Arthroscopic rotator cuff repair using modified Mason Allen technique

Thesis submitted for partial fulfillment of MD degree in orthopedic surgery

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<td>ADL</td>
<td>Activities of daily living</td>
</tr>
<tr>
<td>AI</td>
<td>Acromial index</td>
</tr>
<tr>
<td>AHI</td>
<td>Acromio-humeral interval</td>
</tr>
<tr>
<td>BPT</td>
<td>Belly press test</td>
</tr>
<tr>
<td>BHT</td>
<td>Bear Hug test</td>
</tr>
<tr>
<td>BT</td>
<td>Biceps tendon (figure of the rotator cable and crescent)</td>
</tr>
<tr>
<td>CA</td>
<td>Coracoacromial ligament</td>
</tr>
<tr>
<td>COX-2</td>
<td>Cyclooxygenase-2</td>
</tr>
<tr>
<td>C S</td>
<td>Constant score</td>
</tr>
<tr>
<td>CT</td>
<td>Computed Tomography</td>
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<tr>
<td>DR</td>
<td>Double row</td>
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<td>EMG</td>
<td>Electromyography</td>
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<td>ER</td>
<td>External rotation</td>
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<tr>
<td>ERLS</td>
<td>External rotation lag sign</td>
</tr>
<tr>
<td>FU</td>
<td>Follow-up</td>
</tr>
<tr>
<td>ICU</td>
<td>Intensive care unit</td>
</tr>
<tr>
<td>IR</td>
<td>Internal rotation</td>
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<td>IRLS</td>
<td>Internal rotation lag sign</td>
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<tr>
<td>LHB</td>
<td>Long head of biceps</td>
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<tr>
<td>IS</td>
<td>Infraspinatus</td>
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<tr>
<td>MMA</td>
<td>Modified Mason-Allen</td>
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<td>MMLS</td>
<td>Modified mattress locking stitch</td>
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<td>MMP</td>
<td>Matrix metalloprotease</td>
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### Abbreviations

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<tr>
<td>MRA</td>
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</tr>
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<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
</tr>
<tr>
<td>PG</td>
<td>Prostaglandin</td>
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<tr>
<td>ROM</td>
<td>Range of motion</td>
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<tr>
<td>ROS</td>
<td>Reactive oxygen species</td>
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<td>SAD</td>
<td>Sub-acromial decompression</td>
</tr>
<tr>
<td>SC</td>
<td>Subscapularis</td>
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<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
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<td>SR</td>
<td>Single row</td>
</tr>
<tr>
<td>SS</td>
<td>Supraspinatus</td>
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<tr>
<td>SSV</td>
<td>Subjective shoulder value</td>
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<tr>
<td>TOE-SB</td>
<td>Transosseous equivalent suture bridge</td>
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<tr>
<td>TM</td>
<td>Teres Minor</td>
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<td>UCLA</td>
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<td>UMI</td>
<td>Upward migration index</td>
</tr>
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<td>US</td>
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<td>Age, date of birth:</td>
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<tr>
<td>Occupation:</td>
</tr>
<tr>
<td>Dominance:</td>
</tr>
<tr>
<td>Affected shoulder:</td>
</tr>
<tr>
<td>Medical conditions:</td>
</tr>
<tr>
<td>Medications:</td>
</tr>
<tr>
<td>History of Trauma:</td>
</tr>
<tr>
<td>Duration of symptoms:</td>
</tr>
<tr>
<td>Current complaint:</td>
</tr>
<tr>
<td>Analysis of the complaint:</td>
</tr>
<tr>
<td>Night pain:</td>
</tr>
<tr>
<td>Previous surgeries:</td>
</tr>
<tr>
<td>Special habits of medical importance:</td>
</tr>
<tr>
<td>Physiotherapy period:</td>
</tr>
<tr>
<td>Date of form completion:</td>
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**ROM**

<table>
<thead>
<tr>
<th>RT SHOULDER</th>
<th>LT SHOULDER</th>
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</thead>
<tbody>
<tr>
<td>Flexion</td>
<td></td>
</tr>
<tr>
<td>ER ADD</td>
<td></td>
</tr>
<tr>
<td>ER ABD</td>
<td></td>
</tr>
<tr>
<td>IR ADD</td>
<td></td>
</tr>
<tr>
<td>IR ABD</td>
<td></td>
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<tr>
<td>ABD</td>
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Constant score:

+ve Special tests:
Appendices

Appendix 2: Constant Murley score

<table>
<thead>
<tr>
<th>Constant Shoulder Score</th>
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<tbody>
<tr>
<td>Clinician's Name:</td>
</tr>
<tr>
<td>Patient's Name:</td>
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</table>

Answer all questions, selecting just one unless otherwise stated.

During the past 4 weeks:

1. Pain
   - Severe
   - Moderate
   - Mild
   - None

2. Activity Level (check all that apply)
   - Unaffected Sleep
   - Full Recreation/Sport
   - Full Work

3. Arm Positioning
   - Up to Waist
   - Up to Xiphoid
   - Up to Neck
   - Up to Top of Head
   - Above Head

4. Strength of Abduction [Pounds]
   - 0
   - 1-3
   - 4-6
   - 7-9
   - 10-12
   - 13-15
   - 15-18
   - 18-21
   - 22-24
   - >24

5. Forward Flexion
   - 31-60 degrees
   - 61-90 degrees
   - 91-120 degrees
   - 121-150 degrees
   - 151-180 degrees

6. Lateral Elevation
   - 31-60 degrees
   - 61-90 degrees
   - 91-120 degrees
   - 121-150 degrees
   - 151-180 degrees

7. External Rotation
   - Hand behind Head, Elbow forward
   - Hand behind Head, Elbow back
   - Hand to top of Head, Elbow forward
   - Hand to top of Head, Elbow back
   - Full Elevation

8. Internal Rotation
   - Lateral Thigh
   - Buttock
   - Lumbosacral Junction
   - Waist (L3)
   - T12 Vertebra
   - Interscapular (T7)

The Constant Shoulder Score is: 0

Grading the Constant Shoulder Score

- >30 Poor
- 21-30 Fair
- 11-20 Good
- <11 Excellent

This form presents outcome measures and any accompanying information as an educational service to our customers. While the information is about musculoskeletal symptoms and disability and their impact on individuals, it is not medical advice.

