High-resolution ultrasound (HRUS) evaluation of the rotator cable (RCa) in young and elderly asymptomatic volunteers

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Purpose

INTRODUCTION

The rotator cuff is a functional complex composed of several tendons and muscles that provide stability of the shoulder by pressing the humeral head on the glenoid and, at the same time, to assure a wide range of motion.

Such complex includes a thick bundle of fibers perpendicular to the supraspinatus tendon that has been described for the first time by Clark in 1990 [1] and called "rotator cable" by Burkhart in 1993 [2]. This structure surrounds the distal zone of the supraspinatus tendon, an hypovascular crescentic region that has been called "rotator crescent" which tears easily [3,4].

The rotator cable plays a central role in shoulder biomechanic and it was described as a structure similar in fashion to the supporting cables of a suspension bridge where stress is trasferred fom the cuff to the cable.

Cable-dominant cuffs are predominant in elderly (>60 years) shoulders [2] in reason of the increasing reliance of the stress shielding action that protects the relatively avascular crescent tissue from tears.

Therefore, according to Morag et al. [5], an accurate characterization of a rotator cuff tear and its relationship to the rotator cable may be important.

ROTATOR CUFF ANATOMY

The rotator cuff is a group of four muscles that form a strong complex around the shoulder joint and help to control the rotation and position of the arm. Each of these muscles has a tendon at the end that attaches to the humerus. These four muscles are:

- The subscapularis
- The supraspinatus
- The infraspinatus
- The teres minor

The tendons of the rotator cuff are seen to fuse into a single structure near their insertions into the tubercles of the humerus. This fusion is apparent when the two surfaces of the intact cuff are exposed by removal of the overlying bursa and the underlying capsule. The supraspinatus and infraspinatus tendons join about 15 mm proximal to their insertions on the humerus and cannot be separated by additional blunt dissection (Fig. 1) on page 16.
Fig.: Axial view of the rotator cuff. The function of this complex is to keep the joint centered on the glenoid rim.

References: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY

Although there is an interval between the muscular portions of teres minor and infraspinatus, these muscles merge inseparably just proximal to the musculotendinous junction. The teres minor and the subscapularis have muscular insertions on the surgical neck of the humerus, which extends approximately 2 cm downward beyond their tendinous attachment on the tubercles. The tendons of the cuff are reinforced near their insertions on the tubercles of the humerus by fibrous structures that are located both superficial and deep to the tendons. The superficial aspects of the infraspinatus and supraspinatus tendons are covered by a thick sheet of fibrous tissue that lies directly beneath the deep layer of the subdeltoid bursa but is not part of the bursa itself.

In a paper published in 2006, Ward et al. [6] report on their examination of the architectural properties of the rotator cuff muscles in ten cadaveric specimens, which they performed
in the hope of understanding their functional design. Based on physiological cross-sectional area, the subscapularis have the greatest force-producing capacity, followed in declining order by the infraspinatus, supraspinatus, and teres minor. Based on fibre length, the supraspinatus operates over the widest range of sarcomere lengths. The supraspinatus and infraspinatus have relatively long sarcomere lengths in the anatomical position and are under relatively high passive tensions at rest, indicating that they are responsible for glenohumeral resting stability. However, the subscapularis contributes passive tension at maximum abduction and lateral rotation, indicating that it plays a critical part in glenohumeral stability in the position of apprehension. This information illustrates the exquisite coupling of muscle architecture and joint mechanics, which allows the rotator cuff to produce near-maximal active tensions in the midrange and to produce passive tensions in the various end-range positions (Fig. 2) on page 17.

![Fig.: Coronal view of the rotator cuff. The function of this complex is to keep the joint centered on the glenoid rim.](image-url)
CRESCENT AND CABLE BACKGROUND

- Anatomy

The intact rotator cuff demonstrates an arching, cable-like thickening surrounding a thinner crescent of tissue that inserts into the greater tuberosity of the humerus; this is known as the cable-crescent complex [2]. This cable-like structure represents a thickening of the coracohumeral ligament and is consistently located at the margin of the avascular zone [7].

