracoid process and distally to anterior surface of the scapula in the locality of the suprascapular notch. The present study found the anterior coracoscapular ligament in 19 of 67 cadavers (28%) which 4 cases (6%) were bilaterally and 15 cases (22%) were unilaterally. All of the specimens which the anterior coracoscapular ligament were presented, the suprascapular nerve passed through the notch in between the superior transverse scapular ligament and the anterior coracoscapular ligament (Figure 5.4).

After crossing the suprascapular notch, the suprascapular nerve pierced into the muscle mass about 1 centimeter distal to the suprascapular notch and sent off 1-2 motor branches to innervate the supraspinatus muscle. Furthermore, just proximal to or at the superior transverse scapular ligament, the nerve sent off sensory fibers to acromioclavicular joint, coracoclavicular ligament, coracohumeral ligament and subacromial bursa. Later, the main trunk of the suprascapular nerve traveled obliquely along the supraspinous fossa under the supraspinatus muscle descended through the spinoglenoid notch. There, it sent sensory fibers to posterior part of the glenohumeral joint capsule.

Subsequently, the suprascapular nerve accompanied with the suprascapular artery traveled around the lateral border of the base of scapular spine, winding around the spinoglenoid notch. At the spinoglenoid notch, the spinoglenoid ligament was occasionally stretched out to strap the nerve (Figure 5.5). Finally, the suprascapular nerve gave 2-4 motor branches to innervate the infraspinatus muscle.

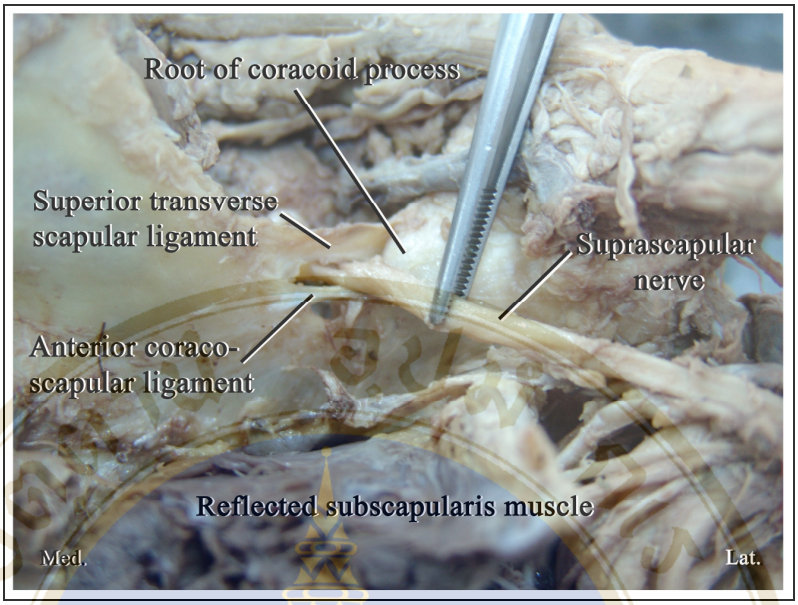


Figure 5.4: Photograph of the anterior view of left scapula demonstrated the presentation of the anterior coracoscapular ligament. The ligament located anterior to the suprascapular foramen, inferior to the superior transverse scapular ligament and the suprascapular nerve travels between the superior transverse scapular ligament and the anterior coracoscapular ligament.

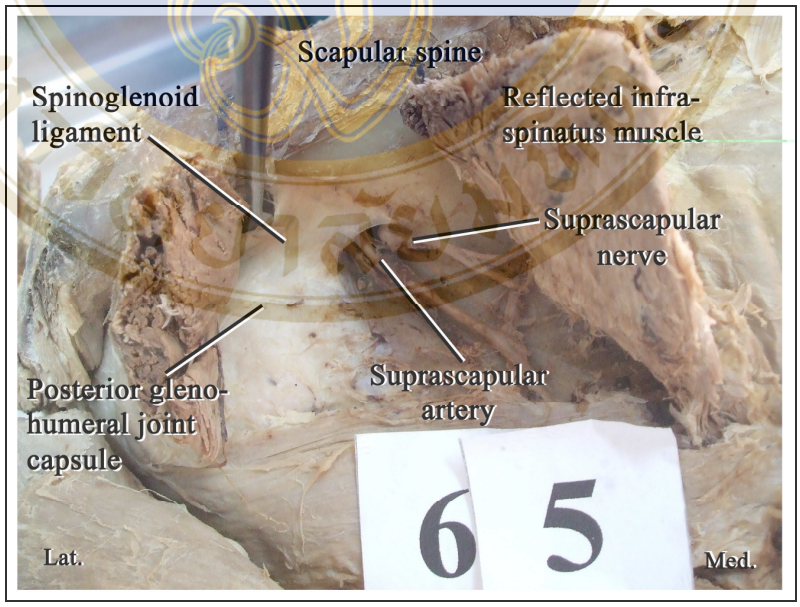


Figure 5.5: Photograph of the posterior view of left scapula demonstrated the relation at the spinoglenoid notch. The suprascapular nerve accompanied with the suprascapular artery and both travel around the lateral border of the base of scapular spine, passing through the spinoglenoid notch beneath the spinoglenoid ligament. Finally, the nerve terminates into 2-4 motor branches to innervate the infraspinatus muscle.

2. Morphology and morphometry of related bony structure and related ligament

2.1) Suprascapular notch types

The morphologic characteristic of the suprascapular notch had been classified into various types ranged from wide depression extending from the superior angle of the scapula to the base of the coracoid process, blunt v-shaped, u-shaped, small v-shaped, partial ossification and complete ossification notch (Rengachary:1979) as showed in Figure 5.6. In the present study, the suprascapular notch type was categorized into wide depression 35.72%, blunt v-shaped 31.51%, u-shaped 10.08%, small v-shaped 3.36%, partial ossification 5.88% and complete ossification 13.45 % (Table 5.2).

Table 5.2: Classification of the suprascapular notch type (n=238)

Shaped of the suprascapular notch	Number of cases
Wide depression	85 (35.72%)
Blunt v-shaped	75 (31.51%)
U-shaped	24 (10.08%)
Small v-shaped	8 (3.36%)
Partial ossification of the superior transverse scapular ligament	14 (5.88%)
Complete ossification of the superior transverse scapular ligament	32 (13.45%)