Although Stylr believes this information to be accurate and timely, because of the rapid advances in medical research we make no warranty or guarantee concerning the accuracy or reliability of the content at this site or other sites to which we link.
Introduction and aim of the work

Arthroscopic repair of rotator cuff tears is becoming a common and popular procedure, having the advantages over open surgery of a minimally invasive approach, smaller skin incisions, no deltoid detachment and less soft-tissue dissection and improved ability to diagnose and treat lesions within the glenohumeral joint.\(^1,2\)

An ideal rotator cuff repair provides initial strong fixation strength and minimization of gap formation during the process of the tendon incorporating into the bone. The single-row technique for repair of torn rotator cuffs has been standard, even though numerous studies have reported re-tears and incomplete tendon healing after using this technique.\(^3-9\)

The double-row technique has been recommended as a means of increasing the contact area between the repaired rotator cuff and the native bone bed. Theoretically, this technique incorporates a medial and a lateral row of suture anchors, increasing the initial coverage of the tendon–bone junction.\(^10,11\)

Restoring the anatomic footprint may enhance healing of the tendon–bone interface and the mechanical strength of the repaired tendons.\(^12\)

The double-row technique provides a greater contact area, which may contribute to developing a better environment for tendon healing.\(^13\)

However, the clinical superiority of double-row techniques has not yet been shown. A series of prospective randomized control studies have compared the two techniques clinically: most of them reported finding no statistically significance differences in clinical outcomes between double and single-row arthroscopic rotator cuff repairs.\(^14-18\)

The most frequent cause of early failure, both in open and arthroscopic cuff repairs, is the pull out of the suture through the tendon.\(^19\) ‘Reinforced’ stitches have been introduced trying to address this problem.\(^20\) Whereas ‘reinforced’ stitches, such as the
modified Mason–Allen, can be used in open rotator cuff repairs, other stitches, such as simple or Mattress, are preferred in arthroscopic surgery (because they are simpler to sew than the ‘reinforced’ stitches). Therefore, there is a need for a stitch, easy to sew arthroscopically, but with an effective holding power for tendon repair. For these reasons, an alternative stitch has recently been proposed for arthroscopic repair of rotator cuff tendons. It consists of two combined stitches, a simple stitch to reattach the tendon to the bone passed around a suture horizontal loop placed in the tendon to prevent the pull out of the simple stitch. This technique was described by Markus Thomas Scheibel and Peter Habermeyer in 2003.

The same concept was introduced by John D. MacGillivray, and C. Benjamin Ma, in 2004 with different technique and was called Mac stitch.

The aim of the study

Was to investigate the short term functional outcome of a series of patients who underwent arthroscopic single row modified Mason Allen stitch rotator cuff repair for a symptomatic full-thickness rotator cuff tear.

The following were assessed and documented:

1. Post-operative range of motion (ROM) at final follow-up compared to pre-operative ROM.
2. Post-operative ROM at final follow-up compared to ROM of normal side.
3. Follow-up of ROM at different time periods during the study (2 months, 6 months and final follow-up).
4. Pre-operative compared to post-operative constant shoulder score.
Literature review

Epidemiology

Shoulder pain is the third (after back and neck pain) most common musculoskeletal complaint among the general population with almost 20 % of people suffering from it during their lifetime.\textsuperscript{24,25} Rotator cuff tear represents one of the most relevant causes of shoulder pain, with a prevalence (of both symptomatic and asymptomatic tears) ranging from 5 to 39 % although higher rates are estimated for age >50 years.\textsuperscript{26}

Anatomical consideration

Many factors can affect rotator cuff repair outcomes, including chronicity, location, size, and tissue quality.

However, an understanding of the normal anatomy of the rotator cuff, especially its attachment to the proximal humerus, is crucial to proper diagnosis and treatment of each tear type and is perhaps the single variable that is within the control of the shoulder surgeon. Use of this information allows restoration of the tendon or tendons to their proper anatomic positions, thus maximizing potential outcomes.

In 1999, Tierney et al.\textsuperscript{27} first reported on the insertional anatomy of the rotator cuff. Their findings demonstrated a consistent, measurable pattern that they called the footprint. Since then, others have used this term as the concept and its applications have grown.

In 2006 they defined the dimensions of the footprint for each rotator cuff tendon and related these dimensions to known, easily identifiable landmarks to provide a guide for open and arthroscopic evaluation and treatment of patients with rotator cuff disease.\textsuperscript{28}
Shape, maximum **length** (anterior to posterior), and maximum **width** (medial to lateral) were measured and recorded for each tendon.

With use of the articular surface, biceps groove, and bare area as reference points, a consistent pattern of rotator cuff attachment was identified for each tendon.

**Subscapularis** (SC)

The SC was the largest muscle–tendon unit. It inserted in a comma-shaped pattern (figure 1) from 7 to 11 o’clock around the tuberosity (with the right shoulder used as a point of reference). The average maximum **length** was 40 mm (range: 35 to 55 mm), and the average maximum **width** was 20 mm (range: 15 to 25 mm). It inserted along the medial aspect of the biceps groove, and its distance from the articular surface tapered from 0 mm superiorly to 18 mm inferiorly.\(^{28}\)

![Figure 1: Footprint of the subscapularis (blue) on the model on the left. Anterior view of the subscapularis on a cadaver before the footprint was dissected on the right side.\(^{28}\)](image)

**Infraspinatus** (IS)

The IS was second in size, inserting from approximately 1 to 3 o’clock. Superiorly, the IS interdigitated and wrapped around the posterior aspect of the SS tendon. The bipennate muscle tapered into a trapezoidal footprint with an average maximum **length** of 29 mm (range: 20 to 45 mm) and **width** of 19 mm (range: 12 to 27 mm). The insertion tapered away from the articular surface, from 0 mm superiorly to 16 mm inferiorly. The gap between the articular surface and the inferior insertion formed the
“bare area.” The tendon of the IS shortened and became more muscular as it ran toward the TM.²⁸

**Supraspinatus (SS)**

The SS tendon was third in size. Its footprint filled the sulcus between the biceps groove and the bare area in a trapezoidal shape that was wider proximally along the articular surface compared with the more distal insertion around the tuberosity. The insertion was located from 11 to 1 o’clock. It had an average maximum **length** of 23 mm (range: 18 to 33 mm) and an average maximum **width** of 16 mm (range: 12 to 21 mm). The insertion appeared at an average of 0.9 mm (range: 0 to 4 mm) from the edge of the articular surface, with most specimens having the SS insertion directly on the articular surface throughout the entire length of the tendon. The lateral most attachment actually continued over the lip of the greater tuberosity. The posterior border of the insertion was overlapped by the anterior border of the IS tendon. Although it was difficult to distinguish the beginning of one and the end of the other, the SS tended to insert closer to the articular surface.²⁸

![Figure 2: Model showing footprints of the supraspinatus (green) and infraspinatus (red). The subscapularis footprint (blue) is anterior to the biceps groove.²⁸](image)

**Teres Minor**

The TM, the smallest muscle–tendon unit, had a relatively large footprint, inserting from 3 to 5 o’clock in a triangular shape (Fig 3). The average maximum length was 29
mm (range: 20 to 40 mm) and average width was 21 mm (range: 10 to 33 mm). The insertion tapered rapidly from a few tendinous fibers superiorly, to purely muscle and capsule along the inferior half. Distance from the articular surface averaged 10 mm (range: 7 to 20 mm).