The coracohumeral ligament and the posterosuperior glenohumeral ligament merge laterally with a broad fibrous "band". This transverse band runs in a crescent shape from the middle facet of the greater tubercle and reaches the biceps groove where it merges with the transverse humeral ligament before continuing anteriorly into the fasciculus obliquus. It was first described as a "transverse band" by Clark [1]; Burkhart [2,8] renamed it the "rotator cable"; and finally, Kolts [9] called it the "ligamentum semicirculare humeri". We believe that the "(semi)circular band", the "transverse band", the "rotator cable", and the "circular fibre system" described by Gohlke et al. [10] are all one and the same (Fig. 3) on page 18.
The rotator cable may function in a way analogous to the functioning of a load-bearing suspension bridge [2]. By this model, stress is transferred from the cuff muscles to the rotator cable as a distributed load, thereby stress-shielding the thinner, avascular crescent tissue.

Burkhart et al. [2,8] defined the suspension bridge model for the rotator cuff. In 12 shoulders with massive rotator cuff tears, they observed that normal kinematics were maintained when the tears involved only the supraspinatus tendon and a small portion of the infraspinatus tendon. In all these shoulders with stable fulcrum kinematics, the free margin of the rotator cuff tear was thick and rind like (Fig. 4) on page 20.
In a second study, the same authors found a rotator cable-crescent complex in cadaver shoulders, corresponding to the free margin of a tear. The rotator crescent was found to measure an average of 41.35 mm in the anteroposterior direction and of 14.08 mm in the mediolateral direction, with an average thickness of 1.82 mm. The average width of the rotator cable surrounding the rotator crescent was seen to be 12.05 mm, with an average thickness of 4.72 mm.

• Arthroscopy

Pouliart et al. [11,12] observed a distinct rotator cable surrounding a distinct rotator crescent in about 50% of cadaveric specimens. "The rotator cable spans from
anterolateral to posterolateral above the intertubercular groove. In about 25% of shoulders the rotator cable is less obvious but might be identified by adding traction to the arm or rotating the humerus. In these shoulders, the rotator crescent is not visible. In the rest, the rotator cable and crescent cannot be discerned despite manipulations, and the rotator crescent therefore cannot be marked. In adduction and external rotation, a longitudinal anterosuperior capsular fold with a distinct anterior leading edge develops in all cases (Fig. 5) on page 20.

![Arthroscopic view of the right shoulder showing the rotator crescent and the rotator cable.](image)

**Fig.**: Arthroscopic view of the right shoulder showing the rotator crescent and the rotator cable.

**References**: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY
In adduction and internal rotation, the posterosuperior capsule becomes tight enough to squeeze the arthroscope downwards and out. The longitudinal posterosuperior fold appears just superior to the posterior arthroscopic portal and runs from the posterosuperior glenoid rim, medial and posterior to the origin of the long tendon of the biceps and the glenoid labrum, to the posterior part of the greater tubercle. Here it merges with the posterior leg of the rotator cable when this is visible. Since both longitudinal superior folds are always seen during either external or internal rotation, they may as well be assessed with the arthroscopic technique in all cases [11,12].

**Histologic Correlation**

Since the rotator cuff is composed of intimately associated tendons that intersect and interdigitate in the region of the supraspinatus and infraspinatus tendons, loads from contraction are not isolated to a single muscle but are dispersed among neighboring cuff tendons. Anatomic dissections of rotator cuffs have demonstrated a thick fibrous sheath called the rotator cable, which arises from the coracohumeral ligament and envelopes the anterior margin of the supraspinatus tendon.

At histologic examination, a fibrillar structure distinct from the rotator cuff was identified, consistent with the rotator cable. This structure is a defined cablelike extension of the coracohumeral ligament along the articular surface of the supraspinatus and infraspinatus tendons that surround the area described by Codman [3] as the "critical zone," a zone with a propensity for tearing [4]. The orientation and appearance of the cable fibres differed from those of the rotator cuff tendon fibers. Samples from the rotator cuff midline demonstrated a cablelike structure situated on the articular surface of the cuff tendons. This fibrillar structure could be identified as oriented perpendicular to the orientation of the rotator cuff tendon fibers.

This aspect is confirmed by Kolt's studies [9,13]; "The rotator cable appears as an approximately 1-cm-wide band of capsular collagen fibres oriented in parallel, running transverse to the longitudinal axis of the supraspinatus muscle tendon".