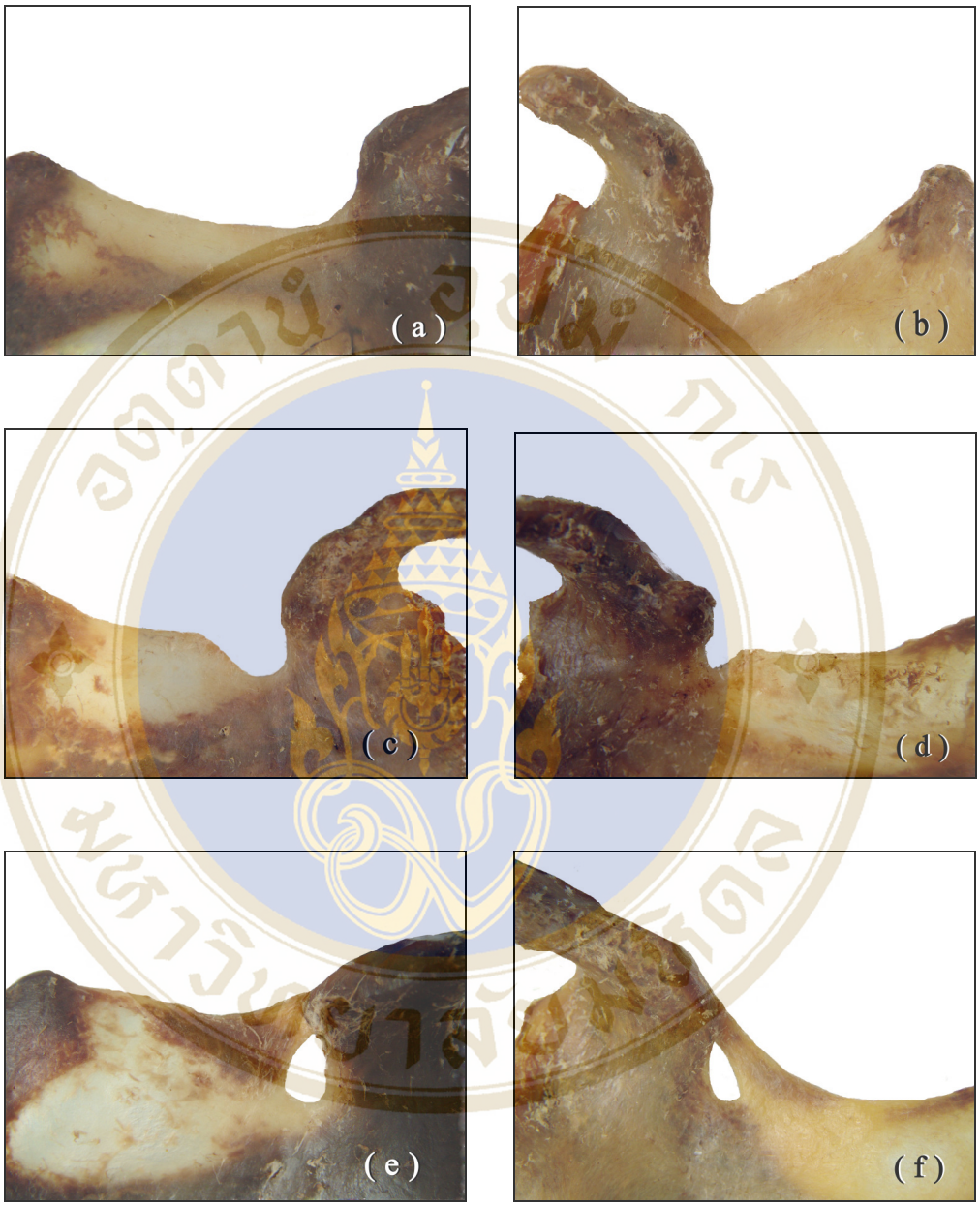


Figure 5.6: Six types of the suprascapular notch;

a = type I; wide - depression suprascapular notch

b = type II; blunt, V- shaped suprascapular notch

c = type III; U- shaped suprascapular notch

d = type IV; small, V- shaped suprascapular notch

e = type V; partial ossified of the superior transverse scapular ligament

f = type VI; complete ossified of the superior transverse scapular ligament

2.2) The superior transverse scapular ligament

The superior transverse scapular ligament, a flat fascicle of dense connective tissue and mostly narrowed at its proximal end and expanded toward the distal end at the medial side of the suprascapular notch. The ligament converted the suprascapular notch into a foramen separating the suprascapular vessels and the suprascapular nerve. Occasionally, ossification of the superior transverse scapular ligament was found and documented in various places. The present study consistently found the single band of the superior transverse scapular ligament in all specimen (217 shoulders), in which was 71 bilaterally (33 male, 38 female). The remaining 75 shoulders were found unilaterally because the ligament on the other side was destroyed during laboratory course dissection. There were 36 on the right (21 male, 15 female) and 39 on the left (20 male, 19 female).

The superior transverse scapular ligament was categorized into 3 types according to the degree of ossification as following: non-ossification 78.34%, partial ossification 6.91% and complete ossification 14.75% as showed in Figure 5.7 and Table 5.3.

The non-ossification was found in 170 shoulders (78.34%). In which, 80 shoulders (36.87%) were found in male (26 bilateral, 12 on the left and 16 on the right) and the remaining 90 shoulders (41.47%) were found in female (36 bilaterally, 9 on the left and 9 on the right).

The partial ossification was found in 15 shoulders (6.91%). In which, 5 shoulders (2.30%) were found in male (1 bilateral, 3 on the left) and the remaining 10 shoulders (4.61%) were found in female (1 bilateral, 6 on the left and 2 on the right).

The complete ossification was found in 32 shoulders (14.75%). In which, 22 shoulders (10.14%) were found in male (6 bilateral, 5 on the left and 5 on the right) and the remaining 10 shoulders (4.61%) were found in female (1 bilaterally, 4 on the left and 4 on the right).

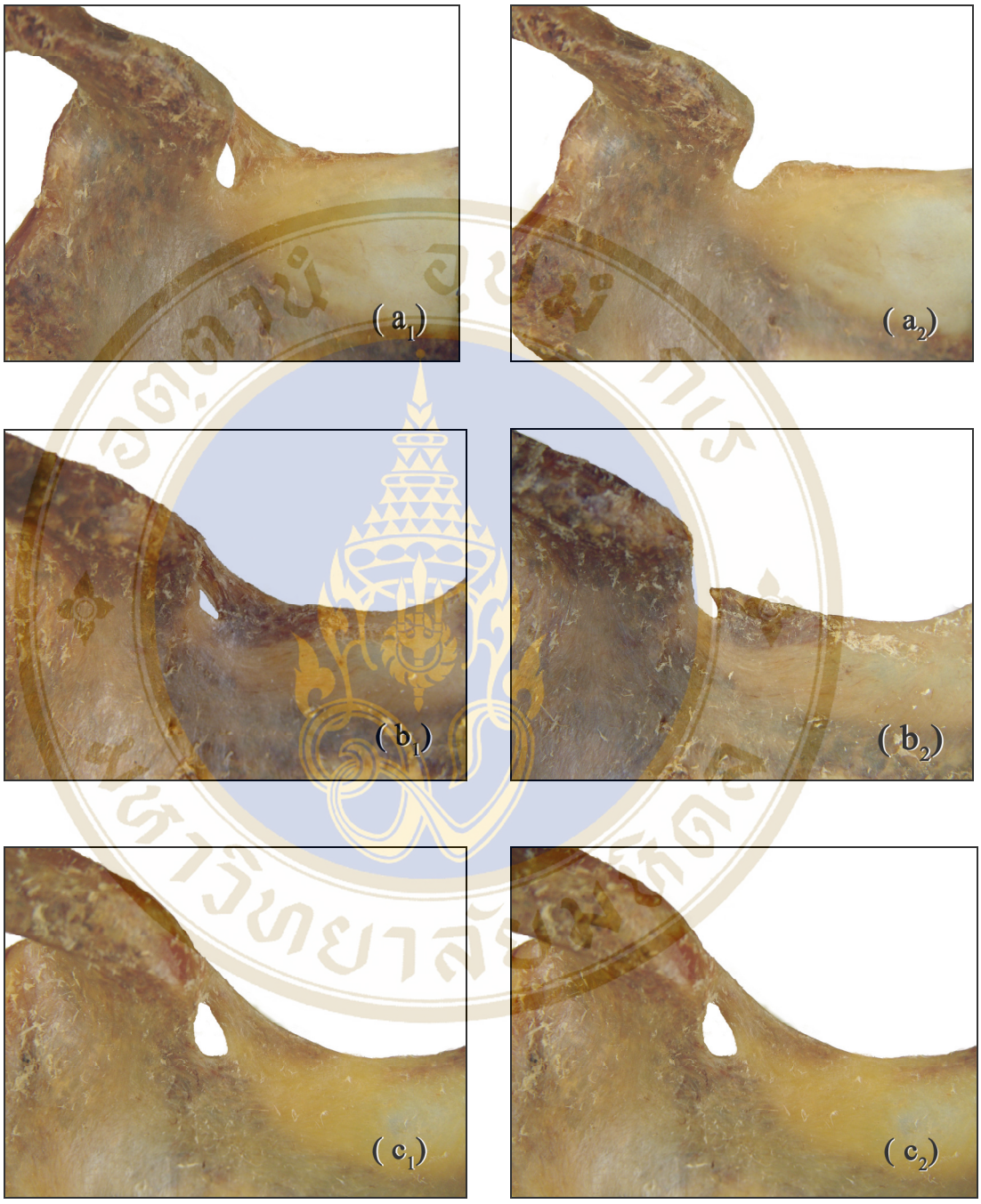


Figure 5.7: Three types of the superior transverse scapular ligament, 1= before and 2 = after remove the ligament;

a_1, a_2 = non-ossified superior transverse scapular ligament

b_1, b_2 = partial ossified superior transverse scapular ligament

c_1, c_2 = complete ossified superior transverse scapular ligament

Table 5.3: The categorization and distribution of the superior transverse scapular ligament according to the degree of ossification between male and female (n=217).

Sex	Number of cases (%)			Total
	Non-ossification	Partial ossification	Complete ossification	
Male	80 (36.87%)	5 (2.30%)	22 (10.14%)	107 (49.31%)
Female	90 (41.47%)	10 (4.61%)	10 (4.61%)	110 (50.69%)
Total	170 (78.34%)	15 (6.91%)	32 (14.75%)	217 (100%)

The dimension of the superior transverse scapular ligament was showed in Table 5.4 and Figure 5.8. The mean length of the superior transverse scapular ligament in the male was 13.24±3.37 mm and 12.92±3.11 mm in the left and right respectively. It was not significantly different to that of female which was 12.70±2.43 mm and 12.23±2.49 mm in the left and right respectively.