![Model showing footprints of infraspinatus (red) and teres minor (black), as well as supraspinatus (green). Posterior view of a cadaver showing infraspinatus and teres minor.](image)

Finally, knowledge of the broad footprint has even led to changes in the techniques of repair, as evidenced by the increasing interest in dual or “double row” repair, which increases the surface area available for healing.10,29

**The Rotator Crescent and Rotator Cable:**

Burkhart et al.30 described a biomechanical model of a rotator cuff tear as a loaded cable or suspension bridge (Figure 4, 5 and 6). He described a cable-like structure with thick bundles of fibers that are perpendicular to the axis of the supraspinatus tendon and arch anteriorly and posteriorly to attach onto the humerus. They concluded that by anatomically confirming the shoulder’s “suspension bridge,” their study supported the hypothesis that the rotator cuff possesses a cable system capable of stress transfer, and that tears within the relatively stress-shielded crescent may be biomechanically insignificant in some shoulders. This concept explains why some rotator cuff tears may be symptomatic and some may not be. Furthermore, by considering the biomechanical integrity of the rotator cuff rather than its anatomic integrity, the authors developed guidelines to select appropriate patients for arthroscopic rotator cuff debridement and decompression—an arthroscopic alternative to the massive open procedures that were state-of-the-art at that time. The “suspension bridge” concept also supports the concept
of partial repair of a massive irreparable rotator cuff tear. With partial repair, the rotator
cable and the transverse plane force couple can be restored. With this technique, muscle
transposition can be avoided in some cases to cover the residual hole in the superior
cuff, which is frequently irreparable.

![Image]

*Figure 4: A rotator cuff tear has a similar configuration to a suspension bridge and can be modeled after the loaded cable of the bridge.*

![Image]

*Figure 5: Superior and posterior projections of the rotator cable and crescent. The rotator cable extends from the biceps to the inferior margin of infraspinatus, spanning the supraspinatus and infraspinatus insertions. C, width of rotator cable; B, medio-lateral diameter of rotator crescent; S, supraspinatus; I, infraspinatus; TM, teres minor; BT, biceps tendon.*

![Image]

*Figure 6: Coronal section of rotator crescent and cable. Note the thickened rotator cable in comparison with the thin rotator crescent. T, thickness of rotator cable; t, thickness of rotator crescent.*
Anatomy, mechanics and function of the long head of biceps:

The LHB arises from the glenoid labrum and the supraglenoid tubercle. The intra-articular portion passes over the head of the humerus before entering the bicipital groove, when it becomes the extra-articular portion. Because of its location, the LHB has to face both extra-articular constraints, because of possible subacromial impingement, and intra-articular restriction, because of the constant sliding movement of the tendon within the bicipital groove during elevation and rotation of the shoulder. Decreased retroversion of the proximal humerus has led to the groove no longer being centered on the plane of the humeral head, but lying at an angle of about 30°. As a consequence, the LHB is forced to bear on the lesser tuberosity and the medial wall of the groove, instead of at its middle. Such a position renders the tendon highly vulnerable, not only to trauma but also during everyday function, with the lesser tuberosity acting as a pulley for it (figure 7).

The contribution of the superior glenohumeral ligament and coracohumeral ligament to the ‘biceps pulley’ mechanism is critical to the stability of the tendon, with failure of this mechanism leading to instability.

The function of the LHB at the shoulder is still a matter for debate. Some authors have considered it a purely vestigial structure with no true function at the glenohumeral joint, viewing it as the ‘appendix of the shoulder’.
Etiology of cuff tear

Cuff tears are either traumatic or degenerative. **Traumatic** tears are due to significant trauma, whereas **degenerative** tears are far more frequent and multifactorial in etiology. The rotator cuff is weakened by both extrinsic and intrinsic factors, leading to gradual failure of tendon with or without superimposed acute injury, which finally results in full-thickness tear.\(^{34}\)

**Extrinsic theory**

Neer's classic work advocated extrinsic factors for rotator cuff tendon failure in which during forward elevation of the shoulder, the anterior part of the cuff abuts against the coracoacromial (CA) arch and leads to impingement, tendonitis, and tear.\(^{35}\) Neer's theory got a boost when Bigliani et al.\(^{36}\) proposed that down sloping acromion in the sagittal plane can impinge upon the anterior cuff, and could cause cuff tear.

Bigliani et al. classified the acromial morphology into three types, namely, type I (flat undersurface), type II (curved), and type III (hooked). Several authors confirmed close relationship between hooked acromion and cuff tear.\(^{36-39}\)

Various other factors such as the presence of acromial spur\(^{40,41}\), acromion slope,\(^{42,43}\) CA ligament,\(^{44-46}\) os acromiale,\(^{47,48}\) and acromioclavicular joint spur\(^{49,50}\) also contribute towards extrinsic compression. Recently, Nyffeler et al. introduced the acromion index as a measurement of lateral extension of the acromion, which is associated with a higher incidence of rotator cuff disease.\(^{51}\) Balke et al.\(^{52}\) also reported that lateral extension of the acromion (acromial index) and low lateral acromial angle are associated with a higher incidence of cuff tear. However, extrinsic theory of tendon failure has failed to explain the tears happening in the IS tendon or articular-side tear.\(^{53}\)

While these extrinsic factors in isolation or in combination certainly seem to be playing an important role in the pathogenesis of SS tear, the consistency in relationship is yet to be proven due to the lack of quality of available data.
**Intrinsic theory**

The intrinsic theory proposed by Codman encompasses multiple possible mechanisms that occur within the rotator cuff tendon to initiate the cuff tear.\textsuperscript{54}

The commonest accepted theory is based on the **degenerative-micro trauma model**, which proposes that age-related degeneration compounded with repetitive micro trauma/loads leads to a partial tear that gradually converts into a full-thickness tear. With advancing age, the cuff undergoes several internal changes, such as collagen disorganization and thinning, myxoid and hyaline degeneration, fatty infiltration, and vascular proliferation.\textsuperscript{55} The degenerative process also leads to muscle atrophy and fatty infiltration, which is a part of the reparative process.\textsuperscript{56} This leads to loss of strength in the muscle and could render the outcome of the cuff repair unfavourable.\textsuperscript{57,58}

