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Superior capsule reconstruction: anatomy, biomechanics, indications, and graft treatment

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Rotator cuff tendons respond to continuous loading in both states of rest and motion; therefore, it is not surprising that rotator cuff tear (RCT) is the most common musculoskeletal injury of the shoulder. According to the classification of RCTs, massive RCT is defined as a tear of >5 cm or a tear involving two or more rotator cuff tendons.[1] When a massive RCT cannot be repaired surgically, i.e., a tear in which direct tendon-to-bone repair in the remaining rotator cuff is not possible, it was termed as irreparable massive RCT.[2] Unsurprisingly, patients with irreparable massive RCT have extremely poor functional outcomes.

Conventional surgical interventions for irreparable massive RCT include debridement and biceps tenotomy, partial rotator cuff repair, bridging patch grafts, tendon transfers, and reverse total shoulder arthroplasty. Superior capsule reconstruction (SCR) was originally described in 2012 by Mihata et al[3] and designed as an alternative to conventional surgery for irreparable massive RCT to restore the superior stability of the shoulder joint. The technique is now increasingly being performed clinically by orthopedic surgeons and is gaining popularity. However, several studies addressing the discrepancy in graft healing and variable clinic outcomes have emerged. Considering that studies over the past 10 years have uncovered some important mechanisms intrinsic to SCR and that there is an evolving recognition of this technique, we present here an overview of the recent advances in SCR.

In this perspective, we have addressed three questions: (1) What is the biomechanical basis of SCR? (2) What are the appropriate indications for SCR? (3) How should one deal with a graft for best clinical outcomes? We believe that the answers to these three fundamental and profound questions will help us understand the underlying rationale of SCR, enabling successful implementation of SCR clinically, and may even aid in its evolution in the future.

Anatomy of the superior capsule: The superior capsule is a relatively thin fibrous structure attached to the undersurface of the supraspinatus and infraspinatus muscle–tendon units. The thickness of the shoulder capsule varies between 0.40 mm and 4.47 mm in different parts. The superior capsule was considerably thicker than the posterior and inferior parts of the shoulder capsule and also significantly thicker in the medial aspect than the lateral.[4] The superior capsule and the coracohumeral ligament intermingle and together envelop the anterior edge of the supraspinatus and then attach to the greater tuberosity. Crosslinking of fibers of the superior capsule, superior glenohumeral ligament, and rotator cuff works as a functional unit and for which the term "superior capsular complex" might be appropriate. The notion of a superior capsular complex enhances our understanding of the pathology associated with internal impingement as well as articular-sided RCTs.

Biomechanics of SCR: The superior capsule plays the role as one of the static stabilizers and stabilizes the glenohumeral joint superiorly at extremes of range of motion. On the abduction of the shoulder, the superior capsule becomes lax; however, contraction of the rotator cuff muscles causes a tensile stiffening of the capsule. In maximum shoulder abduction, the superior capsule was relaxed, whereas the inferior capsule was taut.[5] In a cadaveric biomechanical test, Itoi found that the posterior capsule showed the greatest strength and modulus of elasticity, whereas the superior capsule showed the least strength. The most common mode of failure of the cadaveric shoulder capsules was tear at the mid-substance, followed by tear at the detachment from the humerus.[6]

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Therefore, the shoulder joint loses superior stability once both the supraspinatus tendon and superior capsule are destroyed in irreparable massive RCT. This loss of superior stability is the theoretical premise for the high failure rates of conventional surgical techniques seen in irreparable massive RCT. Superior stability is disrupted not only in irreparable massive RCT but also in medium to large (full-thickness rotator cuff tears). The use of a graft reinforces the superior capsule of the shoulder, providing leverage and support to the proximal humerus that was normally afforded by the supraspinatus tendon and the native superior capsule. Partial articular supraspinatus tendon avulsion (PASTA) is a type of partial-thickness RCT in the joint side. It is logical to presume that the PASTA lesion starts from a superior capsular tear.[5]

The superior capsule establishes a stable fulcrum of glenohumeral joint motion, allowing the remaining intrinsic and extrinsic force couples to exert their effects around that stable fulcrum. In rotator cuff dysfunction, this static stabilization provided by the superior capsule is thrown into disarray. The primary goal of SCR is to preserve the centered position of the humeral head and restore the superior stability of the shoulder joint.

Indications for SCR: SCR improves range of motion and clinical outcomes in irreparable massive RCTs. SCR restores superior stability and theoretically can improve force coupling in the sagittal and coronal planes.[3] Recognition of these factors and advancement in knowledge has, therefore, led to a gradual broadening of indications for SCR. Here, we reviewed four such indications.

Irreparable massive RCTs: Irreparable RCTs show corresponding progressive radiographic changes, such as bone loss, narrow joint space, and so on.[7] By restoring superior stability, SCR can potentially delay or halt these devastating processes. Most orthopedic surgeons agree that irreparable massive RCT without severe glenohumeral arthritis is the prime indication for SCR. First, irreparable massive RCTs have detrimental effects on patients' functional mobility and quality of life. Second, there is insufficient rotator cuff remnant left for repair.

Various surgical techniques to treat irreparable massive RCT and correct joint kinematics, decrease pain, and restore shoulder function have been performed. As compared with partial rotator cuff repair or conservative treatment, the overall outcome after SCR is far more predictable. Reverse shoulder arthroplasty (RSA) is an alternative surgical treatment that achieves satisfactory clinical outcomes in Grade 4 or 5 (Hamada classification) massive RCTs. There is an ongoing debate as to which technique is better for irreparable massive RCT with severe arthropathy: SCR combined with anatomy totals shoulder arthroplasty or RSA. More high-quality studies are needed to settle this debate.