The mean width of the superior transverse scapular ligament in the male was 6.44±2.37 mm and 6.92±2.11 mm in the left and right respectively. It was not significantly different to that of female which was 5.89±2.04 mm and 6.14±1.62 mm in the left and right respectively.

The mean thickness of the superior transverse scapular ligament in the male was 0.78±0.20 mm and 0.75±0.24 mm in the left and right respectively. It was not significantly different to that of female which was 0.76±0.27 mm and 0.72±0.23 mm in the left and right respectively.

Table 5.4: Mean dimension of the superior transverse scapular ligament (Mean ± SD) and comparative result between male (n_{left} =38, n_{right} =42) and female (n_{left} = 45, n_{right} =45).

Dimension (mm)	Side	Male	Female	p-value#
Length	Left	13.24±3.37	12.70±2.43	0.41
	Right	12.92±3.11	12.23±2.49	0.26
Width	Left	6.44±2.37	5.89±2.04	0.26
	Right	6.92±2.11	6.14±1.62	0.06
Thickness	Left	0.78±0.20	0.76±0.27	0.72
	Right	0.75±0.24	0.72±0.23	0.58

p-value of independent sample t-test

* Level of significant at p<0.05

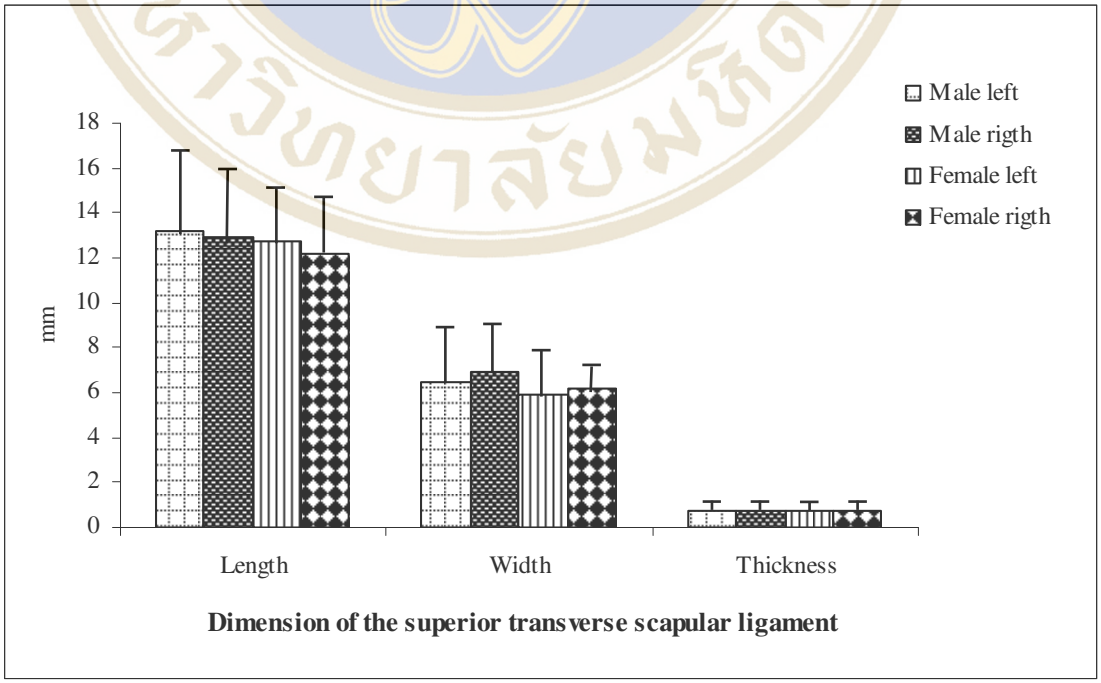


Figure 5.8: Histograms illustrating the dimensions of the superior transverse scapular ligament.

2.3) The anterior coracoscapular ligament

The anterior coracoscapular ligament is never documented in any standard Anatomical textbook. It located anterior to the suprascapular foramen and inferior to the superior transverse scapular ligament which was first called by Avery (25) as the anterior coracoscapular ligament. There is a few recently report of the existence of this ligament (23). The present study also found the anterior coracoscapular ligament in 19 of 67 cadavers (28%) which 4 cases (6%) were bilaterally and 15 cases (22%) were unilaterally.

The anterior coracoscapular ligament was a fibrous band that located inferior to the suprascapular ligament and attached proximally from anteromedial surface of the root of coracoid process to anterior surface of the scapula in the vicinity of the suprascapular notch. It was divided into 3 types (Figure 5.9) according to its distal attachment as following:

Type I: had its distal attachment extended to the anterior surface of the scapula further away from border of the suprascaular notch.

Type II: had its distal attachment extended across the suprascapular notch to the other bank of the suprascapular notch and subdivided the notch into 2 foramina.

Type III had its distal attachment extended to the nearby area of the bottom of the suprascapular notch.

The result revealed that there were 3 cases of type I, 12 cases of type II and 4 cases of type III.

The dimension of the anterior coracoscapular ligament was estimated and showed in Table 5.5 and Figure 5.10. The mean length of the ligament was 10.38 ± 1.89 mm and 11.53 ± 3.44 mm in the left and right respectively.

The mean width of the anterior coracoscapular ligament was 2.99 ± 1.34 mm and 4.95± 1.75 mm in the left and right respectively.

The mean thickness of the anterior coracoscapular ligament was 0.31 ± 0.06 mm and 0.19 ± 0.04 mm in the left and right respectively.

There was no significant difference between sides in the length and thickness of the anterior coracoscapular ligament except the width was significantly different between side ($p<0.05$).

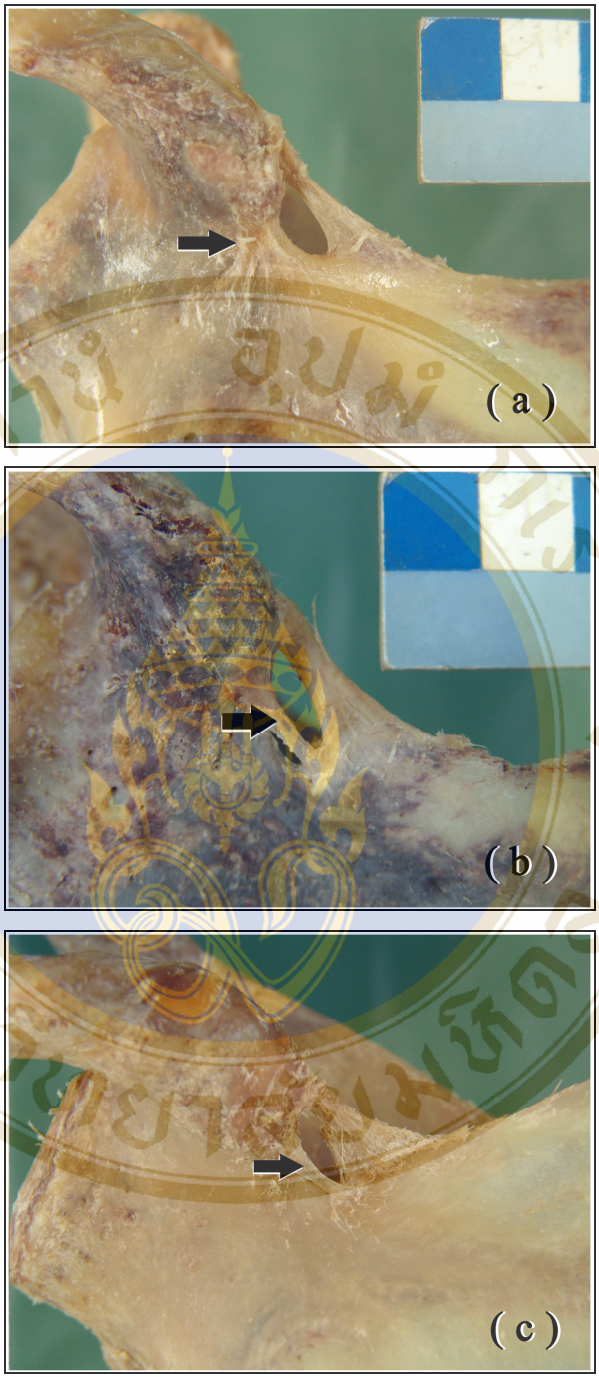


Figure 5.9: Three types of the anterior coracoscapular ligament (black arrow); a= type I, b= type II and c= type III.