Another possible intrinsic theory is of **oxidative stress** in the local environment. The oxidative stress is perhaps produced due to repetitive injury followed by the reparative process. This oxidative stress induces tenocyte apoptosis due to excess levels of reactive oxygen species (ROS) that damages the tendon.\textsuperscript{59,60} Other inflammatory mediators that are found to be high during the process of oxidative stress are a local concentration of metalloproteases [matrix metalloprotease-1 (MMP-1), MMP-3, and MMP-13], cyclooxygenase-2 (COX-2), and prostaglandin E2. MMPs probably mediate the process of apoptosis and alter collagen structure, whereas COX-2 and prostaglandin E2 might be responsible for pain associated with cuff tear.\textsuperscript{61} Within 4 months of the onset of a tear, there is a drastic decrease in procollagen alpha-1-positive tendon cells in the tendon margin, which are responsible for tendon healing.\textsuperscript{62}

Many authors have also investigated the role of cuff **vascularity** in cuff tear. Traditionally, the area 10-15 mm proximal to the SS tendon insertion is thought to be the site of critical ischemia or hypovascular zone. Benjamin et al\textsuperscript{63} asserted that histological transition from tendon to calcified fibrocartilage during tendon-to-bone insertion leads to hypovascular zones in tendon and is also responsible for ruptures and poor healing of tendon after repair. However, the existence of such an area was
challenged by Moseley and Goldie in cuff specimens. Rudzki et al. demonstrated that cuff vascularity is significantly less after the age of 40 as compared with those under the age of 40, especially on the medial articular side. This might explain Codman's theory that lesion peel off starts on the medial articular side of the cuff probably due to decreasing vascularity in ageing tendons. Walch et al. proposed the internal impingement mechanism of the undersurface as a cause of tendon failure in the posterior SS and the anterior IS along with posterosuperior labral tears in throwing athletes or those involved in overhead sports with extreme abduction and external rotation.

**Diagnosis**

**A. History, physical examination and Constant score:**

A meticulous and detailed clinical history and examination are imperative to properly diagnose and treat patients with suspected rotator cuff syndrome.

**Accuracy of Elements of the History and Clinical tests in the Diagnosis of Rotator Cuff Tears**

Patient age is important because the prevalence of tears increases with age. Approximately 40% of asymptomatic patients over 50 years old have full thickness rotator cuff tears, and the prevalence of partial and full-thickness tears in symptomatic patients over 60 years old is greater than 60%.

Dinnes et al. recently reviewed 10 cohort studies on the clinical evaluation of the shoulder. Pooled data from four of these studies suggested that clinical examination as a whole has a sensitivity of 90% and a specificity of 54% in the detection of full-thickness rotator cuff tears. Although 23 different signs, symptoms, and tests were assessed in the 10 studies, no definite conclusion about individual tests could be reached, since too few studies evaluated any one test. In addition there is some variability in how individual tests are performed.

In a prospective cohort study by Van Kampen et al. included 169 patients with shoulder complaints. An experienced clinician conducted 25 clinical tests of which 9 are specifically designed to diagnose rotator cuff pathology. The final diagnosis, based
on magnetic resonance arthrography (MRA), was determined by consensus between the clinician and a radiologist, who were blinded to patient information. A prediction model was developed by logistic regression analysis.\textsuperscript{69}

Out of the \textbf{history parameters}, they found that \textit{weakness} has no diagnostic value and \textit{night pain} has only limited diagnostic value for rotator cuff tear. The individual clinical tests had moderate sensitivity and specificity, and overall accuracies ranged from 61\% to 75\%. No single test had a good discriminative value.\textsuperscript{69}

A few \textbf{clinical tests} have a very high specificity, the drop arm, lift-off test, external rotation lag sign, and infraspinatus muscle strength test, which was also found by Bak et al.\textsuperscript{70} This could suggest that these are very useful clinical tests. However, because of the low incidence of a positive test result (two to seven times in that study), they seem to be less useful as a general screening tool for RC tears. However, if the test is done and it is positive, you can be almost sure that you will find a rotator cuff tear on the MRA.\textsuperscript{69}

\textbf{Special tests in rotator cuff examination:}

Testing of rotator cuff integrity should be part of all shoulder examinations. There are two types of integrity tests: first, those that determine whether a movement can be undertaken actively and, second, those that determine whether a passive position can be maintained (the lag signs). Gerber and his associates\textsuperscript{71,72} and Hertel et al.\textsuperscript{73} have described the majority of these signs.\textsuperscript{74}

\textbf{Subscapularis special tests:}

\textbf{Lift-off Test}

Gerber and Krushell described the lift-off test for examination of an isolated rupture of the subscapularis tendon in 1991 (figure 8).

In which they reported that the weakness of internal rotation is most easily demonstrated at the limit of amplitude of contraction of the muscle, namely, when the arm is fully extended and internally rotated. A patient with subscapularis rupture is unable to lift the dorsum of his hand off his back, a finding which they called a ‘pathologic lift-off test.’\textsuperscript{72}
Figure 8: Lift off test which is normal on the left side and pathological on the right side denoting torn subscapularis tendon and full internal rotation cannot be maintained in hyperextension. This is manifested by the patient’s inability to lift the hand off the back.\textsuperscript{72}

**Internal rotation lag sign (IRLS)**

Described by Hertel et al.\textsuperscript{73} The patient is seated, with his or her back to the physician. The affected arm is held by the physician at almost maximal internal rotation. The elbow is flexed to 90º, and the shoulder is held at 20º elevation and 20º extension. The dorsum of the hand is passively lifted away from the lumbar region until almost full internal rotation is reached. The patient is then asked to actively maintain this position as the physician releases the wrist while maintaining support at the elbow. The sign is positive when a lag occurs (figure 9). The magnitude of the lag is recorded to the nearest 5º. An obvious drop of the hand may occur with large tears. A slight lag indicates a partial tear of the cranial part of the subscapularis tendon.

Figure 9: Internal rotation lag sign. A, Arm is held at slight extension and near full internal rotation; patient is then asked to maintain this position. B, Sign is positive when lag occurs. Magnitude of lag is judged in degrees.\textsuperscript{73}
Belly Press Test (BPT)

Gerber et al. described this test for patients in whom there was decreased internal rotation. They reported: “In this test the patient presses the abdomen with the flat of the hand and attempts to keep the arm in maximal internal rotation. If active internal rotation is strong, the elbow does not drop backward, meaning that it remains in front of the trunk. If the strength of subscapularis is impaired, maximum internal rotation cannot be maintained, the patient feels weakness, and the elbow drops back behind the trunk. The patient exerts pressure on the abdomen by extending the shoulder rather than by internally rotating it.”