**Biomechanic**

Transverse plane force couple is the predominant mechanism resisting superior humeral head displacement with cuff tears. As long as the force couple between subscapularis and infraspinatus remains balanced the joint remains centred and functional [14]. The intact rotator cuff demonstrates an arching, cable-like thickening surrounding a thinner crescent of tissue that inserts into the greater tuberosity of the humerus; this is known as the cable-crescent complex [2]. This densely packed unidirectional collagen fibres extend from the coracohumeral ligament (CH) posteriorly to the infraspinatus, running both superficial and deep to the tendon proper, at the margin of the avascular zone [7]. The crescent, comprises supraspinatus and infraspinatus insertions that are contained within the avascular zone. On arthroscopic examination, the margin of the crescent is seemed
to have thick bundles of fibres that are perpendicular to the axis of the supraspinatus tendon and arch anteriorly and posteriorly to attach on the humerus.

The marked differences in thickness between the rotator cable (4.72 mm) and the rotator crescent bordered by the cable (1.82 mm) is striking. This finding supports the concept of the rotator cable as a functional cable system in which there is stress transfer from the cuff to the thick cable and stress-shielding of the thin capsular tissue distal to the cable and within the crescent \[2\].

The rotator cable work in the same way as the functional cable system of a suspension bridge. By this model, stress is transferred from the cuff muscles to the rotator cable as a distributed load, thereby stress-shielding the thinner, avascular crescent tissue, particularly in older individuals.

Given their fusion into the rotator cable, the coracoglenohumeral ligament and posterosuperior glenohumeral ligament provide the medial anchorage for the rotator cable function. This probably allows the superior complex to maintain its depressing and centring effect as long as one of the medial and one of the lateral points of bony attachment are preserved \[11,12\].

- Imaging

High resolution ultrasound (HRUS) plays a central role in rotator cuff diagnostic imaging and it could be used to demonstrate the clinical implications of the rotator cable \[5\]. Being quick, non invasive, and allowing a dynamic evaluation, HRUS is ideal to focus on a structure as implicated in the shoulder biomechanics as the rotator cable.

Moreover, dynamic scans can be acquired during clinical tests in abduction, adduction, extrarotation, thus magnifying anatomic and pathologic conditions that could be difficult to characterize otherwise.

On HRUS scans the morphology of the rotator cable could vary from a thick cable of fibres to thin flattened fibers traversing deep to the rotator cuff. According to Morag et al \[5\] the ability of US to depict the rotator cable may be greater in older (>60 years) individuals. Larger studies should be undertaken to assess HRUS ability to consistently identify the rotator cable in large groups of symptomatic and asymptomatic patients and to attempt to correlate between rotator cable morphology and shoulder function after a rotator cuff tear (Fig. 6) on page 21.
The marked differences in thickness and width between the rotator cable and the crescent area supports the concept of a functional cable system where stress is transferred from the cuff to the thick cable, acting as a stress-shield of the thin capsular tissue of the crescent. In younger shoulders with thick rotator crescent, this area is not stress-shielded by the cable. On the contrary, older shoulders (>60 years of age) with thin crescent tissue are stress-shielded by the cable. These findings suggest that there may be two different functional classes of rotator cuff based on the behavior of the cable-crescent complex under load: cable dominant (in which the crescent is stress-shielded by the cable) and crescent dominant (in which there is no stress-shielding of the crescent). The arthroscopic view of the rotator cable and crescent often shows that the slight crescent tissue has a redundant invagination adjacent to the rotator cable, suggesting that the rotator crescent is not under tension [15] (Fig. 7) on page 22.
Fig.: HRUS scans on long axis of the supraspinatus tendon showing the two functional classes of rotator cuff: cable dominant (A) and crescent dominant (B). Rotator cable (arrow) is significantly thicker in cable dominant.

References: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY

- Role in rotator cuff tears

The anatomy of the cable-crescent complex and the model of the load-bearing suspension bridge suggests that the location of a rotator cuff tear is much more important than the size of the tear in terms of its effect on shoulder function. That is to say that a tear involving the rotator cable may be biomechanically much more significant than a tear that involves only the rotator crescent (Fig. 8) on page 22.
Fig.: HRUS scans on long (A) and short (B) axis of the supraspinatus tendon showing a cable dominant cuff (arrow) with crescent degeneration (arrowhead).