Table 5.5: Mean dimension of the anterior coracoscapular ligament (Mean ± SD) and comparative result between left side (n=9) and right side (n=8).

Dimension (mm)	Side	Mean ± SD	p-value#
Length	Left	10.38 ± 1.89	0.422
	Right	11.53 ± 3.44	
Width	Left	2.99 ± 1.34	0.020*
	Right	4.95 ± 1.75	
Thickness	Left	0.31 ± 0.06	0.199
	Right	0.19 ± 0.04	

p-value of independent sample t-test

* Level of significant at p<0.05

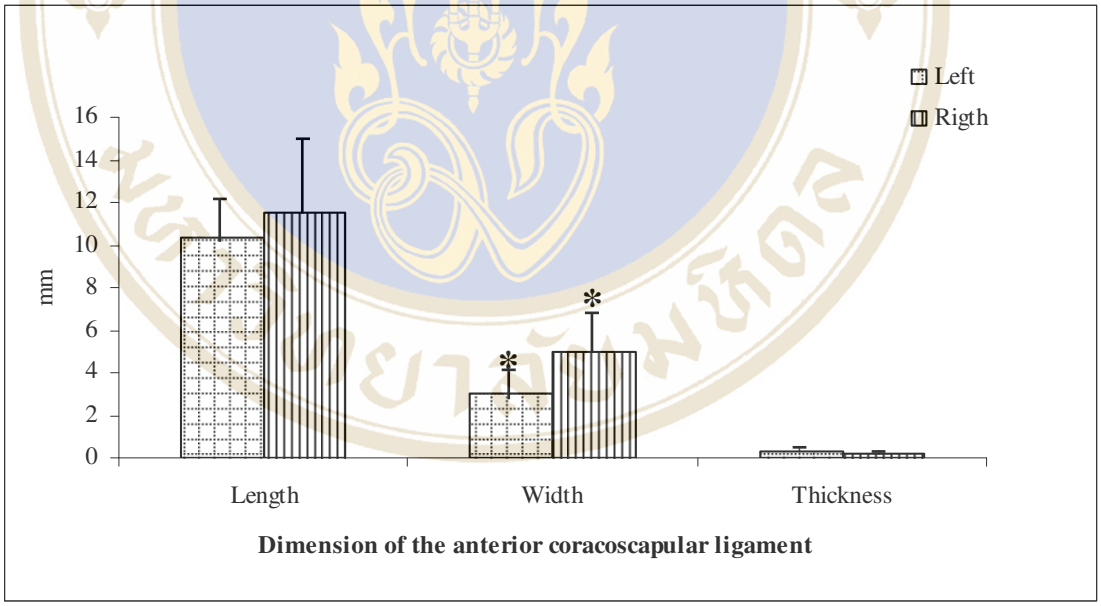


Figure 5.10: Histograms illustrating the dimensions of the anterior coracoscapular ligament. (* = Level of significant at p<0.05 between left and right).

Histological study found that the anterior coracoscapular ligament was composed of bundles of collagen fibers with regular orientation that could be classified as a dense regular arranged connective tissue (Figure 5.11 and 5.12).

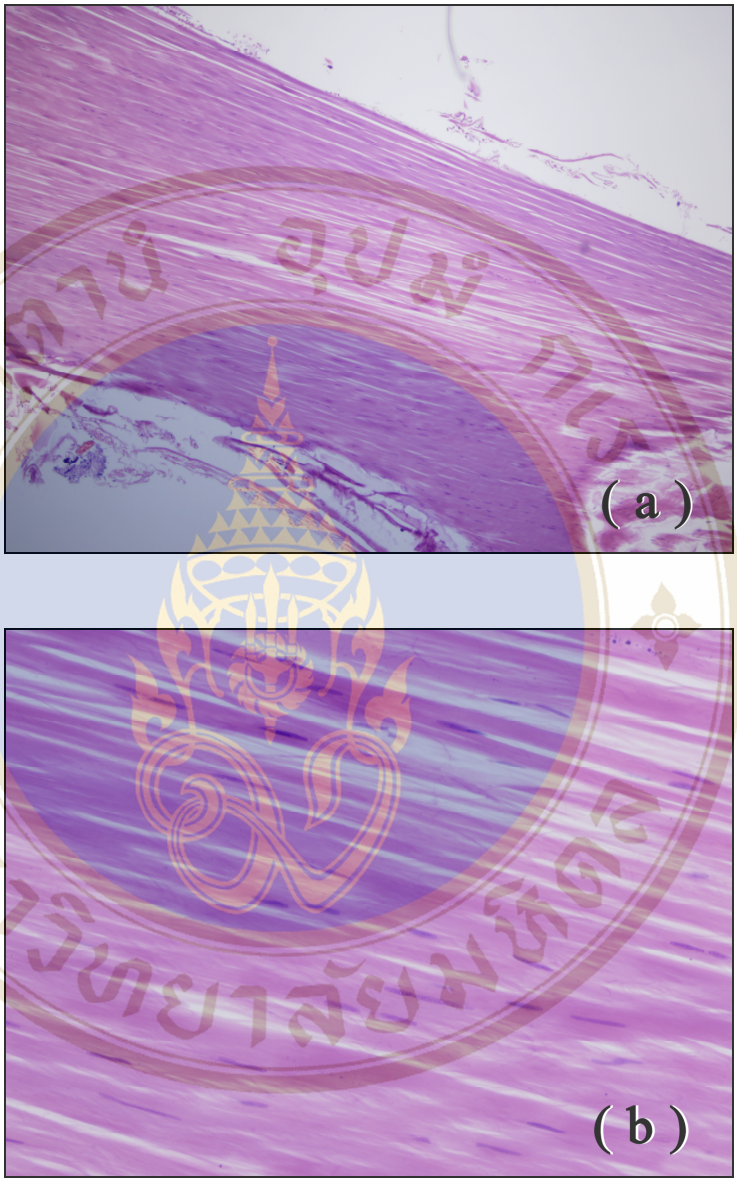


Figure 5.11: Histological characteristic feature of the anterior coracoscapular ligament that composed of collagen fibers with regularly orientation.(a= Hematoxylin-eosin, x 4 and b= Hematoxylin-eosin, x 20)

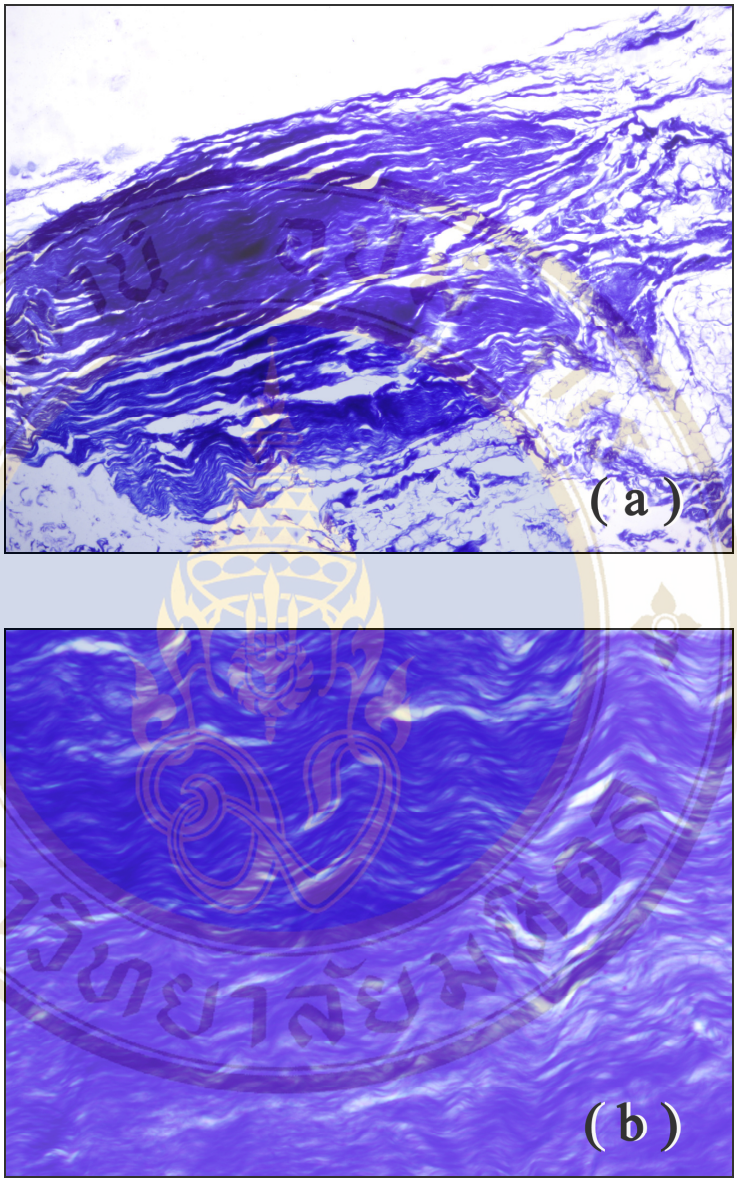


Figure 5.12: Histological characteristic feature of the anterior coracoscapular ligament that composed of collagen fibers with regularly orientation. (a= Mallory's trichome stain, x 4 and b= Mallory's trichome stain, x 20)