Burkhart et al have described a variation of this test: the Napoleon, in which the patient must maintain internal rotation by pushing the palm of the hand against the abdomen with the wrist extended.

The test was considered positive if the wrist was flexed at 90° and intermediate with flexion between 30 and 60°. The more extensive the tear, the greater the degree of positivity of the Napoleon test.

Bear-Hug test (BHT):

Was described by Barth et al. in 2006. The BHT is performed by asking the patient to place the palm of his hand on the contralateral shoulder, with the fingers extended (to avoid gripping), the arm is in anteflexion and the elbow at 90° (figure 10). The patient is asked to perform internal rotation with resistance from the examiner who tries to remove the hand from the patient’s shoulder using force that is perpendicular to the axis of the palm.

The test is positive if the patient cannot resist. As with each of these tests, the results of the BHT are in comparison to the controlateral side to define any weakness. Pain can also be analyzed during the test.

They recorded painful tests without weakness but it was not counted as positive test due to its subjective nature. However they found a high rate of association between this painful BHT and small (30%) upper subscapularis tears.
Figure 10: Bear-hug test at 90°: examiner with a hand on patient’s wrist, as patient’s elbow is held at 90° of forward flexion.
Bear-hug test at 45°: examiner with a hand on patient’s wrist, as patient’s elbow is held at 45° of forward flexion.

**Suraspinatus special tests:**

**Jobe’s Test**

Jobe described the “supraspinatus test” in 1983.” Figure 11 is a demonstration of this test.

This maneuver was originally described for testing the muscle strength and as a rehabilitation procedure, not as a provocative test. The authors reported that “the subject should be seated with the arms abducted 90°, horizontally flexed 30°, and internally rotated.

Figure 11: Jobe’s supraspinatus muscle test.

**The external rotation lag sign (ERLS)**

Is designed to test the integrity of the supraspinatus and infraspinatus tendons. The elbow is passively flexed to 90°, and the shoulder is held at 20° elevation (in the scapular plane) and near maximal external rotation (i.e., maximum external rotation
minus 5° to avoid elastic recoil in the shoulder). The patient is then asked to actively maintain the position of external rotation in elevation as the physician releases the wrist. The sign is positive when a lag occurs.\textsuperscript{73}

**Constant-Murley score:**

The Constant Murley scoring system is the most commonly used international shoulder scoring scale.\textsuperscript{80}

The Constant score was devised by Christopher Constant with the assistance of the late Alan Murley during the years 1981-1986. The score was first presented in a university thesis in 1986 and the methodology published in 1987.\textsuperscript{81}

The Constant-Murley scale is based on 100-point scale. Subjective characteristic are responsible for 35 points. An absence of pain is given 15 points, whereas functional characteristics such as ability to work can be awarded as many as 25 points. Objective measurements are awarded a maximum of 65 points, with 40 points possible for range of motion (ROM) and 25 points possible for strength. (Table 1)

An exact method to measure the strength has not been described, including the position of the hand, elbow and shoulder, and attachment of weight or resistant device, all of which may affect the consistency and validity of the strength testing.

It is proposed that the strength component of the Constant score should be measured by use of either an Isobex isometric dynamometer device or a defined spring balance technique. Comparison between the Isobex device and the standardized spring balance showed no significant difference (P <.76) between the mean of the maximum value of the 5 successive readings with each method in a group of 20 patients with pathologic shoulders.\textsuperscript{82}
Table 1: Illustration of the different points of the Constant Murley score.81

<table>
<thead>
<tr>
<th>Parameter measured</th>
<th>Constant-Murley scale</th>
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<tbody>
<tr>
<td><strong>Pain</strong></td>
<td>15/100 points 15------no pain 10------minimal pain 5------moderate pain 0------severe pain</td>
</tr>
<tr>
<td><strong>Motion</strong></td>
<td>40/100 points Active range of flexion, no pain 0 to 10 points. Active range of abduction, no pain 0 to 10 points. <strong>Flexion and abduction:</strong> 150° 10 points 150°-121° 8 points 120°-91° 6 points 90°-61° 4 points 60°-31° 2 points <strong>Combined active external rotation from 0-10 points</strong> Full elevation from the top of the head 10 points Hand on top of the head, the elbow back 8 points Hand on top of the head, the elbow forward 6 points Hand behind head, elbow back 4 points Hand behind head, elbow forward 2 points <strong>Combined active internal rotation from 0-10 points</strong> Hand to the Interscapular region 10 points Hand to T12 8 points Hand to L3 6 points Hand to Lumbosacral junction 4 points Hand to buttocks 2 points Hand to the lateral thigh 0 point</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td>25/100 points Strength of abduction in the scapular plane, 1 point per pound.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>20/100 points <strong>Ability to work</strong>—4 points <strong>Recreational activities</strong>—4 points <strong>Ability to sleep</strong>—0 to 2 points <strong>Ability to work at the level:</strong> Of the waist 2 points Of the xiphoid 4 points Of the neck 6 points Of the head 8 points Above the head 10 points</td>
</tr>
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B. Radiological assessment:

i. Plain x ray:

Is important to:

a. **Exclude other pathologies** like Impingement which can be suggested radiographically by abnormalities that encroach upon the supraspinatus outlet. For example, spur formation on the undersurface of the acromioclavicular joint and an acromion with an inferolateral tilt can be seen on anteroposterior radiographs of the shoulder. In addition, a type III acromion, in which the anterior aspect of the acromion is hooked inferorly, can be seen on a supraspinatus outlet view (a modified Y view) and has been associated with a higher prevalence of rotator cuff tears (Fig 12).

