Revisiting the Anatomy of Rotator Cuff Relevant to Rotator Cuff Injury

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Abstract

The rotator cuff is the prime stabilizer of the glenohumeral or shoulder joint. The last decade saw introduction of three components, namely, rotator cable, rotator crescent, and rotator interval of rotator cuff, which were being studied and published in dozen of literatures belonging to clinical specialties of orthopaedics and radiology. At times when these terms have helped the clinician to understand the biomechanics of the rotator cuff while improving the outcome of its repair, the knowledge of the same remains at large for the anatomists. The preoperative assessment of rotator cuff tear has helped surgeons to identify the structure and its functional deficits thereof. The rotator cable is a thick fibrous band that behaves like a suspension bridge. Tears of rotator cable result in partial loss of function or pseudoparalysis of shoulder joint. The rotator interval is a four-layered protective cover of ligaments and the capsule in the rotator cuff. The current knowledge of the rotator interval revealed that the minor underlying ligaments of the shoulder joint play a crucial role in maintaining the congruency of the rotator cuff. The rotator cuff injury is often misdiagnosed due to a lack of knowledge and identification of its recently reported components. This review intends to sensitize the anatomists to investigate further about rotator cuff anatomy and biomechanics of the shoulder joint.

Keywords
► rotator cable
► rotator interval
► rotator cuff
► rotator crescent
► shoulder joint
► biomechanics

Introduction

The rotator cuff is a musculotendinous envelope around the shoulder joint. It includes tendons of supraspinatus, infraspinatus, teres minor, and subscapularis muscles, popularly known as SITS muscles.¹ The subscapularis is a multipennate triangular muscle that arises from subscapular fossa, and its fibers extend up to lesser tuberosity anterior to the shoulder joint. The subscapularis tendon width was reported to be of 15 mm.² Some of the tendon’s superficial fibers bridged the bicipital groove and gets attached on the greater tuberosity by merging with the coracohumeral and transverse humeral ligaments. The greater tubercle or tuberosity of the humerus has three facets in the coronal plane: superior, middle, and inferior. The supraspinatus tendon is attached to superior facet and measures 23 mm in width. The thickness of the supraspinatus tendon was mentioned to be approximately of 6 mm.³⁴ The infraspinatus tendon is attached to middle facet, measures 22 mm in width, and partially overlaps with the posteriormost part of supraspinatus tendon by 10 mm. Supraspinatus, infraspinatus, and teres minor are clubbed as “tendon footprint of greater tubercle.”¹ Rotator cuff injury is a common disorder in day-to-day practice but mostly undiagnosed and inadequately treated. Sometimes it becomes debilitating when the full-thickness tear remains undiagnosed or missed during radiological examinations. The prevalence of rotator cuff tears was 3 to 39% in cadaveric subjects, but the radiological prevalence is 6 to 23% using magnetic resonance imaging (MRI) or ultrasonography in asymptomatic subjects.⁵⁶ The prevalence of full-thickness rotator cuff tears increases with age. The rotator cuff injury is of significant concern to the clinician while dealing with supraspinatus tendinitis.⁷ The uniqueness of rotator cuff anatomy is due to the presence of rotator cable (RC) and crescent. These two terms along with rotator interval are hardly mentioned in a clinical anatomy text. A clear understanding of these three components is required for students and residents to deal
with shoulder pain. The RC is a curved ligamentous complex in the musculotendinous cuff, which is tying both ends of the cuff. The RC was recognized by Clark and colleagues in 1990 but illustrated by Burkhart and colleagues in 1993.8,9 It is colloquially known as semicircular ligament of the humerus or circular fiber system, subsequently the “transverse band” is renamed as transverse humeral ligament bridging bicipital sulcus to contain the long head of biceps.8,9 The current review was undertaken to understand the anatomy of RC, interval, and crescent. This article aims to summarize their anatomical, biomechanical, and radiological characteristics. The objective of this review article is to provide awareness to anatomists and clinicians about hitherto unraveled aspect of the rotator cuff.

The Rotator Cable and Crescent

Burkhart et al introduced the term “rotator cable and crescent.” The coracohumeral ligament starts from the lateral border of the coracoid process and blends anteriorly with subscapularis. It consists of two layers: superficial and deep, attached to the lesser and greater tuberosity, respectively.8,11 The superficial layer blends with tendons of supraspinatus and infraspinatus muscles. The deep layer is attached to the fibrous capsule of shoulder joint. The RC is a curved extension of coracohumeral ligament, which stretches between lesser tuberosity and the junction of middle and inferior facet of the greater tuberosity (►Fig. 1). It also blends anteriorly with the subscapularis and sometimes with the anterior part of the supraspinatus tendon.12 The cable runs from anterior to posterior direction underneath to the supraspinatus and infraspinatus tendons. It finally blends with the posteriormost fibers of infraspinatus tendon or anterior fibers of the tendon of teres minor. The thickened fibers of RC are perpendicular to the tendinous fibers of supraspinatus.8,13