2.4) The spinoglenoid ligament

The spinoglenoid ligament or inferior transverse scapular ligament is a band of flexible, tough, dense connective tissue. The previous studies, revealed that the presentation of the ligament was varies between 14-100%. The spinoglenoid ligament had an irregular quadrangular shaped with varied in the size and thickness. It had attachments between inferior surface of the base of the scapular spine and posterior aspect of the glenoid. The inferolateral portion or distal attachment of the ligament had distinct superficial and deep layers inserting into the posterior aspect of the glenohumeral joint capsule and the posterior aspect of the glenoid neck, respectively.

The present study found the spinoglenoid ligament in 26 of 67 cadavers (39%) with an average age of 72.65 years (range from 35-95 years, SD=14.37). In which 14 cases (21%) were found in male (11 bilaterally, 3 on the right) and the remaining 12 cases (18%) were found in female (5 bilaterally, 5 on the left and 2 on the right). In all cadavers, the spinoglenoid ligament attached proximally from inferior surface of the base the scapular spine to posterior capsule of glenohumeral joint as was showed in Figure 5.13.

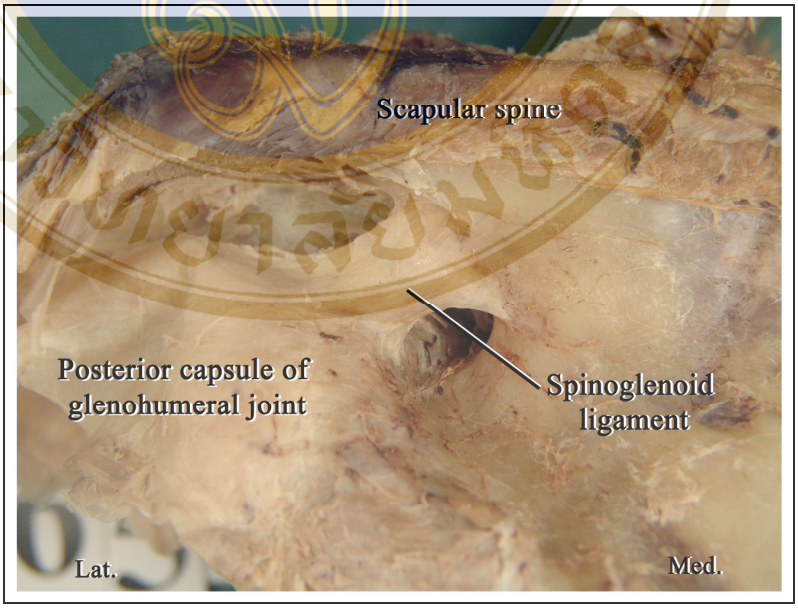


Figure 5.13: Photograph of the posterior view of left scapula demonstrating the spinoglenoid ligament which attached proximally from inferior surface of the base the scapular spine to posterior capsule of glenohumeral joint.

The dimension of the spinoglenoid ligament was showed in Table 5.6 and Figure 5.14. The mean length of the spinoglenoid ligament in the male was 12.58±1.72 mm and 12.39±2.42 mm in the left and right respectively. It was not significantly different to that of female which was 11.45±1.64 mm and 11.27±1.23 mm in the left and right respectively.

The mean width of the spinoglenoid ligament in the male was 13.95±2.89 mm and 12.70±2.54 mm in the left and right respectively while in female, the mean width of the ligament was 11.19±2.38 mm and 9.71±2.65 mm in the left and right respectively. There was significantly different between the width of the ligament in the left and right side and between male and female (p-value < 0.05).

The mean thickness of the spinoglenoid ligament in the male was 0.32±0.12 mm and 0.37±0.12 mm in the left and right respectively. It was not significantly different to that of female which was 0.43±0.32 mm and 0.44±0.16 mm in the left and right respectively.

The mean distance from mid-portion of the spinoglenoid ligament to the base of the spinoglenoid notch in the male was 4.90±1.19 mm and 5.25±1.83 mm in the left and right respectively. It was not significantly different to that of female which was 5.52±1.01 mm and 5.75±1.78 mm in the left and right respectively.

Table 5.6: Mean dimension of the spinoglenoid ligament (Mean ± SD) and comparative result between male (n_{left} =11, n_{right} =14) and female (n_{left} =12, n_{right} =9).

Dimension (mm)	Side	Male	Female	p-value#
Length	Left	12.58±1.72	11.45±1.64	0.14
	Right	12.39±2.42	11.27±1.23	0.27
Width	Left	13.95±2.89	11.19±2.38	0.03*
	Right	12.70±2.54	9.71±2.65	0.02*
Thickness	Left	0.32±0.12	0.43±0.32	0.28
	Right	0.37±0.12	0.44±0.16	0.28
Distance from ligament to bone	Left	4.90±1.19	5.52±1.01	0.22
	Right	5.25±1.83	5.75±1.78	0.56

p-value of independent sample t-test

* Level of significant at p<0.05

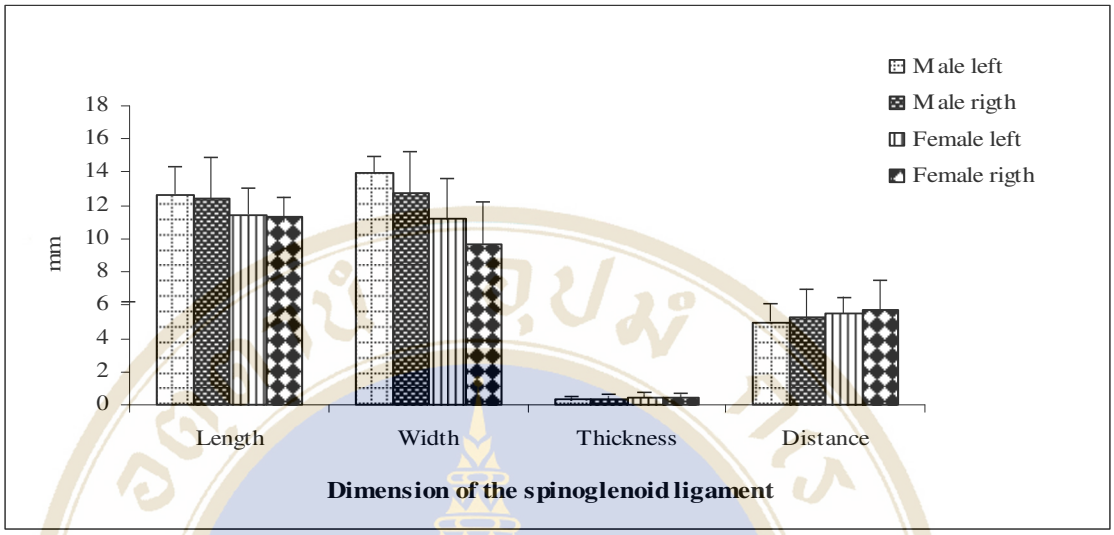


Figure 5.14: Histograms illustrating the dimensions of the spinoglenoid ligament (* = Level of significant at $p<0.05$ between male and female).

3. The area of the suprascapular foramen

The area underneath the superior transverse scapular ligament (suprascapular foramen) is always neglected from the anatomical studies. Most of the previous study focused only on the shaped of the suprascapular notch or the superior transverse scapular ligament. Rengachary (21) has categorized the suprascapular notch into six types and concentrated on the shape of the suprascapular notch as well as the degree of ossification of the superior transverse scapular ligament. Whereas, Ticker (22) has classified it into two types, as a U-shaped notch and V-shaped notch. However, both of them omitted the area of the suprascapular notch with the superior transverse scapular ligament remained intact.