![Radiograph (supraspinatus outlet view) shows the normal supraspinatus muscle, which has a homogeneous appearance with a bulging superior contour (solid arrows). Note also the type III acromion (open arrow).](image)

**Figure 12:** Radiograph (supraspinatus outlet view) shows the normal supraspinatus muscle, which has a homogeneous appearance with a bulging superior contour (solid arrows). Note also the type III acromion (open arrow).

b. **Detect common association** as a large lateral extension of the acromion that appears to be associated with full-thickness tearing of the rotator cuff. The lateral extension of the acromion can be measured on standardized true anteroposterior radiographs made with the arm in neutral rotation as described by Nyffeler et al in 2006. The average acromion index (and standard deviation) was 0.73 ± 0.06 in the shoulders with a full-thickness tear, 0.60 ± 0.08 in those with osteoarthritis and an intact rotator cuff, and 0.64 ± 0.06 in the asymptomatic, normal shoulders with an intact rotator cuff. (Figure 13)
c. Proximal humeral migration

In 1962, measurement of the acromiohumeral interval (AHI) on plain radiographs was identified as a useful method of assessing disorders of the rotator cuff.\textsuperscript{88} Several studies have shown a distance less than 7 mm between the lowest point on the acromion and the highest point on the humeral head on radiographs correlates with the presence of a tear of the rotator cuff\textsuperscript{88–90}. Hirooka et al.\textsuperscript{91} described the upper migration index (UMI) in 1996; they divided the distance from the center of the humeral head to the undersurface of the acromion by the radius of the humeral head. Compared with the acromiohumeral interval, this ratio made data comparison between patients more reliable.\textsuperscript{91,92}

Figure 14: A radiograph shows proximal migration (A = undersurface acromion; C = center of the humeral head; R = radius of the humeral head; AH = acromiohumeral interval).\textsuperscript{93}
ii. **Ultrasound:**

Crass et al ⁹⁴ and Middleton et al ⁹⁵ in 1984 were the first to describe ultrasonographic (US) evaluation for rotator cuff tears, and US has proved to be as accurate as magnetic resonance (MR) imaging in the detection of supraspinatus tendon tears.⁸⁷

iii. **MRI:**

Several studies have demonstrated the usefulness of conventional spin-echo MR imaging for diagnosing moderate to large full-thickness rotator cuff tears.⁹⁶–⁹⁸ Results with partial-thickness tears have been less satisfactory.⁹⁶,⁹⁹–¹⁰¹ Fat-saturation technique has been shown to increase the visibility of water on T2-weighted images and to reduce the signal from adipose tissue that might confound image interpretation.¹⁰²,¹⁰³

These features suggest that fat saturation might be a valuable tool to increase the visibility of rotator cuff tears on MR images, particularly smaller partial-thickness tears.¹⁰⁴(Figure show full thickness tear of the SS using the conventional and fat-saturation T2-weighted spin-echo coronal MRI).

![Figure 15: Full-thickness tear. Conventional (on the left) and fat-saturated (on the right) T2-weighted spin-echo coronal MR images (2700/70 [TRITE]) through supraspinous tendon show an area of bright signal extending through entire extent of rotator cuff (arrowheads), consistent with full-thickness at arthroscopy.¹⁰⁴](image-url)
Classifications of Rotator cuff tears

There are many rotator cuff classification systems in use today, making it difficult to compare results and to agree on proper treatment. In addition, when using any system, surgeons may not always agree on how a particular tear is classified.

Full-Thickness Tear Classification Systems

Many factors are important in describing full-thickness rotator cuff tears. These include: size, number of tendons involved, tear shape tissue quality, and CT/MRI assessment of fatty infiltration and atrophy of the muscles attached to the torn tendons. In a review of the commonly used systems, not one included all of these factors.\textsuperscript{105}

**Tear Size**

One of the most commonly used classification systems was developed by DeOrio and Cofield.\textsuperscript{106} They classified tears by the anterior-posterior length of the tendon that was torn off of the humeral head as measured at the time of surgery. The system classified tears as small if the tear was less than one cm, medium if the tear was between 1 and 3 cm, large 3–5 cm, and massive if the tear was greater than 5 cm in length.

Bayne and Bateman\textsuperscript{107} used a similar, but less commonly used system in which they classified tears as Grade 1 if the tear was less than 1 cm after surgical debridement, Grade 2: 1–3 cm after debridement, Grade 3: 3–5 cm and Grade 4: global tear, no cuff left. It would appear that the classifications are similar and could be used interchangeably, but there have been no direct comparisons. The major drawback is these are not 3-Dimensional, so they can overestimate the difficulty of repair.\textsuperscript{108} For example, a tear classified as large or Grade 3 could be a 4 cm tear with minimal retraction and healthy, robust tissue, or a 4 cm tear retracted to the labrum with thin, friable tissue. In addition, they do not identify which tendon(s) are involved. Most surgeons would agree that a repair 2 cm tear of the supraspinatus may have a very different outcome when compared to a 2 cm tear of the subscapularis. These
classifications do not normalize to the patient’s size, so the value of the absolute size of the rotator cuff tear remains in question.\textsuperscript{109}

Finally, important factors related to surgical procedures as tear shape and fatty infiltration are not included. Nevertheless, the DeOrio and Cofield classification is one of the two most systems most commonly used in the orthopaedic literature.\textsuperscript{105}

**Number of Compromised Tendons**

**Harryman**\textsuperscript{8} developed a classification system based on the number of tendons involved in the tear identified at the time of surgery. Stage 1A is a partial thickness tear, Stage 1B is a full-thickness tear isolated to the supraspinatus. Stage II includes the supraspinatus and at a portion of the infraspinatus. Stage III includes the entire supraspinatus, the infraspinatus and the subscapularis tendons. Stage IV is rotator cuff arthropathy. This system has not been validated. Classifications systems based in the number of tendons involved as Harryman’s\textsuperscript{8} are important predicting the extent of surgical procedure necessary to repair the tear\textsuperscript{110}, but do not differentiate the tear pattern or method of repair.\textsuperscript{108}

**Tear Shape**

**Ellman and Gartsman**\textsuperscript{111} developed a classification system to take into account the three dimensional nature of rotator cuff tears. Crescent-shaped tears are wide (anterior-posterior) with minimal retraction. Reverse-L and L-shaped tears have some portion of the tendon torn off of the humeral head and then extend into the tendon medially forming the shape of the letter L or a backwards L. The medial- lateral tear often is through the rotator interval between the subscapularis and supraspinatus, or in the interval between the supraspinatus and infraspinatus. Trapezoidal tears are larger looking like a trapezoid and Massive tears are larger and irreparable. The classification, like the previous ones, is based on the findings at the time of surgery. It has not been validated. One large drawback to each of the systems described above is the inability to use them pre-operatively to give the patient a prognosis for a successful outcome. The ideal classification system, once validated, should not only describe and categorize tear patterns, but it should also eventually be used to predict the type of surgery necessary
to repair the tear and give a patient an idea of the eventual outcome of the surgical procedure. Because these systems classify the tear only during surgery, they cannot be used to prognostic purposes.