References: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY

Another important topic in the biomechanics of articular-sided rotator cuff tears is they reflect a damage to the superior complex rather than to the rotator cuff tendons. This damage compromises the head-depressing and centring effect normally performed by the superior complex. When the superior complex remains intact or is only partially damaged, it may limit the retraction of the torn rotator cuff tendons. This effect has already been demonstrated in the studies of Burkhart et al. [2,8], who proved that the rotator cable is the pivot in maintaining normal kinetics in the presence of massive rotator cuff tears. He also coined the term "functional rotator cuff tears" that must satisfy five biomechanical criteria:

1. Force couples must be intact in the coronal and transverse planes.
2. A stable fulcrum kinematic pattern must exist.
3. The shoulder's "suspension bridge" must be intact.
4. The tear must occur through a minimal surface area.
5. The tear must possess edge stability.

The indication of operative treatment of a partial lesion of the cuff is based on persisting pain, diagnostic imaging demonstration and on failure of medical, infiltrative and rehabilitative treatments. In fact, many patients with partial articular lesions commonly refer no symptoms even after a lot of time from diagnosis and from the first conservative treatment: this happens because of the central localization in the crescent zone of the partially teared tendon.

This tear can be affected by biologically- and drug-mediated processes resulting in the protection of the cable from muscular and mechanic forces (Fig. 9) on page 23 (Fig. 10) on page 23.
**Fig.**: US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).

**References:** L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY
**Fig.**: US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).

**References:** L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY

**Images for this section:**
Fig. 1: Axial view of the rotator cuff. The function of this complex is to keep the joint centered on the glenoid rim.
Fig. 2: Coronal view of the rotator cuff. The function of this complex is to keep the joint centered on the glenoid rim.
**Fig. 3:** Coronal cross-sectional illustration showing the location of rotator cable with sonographic correlation.

**Fig. 4:** Axial cross-sectional illustration showing the fibres orientation of rotator cable and rotator crescent.
Fig. 5: Arthroscopic view of the right shoulder showing the rotator crescent and the rotator cable.
**Fig. 6:** HRUS scans on long (A) and short (B) axis of the supraspinatus tendon showing the rotator cable (arrow).

**Fig. 7:** HRUS scans on long axis of the supraspinatus tendon showing the two functional classes of rotator cuff: cable dominant (A) and crescent dominant (B). Rotator cable (arrow) is significantly thicker in cable dominant.
Fig. 8: HRUS scans on long (A) and short (B) axis of the supraspinatus tendon showing a cable dominant cuff (arrow) with crescent degeneration (arrowhead).

Fig. 9: US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).
**Fig. 10:** US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).
Methods and Materials

EXPERIMENTAL STUDY

• Purpose

In reason of the limited number of publications dealing with the rotator cable and only a single example about the ultrasonographic (US) appearance of the rotator cable [5], the purpose of our work is to characterize the US appearance of the rotator cable and to compare the HRUS consistency of such structure in young and elderly asymptomatic volunteers.

• Methods and materials

Twelve young (six males, age range 21-39 years, mean age 33 years) and twelve elderly (six males, age range 62-83 years, mean age 75 years) asymptomatic volunteers were included in our study (twentyfour shoulders for each group).

Volunteers with shoulder pain, limited range of motion, or history of symptomatic shoulders were excluded from the study.

HRUS evaluation of supraspinatus and infraspinatus tendons was performed both on long and short axis with an ultrasound equipment (Esaote MyLab 70 XVG; Esaote Biomedica SPA, Italia) provided with a high-resolution 12-5 MHz transducer. Images were reviewed for the presence of a hyperechoic bundle of fibers running perpendicular to the supraspinatus or infraspinatus tendons in the expected location of the rotator cable. Identification of the rotator cable is based on demonstration of cable fibers in both transverse and longitudinal scans.

For each shoulder, we noted whether the rotator cable was detectable or not, and - if yes - its thickness (craniocaudal dimensions) and width (mediolateral dimensions). Fisher’s exact and U Mann-Whitney tests were used (Fig. 1) on page 26.
Fig.: HRUS scan on short axis of the supraspinatus tendon showing the rotator cable (arrow).