The area underneath the ligament was categorized into 3 forms according to the shape of the suprascapular foramen as following; ellipsoidal shaped 52.34%, parabolic shaped 45.79%, and triangular shaped 1.87% (Figure 5.15). The distribution of each form of the suprascapular foramen in different age groups was showed in Table 5.7 and Figure 5.16.

The ellipsoidal shaped was found in 112 shoulders (52.34%). In which, 56 shoulders (26.17%) were found in male (16 bilateral, 9 on the left and 15 on the right) and the remaining 56 shoulders (26.17%) were found in female (17 bilateral, 11 on the left and 11 on the right).

The parabolic shaped was found in 98 shoulders (45.79%). In which, 51 shoulders (23.83%) were found in male (14 bilateral, 14 on the left and 9 on the right) and the remaining 47 shoulders (21.96%) were found in female (13 bilateral, 11 on the left and 10 on the right).

The triangular shaped was found in 4 shoulders (1.87%). In which, 2 shoulders (0.935%) were found in male (1on the left and 1 on the right) and the remaining 2 shoulders (0.935%) were found in female (1on the left and 1 on the right).

Considering to each age group, the suprascapular foramen in 21-40 year group was 4 (2 bilateral) ellipsoidal shaped, 8 (4 bilateral) palabolic shaped and none of the triangular shaped.

The suprascapular foramen in 41-60 year group was 20 (8 bilateral, 1 on the left and 3 on the right) ellipsoidal shaped, 23 (8 bilateral, 4 on the left and 3 on the right) parabolic shaped and 2 (1 on the left and 1 on the right) triangular shaped.

The suprascapular foramen in 61-80 year group was 60 (16 bilateral, 11 on the left and 17 on the right) ellipsoidal shaped, 50 (12 bilateral, 15 on the left and 11 on the right) parabolic shaped and 2 (1 on the left and 1 on the right) triangular shaped.

Finally, the suprascapular foramen in over 80 year group was 28 (7 bilateral, 8 on the left and 6 on the right) ellipsoidal shaped, 17 (3 bilateral, 6 on the left and 5 on the right) parabolic shaped and none of the triangular shaped.

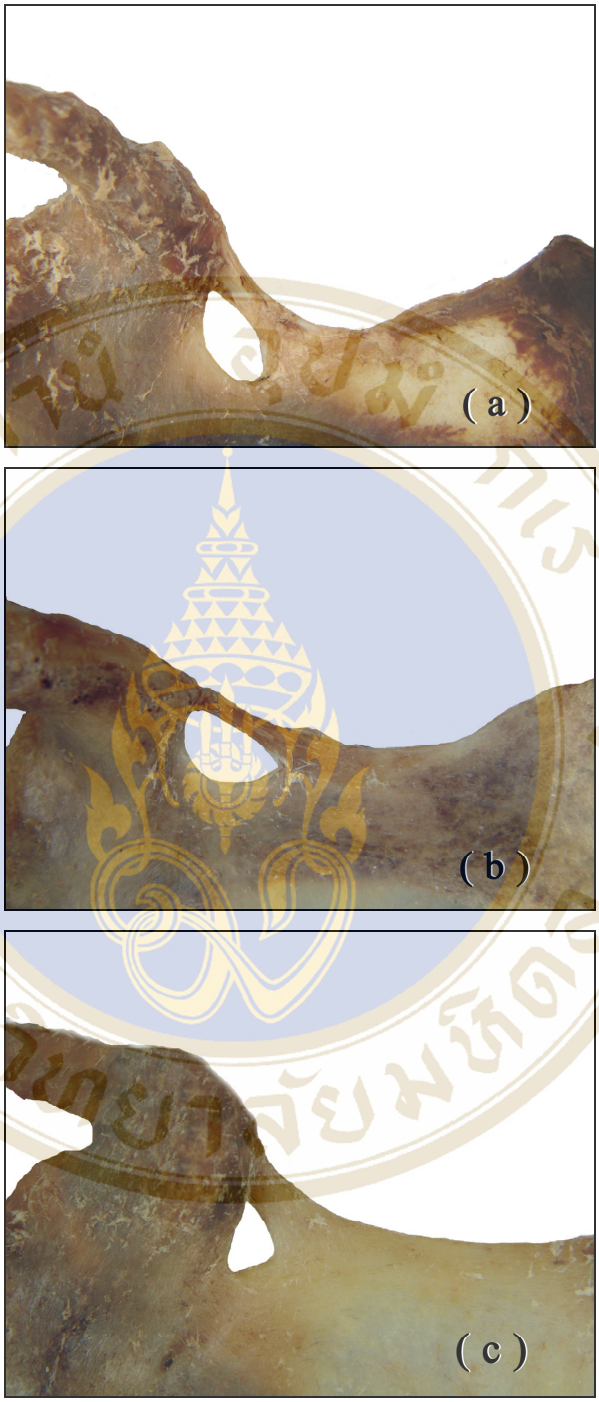


Figure 5.15: Three types of the suprascapular foramen**;** a = ellipsoidal shaped, b = parabolic shaped, c = triangular shaped.

Table 5.7: The distribution of the number of case of the suprascapular foramen (n=214).

Age group (yr.)	Type of the suprascapular foramen					
	Ellipsoidal shaped		Parabolic shaped		Triangular shaped	
	Bilateral	Unilateral	Bilateral	Unilateral	Bilateral	Unilateral
21-40	2	-	4	-	-	-
41-60	8	4	8	7	-	2
61-80	16	28	12	26	-	2
> 80	7	14	3	11	-	-
Total	33	46	27	44	-	4

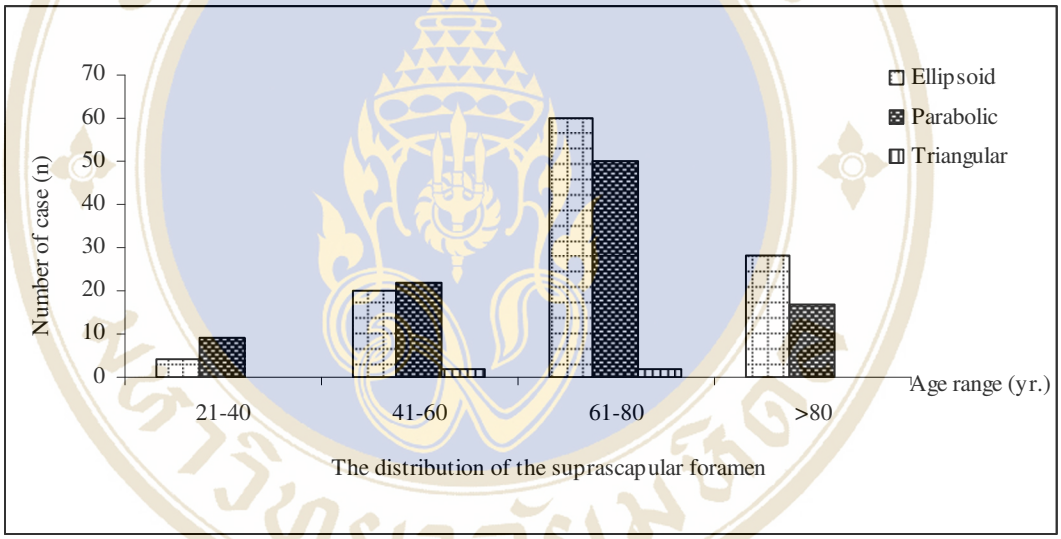


Figure 5.16: Histograms illustrating the distribution of the number of case of the suprascapular foramen.

The mean area of the suprascapular foramen was showed in Table 5.8 and Figure 5.17. Considering to the shape of the suprascapular foramen underneath the superior transverse scapular ligament, the ellipsoidal shaped had mean area of the foramen as 0.08±0.04 cm^2, 0.23±0.22 cm^2, 0.33±0.22 cm^2, 0.30±0.14 cm^2 in the age groups between 21-40, 41-60, 61-80 and over 80 year, respectively. There was no significant difference between age groups.

The mean area of the parabolic shaped was 0.50 ± 0.26 cm^2, 0.59 ± 0.23 cm^2, 0.50 ± 0.28 cm^2 and 0.54 ± 0.23 cm^2 in the age groups between 21-40, 41-60, 61-80 and over 80 year, respectively. There was no significant difference between age groups.