Figure 16: patterns of full thickness rotator cuff tears a. crescent. b. Triangular defect: reverse L shaped tear. c. Triangular defect: L shaped tear. d. Trapezoidal. e. Massive tear.111

Burkhart108 developed a geometric classification system based on preoperative MRI imaging. He classified the tear pattern into 4 shapes and felt that this shape was correlated to outcome. Measuring the tear on both sagittal and coronal MRI images, Type 1 tears are crescent-shaped tears that are relatively short in the coronal image and wide on the sagittal image. Type 2 tears are longitudinal (U-shaped and L-shaped) tears that are relatively long on the coronal and short on the sagittal images. Type 3 tears are massive and contracted tears being both long on the coronal and wide on the sagittal images. Type 4 tears include a massive tear and glenohumeral arthrosis and loss of acromiohumeral distance indicative of rotator cuff arthropathy. The advantage of this system is that it is used preoperatively.

Figure 17: (A) A type 1, crescent-shaped tear is short and wide with a medial-to-lateral length (L) less than the anterior to posterior width (W). (B) Crescent tears can usually be repaired with a direct tendon end to bone technique. (IS, infraspinatus; SS, supraspinatus.)108
These classifications rely in tear exclusively configuration alone. Although they add information that can help the surgical preparation (and prognosis in Burkhart’s), they lack information about size, retraction and tendon quality.\textsuperscript{105}

**Others (Complete/Complex)**

**Patte**\textsuperscript{112} developed a system that incorporated several factors including: (1) Extent of the rotator cuff tears; (2) Topography of the tear in sagittal plane; (3) Topography of the tear in frontal plane; (4) Topography quality of the muscles of the torn tendons; and (5) State of the long head of the biceps as measured on preoperative imaging.

Patte’s classification is divided in 5 main categories and which one of them is further separated in many items. The most commonly used portion of the classification is retraction of the supraspinatus tendon in the coronal plane as shown below. Stage I is a tear with minimal retraction, Stage II is a tear retracted medial to the humeral head footprint but not to the glenoid, and Stage III is a tear retracted to the level of the glenoid (figure 18). The Patte classification has been found to have consistently moderate agreement in assessing tear retraction in various studies.\textsuperscript{109,113} It has also been shown to have some prognostic value after rotator cuff repair.\textsuperscript{114} However, size, shape and tissue quality as well as differentiation of the tendons involved are not included.

![Figure 18: Patte classification of rotator cuff tears. The Patte score assesses the degree of tendon retraction in the frontal plane on MRI: full-thickness tear with little tendon retraction (1), retraction of tendon to level of humeral head (2), and retraction of tendon to level of glenoid (3).](image)

**Snyder** developed a comprehensive classification to describe the extent of the tear, the location and the size. Full Thickness tears are classified as: C1—Small
complete tear, pinhole sized, C2—Moderate tear < 2 cm of only one tendon without retraction, C3—Large complete tear with an entire tendon with minimal retraction usually 3–4 cm, C4—Massive rotator cuff tear involving 2 or more rotator cuff tendon with associated retraction and scarring of the remaining tendon.\textsuperscript{115}

This system, as the others does not include all of the factors felt to be important in fully classifying tears of the rotator cuff tendons. It is clear that the more complex the system, the less likely the agreement will be; on the other hand, a good classification should give solid information about type of surgery, difficulties and prognosis.

**Tendon Quality**

It has been shown that repair integrity is related to preoperative tear size and fatty infiltration on preoperative magnetic resonance imaging (MRI).\textsuperscript{56,116} It has also been shown that fatty infiltration and muscle atrophy do not improve after successful structural repair of the rotator cuff and their presence correlates with poor functional outcomes.\textsuperscript{114,117} Thus, a complete rotator cuff classification system should include information about the pre-operative muscle atrophy and fatty infiltration of the rotator cuff muscles.

Thomazeau\textsuperscript{118} classified the supraspinatus muscle belly based on the occupation ratio in the supraspinatus fossa in T1-weighted oblique-sagittal images (MRI). Stage I was normal or slightly atrophied, Stage II showed moderate atrophy, and Stage III was serious or severe atrophy.

Figure 19: Calculation of the occupation ratio \( R \) on the oblique-sagittal view. \( S1 \) surface of the supraspinatus muscle; \( S2 \) surface of the entire supraspinatus fossa. \( R=S1/S2 \). Thomazeau classified the supraspinatus muscle belly based on the occupation ratio in the supraspinatus fossa.\textsuperscript{118}
Figure 20: Three grades of the supraspinatus muscle atrophy based on the occupation ratio, in case the ratio between 1.00 and 0.60 (stage 1), the muscle can be considered normal or slightly atrophied. Values between 0.60 and 0.40 (stage 2) suggest moderate atrophy. Values below 0.40 suggest severe atrophy.118

Zanetti et al 119 described a grading scale for muscle atrophy based on the oblique sagittal-plane magnetic resonance images (see Fig. 21).

The system grades the atrophy of either the supraspinatus or infraspinatus muscle belly as none, mild, moderate or severe.

For quick qualitative assessment evaluation of the atrophy of the supraspinatus muscle a morphological sign was introduced (Tangent sign), which is a line drawn through the superior borders of the scapular spine and the superior margin of the coracoid.

The tangent sign is defined as abnormal (positive) if the supraspinatus is not crossing the tangent line. The tangent sign is a qualitative sign of the muscle atrophy with a high predictive value. Obviously, its use is limited to the supraspinatus muscle, which is not adequate to all types of tears.
The Zanetti grading of muscle atrophy is based on the relation of the muscle to a straight line connecting either the coracoid to the scapular spine (assessing the supraspinatus) or the scapular spine to the tip of the scapula (assessing the infraspinatus).

Goutallier introduced a classification of fatty infiltration of the supraspinatus based on the presence of fatty streaks within the muscle belly using CT images; Stage 0 is normal muscle, Stage I: muscle with some fatty streaks, Stage II: fatty infiltration is important, but there still more muscle than fat, Stage III: there is as much fat as muscle and Stage IV: more fat than muscle is present.

Fuchs has published a similar classification using MRI.
Management of rotator cuff tear

While managing a cuff tear, certain factors are taken in account before repair.

- Traumatic versus degenerative tears.
- Asymptomatic and symptomatic cuff tears.
- Patients and their demographic factors.
- Reparability of the cuff.

Traumatic versus degenerative tears

In patients with traumatic full-thickness cuff tear with loss of active elevation, repair could be undertaken soon after oedema and inflammation subside and before the cuff retracts medially. The repair of traumatic cuff tear provides good result, but there is weak evidence in favour of early repair.\textsuperscript{121,122}

Asymptomatic versus symptomatic chronic reparable tear

A large number of cuff tear patients are asymptomatic and are two times as common as symptomatic ones.\textsuperscript{123} Keeping symptoms and function in mind, there are three broad categories of patients with “potentially reparable chronic full-thickness cuff tear”: (1) asymptomatic and functionally compensated, (2) mildly symptomatic but functionally compensated, and (3) functionally decompensated.