Interestingly, it binds both the infraspinatus and supraspinatus to the head of the humerus. Its primary function is to distribute the forces across the rotator cuff complex. The RC helps the rotator cuff to remain functional in the event of partial or full-thickness tears. It forms the suspension bridge between the tendons of subscapularis & infraspinatus. The mean width and thickness of the RC were 12.05 mm and 4.72 mm, respectively. The ratio of cable and crescent thickness is ~2.59 (1.23-5.81).9,14

The rotator crescent is a thin crescent-shaped sheet of the rotator cuff, which consists of lateralmost end of supraspinatus and infraspinatus tendinous sheet. Rotator crescent is an avascular zone of the rotator cuff which tears easily (►Fig. 2). The dimensions of the rotator of the crescent as reported by Burkhart et al were 41.35 mm × 14.08 mm, while the mean thickness was 1.82 mm.14 They reported thick rotator crescent in younger cadaveric specimens as compared with the cable. They categorized the rotator cuff into two types—cable dominant and crescent dominant. RC is thick and the rotator crescent is thin in old subject, but crescent dominant is seen in younger age groups because of a thick crescent.8,14 The strength of the superior rotator cuff is more dependent on RC integrity in older patients. Despite these findings, some researchers observed that the RC is more detectable with ultrasound (US) in younger patients.11 Understanding the type of RC is crucial to making a proper diagnosis and surgical repair.

The Rotator Interval

The term “rotator interval” was introduced by Neer et al in 1970.15 The rotator interval (RI) was presumed to be a semifunctional and relatively empty area in the rotator cuff. There are two different RIs in shoulder anatomy: the anterior and posterior RIs. The anterior RI is a triangular space in the supraanterior part of the shoulder joint.16 In

Fig. 1 (a and b) The rotator cable extends from lesser tubercle of humerus to greater tubercle. It covers the tendon of long head of biceps (LHB). (Rotator cable marked with yellow color and crescent marked with blue color.)
2002, Kolts et al identified that the superior, inferior, and medial borders of RI are formed by supraspinatus, subscapularis, and base of coracoid process, respectively, in a cadaveric study done on 19 shoulder joints. The joint capsule forms the roof of anterior RI whereas the floor is formed by the articular surface of the humerus. A fibrous capsule envelopes the long head of the biceps tendon present on the base of the RI space and has opening for long head of biceps tendon (LHBT). The RI is a relatively small space but includes the extra-articular coracohumeral ligament (CHL), the superior and middle glenohumeral ligaments (SGHL and MGHL, respectively), LHBT, and a thin layer of the capsule that fills the capsular openings in the RI region. The CHL is known as the rotator interval capsule, and it is strengthened by the CHL laterally and by the SGHL medi ally. Microscopically, the RI has four layers as reported by Jost et al. The first layer includes superficial fiber of CHL, which starts from the coracoid process and attaches to the edge of this triangular space of RI (►Fig. 3). The second layer has an amalgamation of the CHL and rotator cuff tendons. The third layer includes deep fibers of CHL, and the fourth layer is a combined sheet of the SGHL and capsule. The coracoglenoid ligament (CGL) is another vital component of the RI, which is attached to the anterosuperior ligament complex of CHL and SGHL. It is stretched from the coracoid process to the supraglenoid tubercle, and is extra-articular in location. Its function is still debatable as a stabilizer of the shoulder joint. Wilson et al described the variations of the fibrous capsule of the glenohumeral joint at RI. They identified the capsular opening being superolateral to middle glenohumeral ligament (MHG) in 59% individual. This opening is very close to anteriormost fibers of the supraspinatus and makes the long head of biceps tendon vulnerable to injury. Harryman et al summarized that the overall function of the RI was to (1) act as a shackle to prevent extreme flexion, extension, adduction, and external rotation; (2) stabilize the humeral head against inferior translation during extreme adduction; and (3) steady the humeral head against posterior translation during extreme flexion or external rotation of abducted shoulder.

The posterior rotator interval is located between supraspinatus and infraspinatus. It consists of the glenohumeral capsule fused with supraspinatus tendon medially, and infraspinatus tendons laterally. The reported mean length of the posterior rotator interval was 77.8 mm, which includes the distance from the spinoglenoid notch to the glenoid border of scapula. Release of the posterior rotator interval may be required to realign supraspinatus tendon when retracted or scarred at the posterior end.

**Biomechanics**

If the rotator cuff is intact, then the humeral head is located in the center and completely congruent during movement. The rotator cable keeps the humeral head centered because of the force coupled between subscapularis and infraspinatus tendons.
The supraspinatus, infraspinatus, and subscapularis are active stabilizers. They prevent depression of humeral head in overhead abduction and superior migration toward the coracoacromial arch in initial abduction. Both tendons provide a force couple to depress the humeral head and restrict it from migrating upward during early abduction. The presence of rotator cuff tear leads to failure of the mechanism as mentioned, thus causing upward displacement of humeral head toward the coracoacromial arch.