The mean area of the triangular shaped was 0.12 ± 0.01 cm^2 and 0.17 ± 0.13 cm^2 in the age group between 41-60 and 61-80 year, respectively. There was no significant difference between age groups.

While, considering in each age group found that in the group of 21-40 year, the mean area of the suprascapular foramen was 0.08±0.04 cm^2 and 0.50±0.26 cm^2 in the ellipsoidal and parabolic shaped, respectively. It was significantly different between types ($p<0.05$).

In the group of 41-60 year, the mean area of the suprascapular foramen was 0.23±0.22cm^2, 0.59±0.23 cm^2 and 0.12±0.01 cm^2 in the ellipsoidal, parabolic and triangular shaped, respectively. It was significantly different between types ($p<0.05$).

In the group of 61-80 year, the mean area of the suprascapular foramen was 0.33±0.22cm^2, 0.50±0.28cm^2 and 0.17±0.13cm^2 in the ellipsoidal, parabolic and triangular shaped, respectively. It was significantly different between types ($p<0.05$).

In the range over 80 year, the mean area of the suprascapular foramen was 0.30±0.14 cm^2 and 0.54±0.23cm^2 in the ellipsoidal and parabolic shaped, respectively. It was significantly different between types ($p<0.05$).

In summary, every age group, the mean area of the suprascapular foramen which resembled parabolic shaped was significantly greater than the ellipsoidal shaped and the triangular shaped, respectively.

Table 5.8: Mean area (cm^2) of the suprascapular foramen underneath the superior transverse scapular ligament (Mean ± SD) and comparative result between types according to age group.

Age group (yr.)	Area of the suprascapular foramen			p-value
	Ellipsoidal shaped	Parabolic shaped	Triangular shaped	
21-40	0.08 ± 0.04	0.50 ± 0.26	-	0.001*
41-60	0.23 ± 0.22	0.59 ± 0.23	0.12 ± 0.01	0.000#
61-80	0.33 ± 0.22	0.50 ± 0.28	0.17 ± 0.13	0.001#
> 80	0.30 ± 0.14	0.54 ± 0.23	-	0.000*
p-value	0.07	0.43	0.67	-

* p-value of independent sample t-test, level of significant at p<0.05

p-value of one-way ANOVA, level of significant at p<0.05

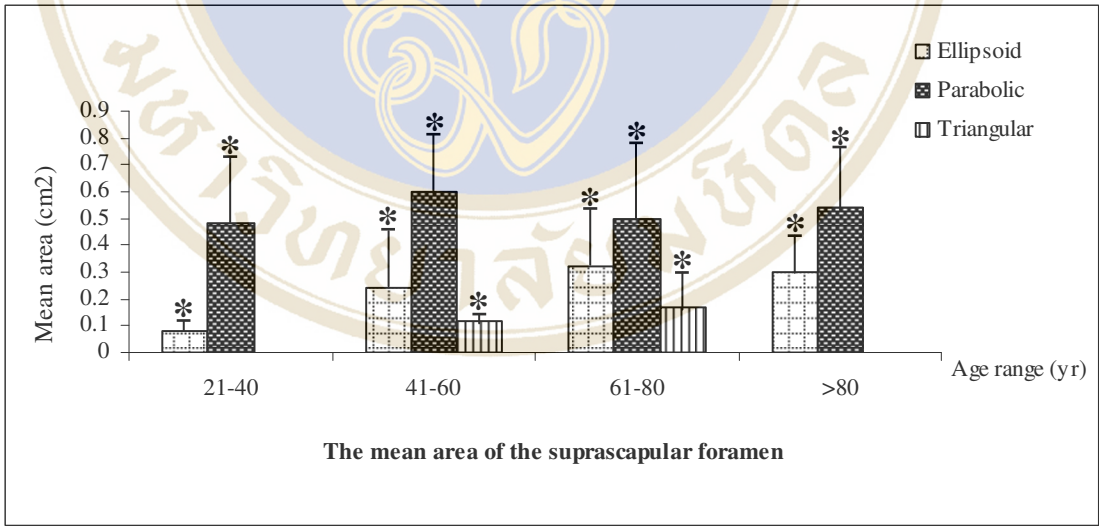


Figure 5.17: Histograms illustrating the mean area of the suprascapular foramen categorized by age range (* = Level of significant at p<0.05 between types).

CHAPTER VI
DISCUSSION

In spite of the suprascapular nerve entrapment syndrome is a rare neuropathy among all shoulder disorders, it is the most frequently injuried peripheral branch of the brachial plexus in athletes and labor workers and is an important complication in clinical problem. Sign and symptom of suprascapular nerve neuropathy are frequently pain on the posterolateral aspect of the shoulder, characterized as a dull ache and exacerbated by overhead activities or cross-body adduction of the extended arm, atrophy of the scapular muscles and weakness of the external rotation and abduction of the shoulder (36,37,44).

The suprascapular nerve is a mixed peripheral nerve, containing motor and sensory components. It is the main sensory innervations of the shoulder joint and also supplies two of the rotator cuff muscles, the supraspinatus and infraspinatus muscles (80-81). Anatomic structure of the suprascapular nerve had been studied and noticed that it had a long course and related to various bony structures, thus, it's vulnerable to be compressed and injuried. The two most vulnerable sites of the suprascapular nerve injury have been documented, at the suprascapular notch and the spinoglenoid notch (1).

In the present study, the anatomical relation of the suprascapular nerve is corresponding to that mentioned in the standard textbook. After separating from the upper trunk of brachial plexus, the nerve travels laterally across the posterior triangle of neck and accompanies with the suprascapular artery. Then, it points towards the superior border of the scapula, passes through the fibro-osseous tunnel which is formed by suprascapular notch and superior transverse scapular ligament. This study found that most of the suprascapular nerve (76.38%) enters the supraspinous fossa by passing beneath the superior transverse scapular ligament, while the suprascapular artery travels above the ligament. Whereas, the rest (23.62%) is a variation case which the suprascapular artery and nerve pass together underneath the superior transverse

scapular ligament. This is accordance with previous reports (78,79,96). This arterial variation may be result from the variation in the branching patterns of the subclavian artery during fetal development. The formation of the subclavian artery occurs during the seventh fetal week of development (96-97). It has been documented that the vertebral arteries anchor the developing subclavian arteries during their descent into the thorax. Any alteration during this process results in variations of its branching pattern of the vessel. The variation of the suprascapular artery which travels through the suprascapular foramen together with the nerve causes a narrowing of the suprascapular foramen. Consequently, the suprascapular nerve at the suprascapular notch is compressed and irritated which leading to the nerve entrapment. This suggestion was corroborated by recent report of Reineck and Krishnan (98). They described the subligamentous suprascapular artery that encountered during performing the arthroscopic decompression of suprascapular nerve entrapment in 3 patients (98).

On the bony structure aspect, the suprascapular notch is varied in size and shape that can potentially affect an individual's tendency to the entrapment of the suprascapular nerve. Hrdlicka (99) originally proposed a suprascaplar notch classification into 5 types. Later, Rengachary and colleges (21) expanded this to 6 types by focused on the shape of the inferior surface of the notch together with the degree of ossification of the superior transverse scapular ligament. In addition, they reported the frequencies and dimensional parameter of the notch after removing the superior transverse scapular ligament. Rengachary presumed that the small v-shaped notch would be more likely encouraged the entrapment of the suprascapular nerve. Different from Rengachary work, Ticker and colleges (22) used a simplified form to classified the morphology of the suprascapular notch with the absence of superior transverse scapular ligament into 2 types, as u-shaped and v-shaped. They hypothesized that a u-shaped notch presented a less constricting passageway for the suprascapular nerve than a v-shaped notch.

The present study revealed the forms of the suprascapular notch as wide depression, blunt v-shaped, u-shaped, small v-shaped, partial ossification and complete ossification which corresponded with Rengachary's work (21). The highest frequency of the suprascapular notch shape was wide depression while the lowest frequency was small v-shaped notch. However, if one visually observed the

suprascapular notch without the superior transverse scapular ligament, one would predetermine that a small v-shaped notch was the most associated with the predisposing cause of the suprascapular nerve entrapment. It gave an impression of the least area in the small v-shaped notch which corresponded to the works of Rengachary (21) and Ticker (22).

The study of the superior transverse scapular ligament revealed that the ligament was single band and mostly non-ossification (78.34%) with varied in dimension. Previous studies had reported multiple bands of the superior transverse scapular ligament as bifid bands (100) or trifid bands (22) and suggested that it could be predisposing cause of suprascapular nerve entrapment. However, the present study did not find any multiple bands of the superior transverse scapular ligament.