References: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY

HRUS of asymptomatic volunteer’s and patient’s shoulders successfully depicted a hyperechoic fibrillar structure deep to the supraspinatus tendon tracking in a perpendicular fashion relative to the rotator cuff fibers; this hyperechoic and fibrillar rotator cable demonstrated anisotropy and therefore appeared artifactually hypoechoic when not imaged perpendicular to the ultrasound beam.

Images for this section:
Fig. 1: HRUS scan on short axis of the supraspinatus tendon showing the rotator cable (arrow).
Results

- Results

Rotator cable was less frequently detected in young than in elderly volunteers (5/24 vs. 13/24 shoulders; p=0.041). In patients where rotator cable was detected, it was significantly thicker in young (range 1.2-1.5 mm, mean 1.3±0.1 mm, median 1.3 mm) vs. elderly (range 0.9-1.4 mm, mean 1.2±0.1 mm, median 1.2 mm) volunteers (p=0.025). Rotator cable width was not significantly different in young (range 4.5-7.1 mm, mean 5.6±1.1 mm, median 5 mm) vs. elderly (range 2.5-7.1 mm, mean 4.2±1.4 mm, median 4.0 mm) volunteers (p=0.074) although a tendency can be highlighted (on page 30 Fig. 1) on page 30.

Fig.: HRUS scan on short axis of the supraspinatus tendon showing the rotator cable (arrow).

References: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY

- Discussion
Rotator cable was more frequently detected in elderly volunteers (13/24 shoulders). A reason for that can be found in reason of the increased hypoechogenicity of the surrounding tendon matrix and, according with Burkhart, for the adaptive changes that lead the crescent to progressive thinning with advancing age [2].

When detected, rotator cable was significantly thicker in young volunteers. We believe that this finding can be related to the overall thinning of the tendon during the ageing process.

The prevalence of cable dominant shoulders in elderly volunteers could be explained by the intrinsic characteristics of resistance, fibres orientation, and strategic position that lead the rotator cable to be the last structure involved by degenerative thinning processes (Fig. 2) on page 30.

Fig.: HRUS scan on long axis of the supraspinatus tendon showing a cable dominant cuff (arrow) with crescent degeneration (arrowhead).

References: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY
Fig. 1: HRUS scan on short axis of the supraspinatus tendon showing the rotator cable (arrow).
**Fig. 2:** HRUS scan on long axis of the supraspinatus tendon showing a cable dominant cuff (arrow) with crescent degeneration (arrowhead).
Conclusion

• Conclusions

In summary, HRUS is an emergent, rapid and cheap technique able to perform an accurate, non invasive and dynamic study of the rotator cable, in both young and elderly patients. The rotator cable is a well-known structure among orthopedic surgeons, often visualized during arthroscopy with proved anatomic correlation.

Our ability in demonstration of cable integrity with a tear isolated to the crescent may have clinical and surgical implications. It may redirect the therapeutic strategies of cuff tears: clinical and infiltrative strategy for cable dominant patients with central tears localized in the crescent and a good muscolar trophism (non progressive lesions); arthroscopic or surgical strategy for crescent dominant patient and for tears in eccentric position (progressive and painful lesions).

(Fig. 1) on page 33 (Fig. 2) on page 33

Fig.: US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).

References: L. M. Sconfienza; Unit of Radiology, IRCCS Policlinico San Donato, Milan, ITALY
However, further studies are needed to determine if the rotator cable can be uniformly depicted at US and to determine if this information can potentially alter treatment of rotator cuff tears.

In conclusion, nevertheless the amazing progress of the diagnostic imaging, we believe that a wide background above the anatomy and the biomechanic of the shoulder is strictly recommended for an appropriate approach at diagnostic and treatment of the rotator cuff. Quoting Burkhart SS "As with any breakthrough technology, this rapid progress was made possible by the marriage of insight to technology. The great misconception of our era is that technology alone will advance a discipline; the irony is that technology in a vacuum produces no advancement. Technology without understanding produces mere gadgets; technology guided by insight produces tools." [16]

**Images for this section:**

![US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).](image-url)

**Fig. 1:** US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).
**Fig. 2:** US scan of the supraspinatus tendon showing a crescent zone tear (arrowhead) limited by the rotator cable (arrow).
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Personal Information

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