The “Suspension Bridge” Model

The suspension bridge model was advised by Burkhart et al to explain the rotator cuff tear. They demonstrated that uppermost suspension cable of a bridge transfers the force to towers (located at the ends). Here, the rotator cable (RC) stretches between lesser and greater tubercle, below the middle facet. The RC is ~2.5 times thicker than rotator crescent. The rotator cuff redistributes the stress forces created by supraspinatus tendon. This mechanism prevents the tear of the rotator crescent. The above mechanism is explained by the stress shielding effect of the rotator cuff to the thinner tissue of the rotator crescent (►Fig. 5). This stress shielding effect is more effective in old individuals than young or in athletic subjects because of thin RC (crescent-dominant rotator cuff). So, violent contraction of supraspinatus tendon may lead to tear of RC, causing painful arc syndrome. The rotator crescent is much thinner in the shoulders of old subjects and is damaged even in trivial trauma (cable-dominant rotator cuff). The cable is better able to shield the cuff from loads than a crescent. This mechanism explains asymptomatic or minor symptomatic clinical presentation in rotator cuff injury in the older individual, but it may lead to degeneration of rotator crescent. So, RC tears are biomechanically more debilitating than rotator crescent tears. Few authors have suggested some modifications to the suspension bridge model. Namdari et al advocated that the anteriormost junction of the supraspinatus tendon and its cable attachment were the most vulnerable to injury. Adams et al demonstrated that capsular tear of the rotator cuff might lead to failure of suspension bridge mechanism in cadaveric studies.

Radiological Anatomy of Rotator Cuff

The rotator cuff or its components aren’t visible on plain radiographs. MRI or US has been accepted modalities for the screening of rotator cuff anatomy. Arthroscopy is a choice but secondary to MRI or US. Some authors advised that the abduction external rotation (ABER) is the best suitable position for the assessment of the rotator cuff. A routine oblique coronal plane MRI is the right choice because the glenoid cavity is placed 30° anterior from the coronal plane (►Fig. 6). The RC could be identified in the fat-suppressed T2 view, where it appears as a 2 to 5 mm broad hypointense region under supraspinatus tendon. The RCs were detectable in 75% subjects because of small diameter in crescent-dominant young subjects. Additionally, it is difficult to differentiate between the RC and a small tear of the anterior supraspinatus tendon. The axial scanning may help in such cases. On
Anatomy of Rotator Cuff  Asghar et al.
National Journal of Clinical Anatomy Vol. 9 No. 1/2020

Asghar et al. 2020

the axial plane, the hypointensity of the RC extends from the greater tubercle (GT) to the inferior facet of GT, similar to its anatomical shape. So, the coronal and axial images help to identify the RC, but confirmation is done in the sagittal plane and ABER position.31

The MR arthrogram is used to identify the intra-articular RI capsule with the help of a synovial fluid (►Fig. 7). The oblique sagittal plane of MRI is most helpful for the evaluation of RI. The RI capsule is localized over the biceps pulley as a hypointense band. Tracing the scans of the medial side is helpful in delineating the CHL whereas he SGHL is hardly visible.32 Chung et al identified CHL in 60% of subjects, while SGHL remained invisible. Similarly, the identification of coracoglenoid ligament (superoanterior capsule-ligamentous complex) needs a trained eye.16

US is another screening tool to assess RC and RI. Some authors were able to identify RI by US in 77 to 99% subjects which is better than MRI.29 Sconfienza et al advised that the RC was more easily detectable in older subjects (cable-dominant anatomy) and this finding was consistent with observation of Burkhart et al. The subclinical tendinosis also help in identification of RC in old subjects.33

Tamborrini et al advocated that musculoskeletal US (high resolution) is superior for visualization of the RI and RC and their pathologies (e.g., tendinosis, tears, and capsulitis). The only limiting factor is the presence of acromion, which compromises visualization of underneath soft tissue, for example, RC and RI.34

Anatomical proximity of the anterior RC and RI presents with “superoanterior lesions.” This distinct type of rotator cuff tear involves the subscapularis and anterior portion of the supraspinatus tendon and adjacent RI structures, for example, SGHL, CHL, and biceps tendon.14 Case-control clinical studies and further investigation are needed to define the clinical importance of this new concept.

Summary

The rotator cuff integrates an exceptional anatomical feature known as the rotator cable. The RC binds the tendons of the rotator cuff muscles, and this cable provides a stress shield effect across both tuberosities of humerus like a suspension bridge. The location of tears in the rotator cuff tendons is more important than the size of the tear. The tear of RC is debilitating, so debridement or conservative treatment would not be helpful and hence requires surgical repair. Therefore, the prognosis of rotator cuff injuries may depend upon more on the location of the tear than the size of the tear. Besides RC and RI, the role of coracoglenoid ligament needs to be investigated further in the suspension bridge model.

Key Messages

- The rotator cable (RC) is important element of glenohumeral biomechanics.
- Tear of RC may lead to significant joint translation and instability.
• RC and crescent form stress shield “suspension bridge model.”
• Rotator crescent is avascular and rotator cuff injury involving crescent heals slowly.
• The rotator interval (RI) anatomy is also disturbed during rotator cuff injury.

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Conflict of Interest
None declared.

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