Additionally, the ossified ligament had been found 21.66% of the specimens. In these, 6.91% was partial ossification and other 14.75% was complete ossification. This category was corresponded to the Ticker's work (22). Previous report on ossified superior transverse scapular ligament was rare (21-22,34,104-105). In 1979, Rengachary (21) examined 211 bony scapulae and reported 10% of ossified superior transverse scapular ligament, in 1994 Edelson (104) examined in 1000 scpular bones and found 3.7% the ossified ligament and in 1998 Ticker (22) found the ossified ligament in 23% of 79 shoulders. Recently, in 2007 Silva and coworkers (105) reported a high incidence of complete ossification of the superior transverse scapular ligament in Brazillians in which they found these 76% of total 221 scapular bones. However, most of the studies mentioned only as hypothetical condition that promoted the suprascaplar nerve entrapment (21,33-34) but failed to elucidate the pathophysiologic mechanism of the syndrome.

Theoretically, ligament is a connective tissue structure which connects between bones and plays role in supporting a joint and limit the mobility or prevent certain movements. Therefore, it is subject to both compressive and tensile loading. The attached sites of the ligament into the bone named entheses, are the area of stress concentration and has a highly capable to adapt or alter to the fibrocartilage for reduction and dissipation of forces over the bony surface area during joint movement (106-110). Nevertheless, the superior transverse scapular ligament is an exceptional ligament that connects two regions of the same bone and does not cross any joint. The

direct mechanical function attributed to the ligament is still questionable. However, Moriggl and colleges (106) reported that both entheses of the superior transverse scapular ligament were mainly fibrocartilaginous and a moderate fibrocatilagenous matrix was detected throughout the remainder middle portion of the ligament. Therefore, it suggested that the insertion sites of the ligament were subject to both compressive and tensile loading and were regions of stress concentration. This cause in turn probably reflected the ossification of the superior transverse scapular ligament and the complex shaped of the suprascapular notch.

Beside the superior transverse scapular ligament, the present study also reported another ligament related to the scapular notch as the anterior coracoscapular ligament that is the first report in Thais. Previously, the ligament was the first reported and named by Avery (25) in which the ligament was found in 16 of 27 cadavers (60%). Recently, Bayramuglu (23) reported the existence of this ligament in 18.8% of their specimens. The present study regarded as the first report to the anterior coracocapular ligament in Thais population. It was found 19 ligaments from 67 cadavers (28%) with various sizes and attached site. The result showed that the ligament situated on the right was thicker than the left. This study classified the ligament into 3 types (Figure 5.9) which different from the Avery's classification (25). Moreover, it was found that the suprascapular nerve travels through the foramen between the ligament and superior transverse scapular ligament which corresponding to Bayramuglu's work (23). Histological investigation of the anterior coracoscapular ligament confirmed its ligamentous structure. According to its location and relations to the suprascapular notch and nerve, the anterior coracoscapular ligament could cause compression to the suprascapular nerve by reducing the size of the suprascapular foramen.

Previous studies on the predisposing cause of suprascapular nerve entrapment mostly concentrated on the shape of suprascapular notch (21,22) or/and the anomaly of superior transverse scapular ligament (22-23,100). The area underneath the superior transverse scapular ligament is always neglected. The present study paid attention on the area underneath the ligament which was obliged only to the scapula with intact superior transverse scapular ligament. The area underneath the ligament equals to the cross sectional area of the suprascapular foramen provides a clearly numerical expression of the space through which the suprascapular nerve traverses. The area of

suprascapular foramen was categorized into 3 forms according to its shape as; ellipsoidal, parabolic and triangular shaped (Figure 5.15). The ellipsoidal foramen was the most type (52.34%, 112 cases) found and distributed throughout every age group, the second most was parabolic type (45.79%, 98 cases) and the least found was triangular type (1.87%, 4 cases). Detail distribution of the foraminal type according to age group was shown in Table 5.7. All foraminal type was found in age between 41-80 years and triangular type was absent in the youngest (21-40 years) and eldest (over 80 years) groups. One possible reason, which was the limitation in cadavaric study, was the majority was subject to elderly. The adolescent specimen was hardly obtained in embalmed cadaver. Even though the triangular shape was found in the majority group, it presented only in 4 limbs. Corresponding to its very small area of the triangular type which was 0.12-0.17 cm^2 (Table 5.8), the triangular foramen could do harm to the suprascapular nerve.

The mean area of suprascapular foramen showed in Table 5.8 and Figure 5.17 illustrated the consistency of parabolic type which was the greatest foramen in every age group. Thus it should be the safest type to escape from the suprascapular nerve entrapment. The triangular area which resemble to the small V-shaped suprascapular notch was the smallest and less found, so the triangular type could extremely be endangered to the passing suprascapular nerve. The ellipsoidal type was slightly varied between age groups. The area of ellipsoidal type was in the range of 0.23-0.33 cm^2 with the exception of youngest group which had a very small area (0.08 cm^2). This could be owing to the small sample (only 4 limbs) of this age group coincided with the extreme variation of the foramen.

The area of the suprascapular foramen in this study was much lesser than Rengachary's work (21), it was possible due to technical difference as this study measured the area from the scapulae with intact superior transverse scapular ligament, together with ethnic difference of the studied groups.

After the suprascapular nerve passed through the suprascapular notch and innervated the supraspinatus muscle, the nerve traveled around the lateral border of the base of scapular spine and winding around the spinoglenoid notch to innervated infraspinatus muscle. At the spinoglenoid notch, the spinoglenoid ligament was occasionally stretched out to strap the nerve. Several studies reported the entrapment

of the suprascapular nerve at the spinoglenoid notch which was resulted from the spinoglenoid ligament and ganglion cysts. They disclosed the presentation of the ligament which varied between 14-100% (26-28,35,52,94-95). The present study found the spinoglenoid ligament in 26 of 67 cadavers (39%). However, the prevalence of the spinoglenoid ligament in this study was rather low because of the ambiguity of the ligament in the embalmed cadavers and it might be destroyed during the routine dissection class. The study revealed the variation of ligament dimension which the ligament in men was wider than that of the women. Furthermore, the distance between the ligament and the base of spinoglenoid notch where the nerve curved through was no difference between genders. Considering to the insertions of the ligament, this work agreed with the previous reports (26-28,95) that the spinoglenoid ligament was stretched to be a fibrous insertion to the posterior capsule of glenohumeral joint. During cross-body adduction and internal rotation the joint capsule was pulled and led to irritation to the nearby suprascapular nerve and caused a nerve entrapment.

CHAPTER VII
CONCLUSION

The present study revealed the various related structures of the suprascapular notch which possibly predisposing causes of the nerve entrapment. There are several facets of the variation of adjacent related structures which could cause the nerve compression.

1. The small V-shaped of the suprascapular notch was the most risky type, corresponding to the triangular area of the suprascapular foramen which yielded the least area and most likely to cause the nerve entrapment neuropathy.
2. The ossification of the superior transverse scapular ligament could affect the nerve entrapment.
3. The accompanying suprascapular artery traverses underneath the superior transverse scapular ligament could cause the nerve entrapment, particularly if it coincided with the small V-shaped notch.
4. The appearance of the anterior coracoscapular ligament, especially type II ligament which narrowed the suprascapular foramen was another cause of nerve compression.
5. The spinoglenoid ligament also was another possibly cause of the nerve entrapment as it had a close relation to the nerve.

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BIOGRAPHY

NAME	Miss Phongpan Tantipoon
DATE OF BIRTH	14 October 1983
PLACE OF BIRTH	Chonburi, Thailand
INSTITUTIONS ATTENDED	Thammasat University, 2006: Bachelor of Science (Physical Therapy) Mahidol University, 2009: Master of Science (Anatomy)
HOME ADDRESS	54,Moo.2,Nongkhangkok,Muang,Chonburi, 20000, Thailand E-mail: Mawmeaw_pt_tu@hotmail.com
RESEARCH GRANT	Siriraj Graduate Scholarship, 2007
POSTER PRESENTATION	A part of this study was presented as a poster entitled The Anterior Coracoscapular Ligament in Thais: Preliminary Report in the 31st Annual Conference of the Anatomy Association of Thailand 30 April - 2 May 2008, at Methavalai Hotel, Petburi, Thailand.
PUBLICATION	The study was partly published as Subligamentous suprascapular artery in Thais: vulnerability of suprascapular nerve entrapment in Siriraj Med J (in press).