Severely degenerated medium to large RCTs: Some chronic medium to large RCTs, especially in geriatric patients, showed structural degeneration of the rotator cuff, such as fatty infiltration, loss of muscle volume, subtraction of sarcomeres, and sometimes profound muscle weakness.[8] In such cases, the limited healing potential of injured rotator cuff tendons may lead to retear or non-healing of the tendon–bone interface. To obviate retear of rotator cuff tendons, the concept of SCR reinforcement has been proposed. This leads to the question of which are evidently appropriate candidates for SCR reinforcement owing to their inherent degeneration. Mihata classified muscle degeneration, tendon degeneration, and tendon retraction into mild, moderate, and severe types according to the findings on pre-operative magnetic resonance imaging.[9]

Delaminated RCTs: Delamination is described as a horizontal tear between the layers of the rotator cuff. Delamination in RCTs has some peculiar characteristics: common in large-sized tears, limited to the posterior part of the rotator cuff, and affects the thicker deep layers rather than the superficial layers of the cuff.[10] Delaminated RCTs are associated with diminished healing and worse clinical outcomes after repair.

Dual-layer rotator cuff repair based on the retraction pattern of the delamination has been recommended for improvement in repair integrity and better clinical outcomes. Anatomic restoration of the superior capsular and tendon insertion in delaminated RCTs in cadaveric shoulders demonstrated superior footprint restoration with increasing abduction.[11] Anatomical balancing of each layer of the delamination could achieve appropriate tensioning after the repair of the RCT. However, it is almost impossible to simultaneously restore appropriate tensioning of dual layers without causing cleavage of the tendon fibers. In these situations, SCR-reinforcement might be the right choice to resolve this conundrum and circumvent the tendon–tension mismatch.

Pseudoparalysis caused by massive RCTs: Pseudoparalysis from irreparable massive RCTs is one of the toughest challenges faced by shoulder surgeons, also in a sense attributed to superior instability of the shoulder. Mihata reported that SCR caused a reversal of pseudoparalysis in 96% (27/28) and 93% (14/15) of patients who presented with moderate and severe pre-operative pseudoparalysis, respectively.[12] If the deltoid muscle is functional, pseudoparalysis from irreparable massive RCT is a valid indication for SCR.

Graft treatment for SCR: We addressed two important principles for the best possible long-term clinical outcome based on the biomechanical rationale: to enhance graft-bone healing in the short term and to prevent retear of the graft in the long run.

Enhanced graft-bone healing: Originally, Mihata group used fascia lata autograft for SCR[13]; now, however, a varied selection of grafts are used clinically, including human dermal allograft, long head of biceps, autologous hamstring graft, and others. Irrespective of the type of graft used in SCR, the main concern is attaining positive and advantageous biomechanical outcomes, including restoration of the position of the humeral head from its superiorly migrated location, decrease in the acromial–humeral distance, and so on. Therefore, the chief concern is to

attain graft-bone healing in both the glenoid and rotator cuff footprint.

Decreased possibility of graft retear, first, it is imperative to use a graft of appropriate thickness. Superior capsule reconstruction was originally tested using a 5-mm folded fascia lata autograft in cadaveric shoulders.[3] Mihata used 6 to 8-mm-thick grafts by folding the fascia lata twice or thrice on itself clinically.[13] Sutter has reported excellent biomechanical properties of a 3.5-mm-thick dermal allograft.[14] However, grafts thicker than 8 mm likely fail to strike the right balance, that is achieving optimal mechanical advantage while obviating the risk of subacromial impingement.

Second, it is crucial to maintain an appropriate graft tension. Graft tension depends on several factors, including accurate measurement of the distances between the anchors to punch holes in the graft, arm position to set the relationship between the anchor distances. Sutter reported that the ideal arm position is 30° of abduction, 20° of forward flexion, and 10° of external rotation.[14] Passive external rotation could lead to graft strains that may cause graft failure; it is preferable to fix the graft in passive internal rotation biomechanically. In addition, different abduction angles would change the distance between the glenoid and the greater tuberosity asymmetrically in a medial to the lateral direction.

Third, it is vital to ensure better continuity of the graft and infraspinatus tendon. The humeral head might subluxate from the postero-superior space during internal rotation if this space exists. Side-to-side suturing between the graft and infraspinatus tendon remnants resulted in increased superior stability of the glenohumeral joint. However, placing anterior side-to-side sutures did not change any measurements compared with SCR with posterior side-to-side suturing.[15]

In conclusion, SCR can restore superior stability of the shoulder joint. SCR is a valid and well-established joint-preserving surgical option for irreparable massive RCT and/or pseudoparalysis associated with massive RCT without evidence of arthritis of the glenohumeral joint. SCR reinforcement might also be indicated for severely degenerated rotator cuff and/or delaminated medium to large RCT. Improving the quality of degenerated rotator cuff and decreasing retear rates in the long run have broadened the scope of SCR. Graft treatment is a key step for achieving a successful outcome after SCR. Furthermore, to attain graft healing and diminish retear rates in the graft after surgery, it is essential to select a graft of appropriate thickness, fix the graft with the correct tension, and ensure improved capsular continuity.

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