I. Asymptomatic and functionally compensated

Diagnosis of this category is usually made when bilateral ultrasound is performed to assess the contralateral side in a patient with another shoulder symptomatic cuff tear. According to the recent American Academy of Orthopaedic Surgeons (AAOS) group recommendation, such asymptomatic cuff tears should be left alone and can be monitored under regular follow-up.\textsuperscript{122}

II. Mildly symptomatic but functionally compensated Patients

In this category present with pain but retain ability to elevate the arm actively enough to perform activities of daily living (ADLs).\textsuperscript{65} Burkhart\textsuperscript{124,125} suggested that despite having anatomic deficiency in the cuff structure, such functionally compensated patients have functionally optimal cuff probably due to intact
rotator cable, which provides balanced force couple in the coronal and axial planes, maintaining the head centered into the glenoid. Pain may arise not only due to torn cuff but also due to multifactorial causes such as impingement, subacromial bursitis, LHB affection, cartilage degeneration, and scapular muscle dysfunction. Pain can be managed by activity modification, analgesics, steroid injection, and focused physical therapy aiming at strengthening the remaining normal cuff and scapular muscles. Nonetheless, patients in the “Asymptomatic and Functionally Compensated” and “Mildly Symptomatic but Functionally Compensated” categories should be informed about inevitable cuff tear enlargement in due course, which may be few months to years.\textsuperscript{126} In addition, prolonged inactivity in the dysfunctional part of the cuff leads to fatty infiltration and atrophy of muscle and further medial retraction with possible delamination of the tendon.\textsuperscript{117,127,128} Because of delamination and medial retraction, late repairs become technically challenging and anatomical footprint restoration may not be possible without tension that may affect the functional and structural outcomes of the repair.\textsuperscript{114,129}

III. \textbf{Painful and functionally decompensated}

Patients of this category present with pain and inability to elevate the arm with severely compromised ADL. They can be given a trial of analgesics and physical therapy for few weeks. If they regain active elevation, with minimal pain and are able to perform ADL comfortably, they can be kept on regular follow-up to detect further enlargement of tear size, retraction, fatty infiltration, and atrophy using serial ultrasound sonography or magnetic resonance imaging (MRI). If they fail to recover within few weeks, surgical restoration of torn cuff at the footprint is advisable.\textsuperscript{122}

\textbf{Reparability of the cuff}

A cuff tear is considered to be irreparable when it cannot be closed adequately with proper footprint coverage or when its closure will indeed result in postoperative re-tear. Large or massively retracted cuff tears may not be
reparable. If pre-operative radiograph reveals anterosuperior migration or acromiohumeral distance less than 6 mm, chronically retracted two-tendon tear that may not be reparable is indicated.\textsuperscript{130}

In such cases, MRI would be certainly helpful to assess the number of tendon involvement, retraction, fatty infiltration, and atrophy, and the surgeon may take all the factors into account before attempting surgical repair. Reparability also depends on size and shape of the tear. Davidson and Burkhart\textsuperscript{108} and Burkhart\textsuperscript{131} suggested a practical way to assess the shape and possible reparability of a tear. (Discussed previously with classification).

**Operative treatment**

Despite the popularity of surgical repair of rotator cuff tears, literature regarding the indications for and timing of surgery are sparse.

No Level I or II studies have been performed regarding treatment recommendations. Lack of any prospective, randomized clinical trials offering Level I evidence contributes to difficulty in making clinical recommendations. Almost all evidence guiding current treatment is Level III at best.

Unfortunately, the treatment decision for symptomatic full-thickness cuff tears seems largely based on the physicians’ personal experience and Level III and IV evidence, as high quality data for guiding treatment is limited.\textsuperscript{132}

Surgical repair is the gold standard in patients unresponsive to conservative management, resulting in good and excellent functional and clinical outcomes. In the last 2 decades \textsuperscript{133,134} comparable functional results have been observed in patients undergoing open, mini-open, and arthroscopic repair.\textsuperscript{10,14,135–138}

The goal of rotator cuff repairs is to achieve high initial fixation strength, minimize gap formation, maintain mechanical stability under cyclic loading, and optimize the biology of the tendon-bone “healing zone” until the cuff heals biologically to the bone.\textsuperscript{139}


**Mechanism of repair failure**

Early rotator cuff failures and re-tears are caused by a number of potential causes including anchors pulling out of the bone, suture failure, and knot loosening.\(^{19}\) As stronger suture materials were introduced, failures occurred more often at the suture-tendon interface with the sutures pulling out of poor quality tissue before it could heal to the bone. In addition, some of the stronger suture configurations such as the Mason-Allen configuration,\(^{140}\) which is often used in open techniques, are very difficult to replicate arthroscopically, and the usually used simple and mattress sutures alone may not be sufficient to maintain the rotator cuff tendon to its bony bed until it heals. In reality, biomechanical causes of re-tears are often multifactorial including a combination of anchor and suture-tendon interface failures.\(^{139}\)

Repair of rotator cuff tears can be similar to fracture fixation—an anatomic reduction will provide the best restoration of kinematics, with the best potential for healing, because the construct will be under minimal tension.\(^{141}\)

Besides an adequate mobilization of the rotator cuff, a proper reinsertion technique is of tremendous significance for a successful outcome after rotator cuff repair. Various reinsertion techniques for arthroscopic and open rotator cuff repair are reported in the literature.

Currently suture anchor repair represents one of the most commonly used techniques in arthroscopic rotator cuff reconstruction. The weak link of the restored muscle-tendon-bone unit is still located at the suture-tendon interface. The suture technique for grasping the retracted tendon is supposed to provide high initial fixation strength, allowing none to minimal gap formation and maintaining mechanical stability until an osteofibroblastic integration has occurred. In addition strangulation of the tendon should be kept as low as possible in order to avoid local metabolic compromise and damage to the reattached tendon.\(^{22}\)
Several techniques for arthroscopic repair of rotator cuff defects have been introduced over the past few years. Besides established single-row repairs, classical double row (DR), and suture bridge DR transosseous equivalent (TOE) technique.

**Single row (SR):**

At present, single row is the most frequently used repair, with suture anchors disposed in 1 row over the humeral head, at the native site of insertion of the tendon.\(^{140,142-148}\)

In single row repairs, the anchors are disposed in a linear fashion, close to the lateral aspect of the footprint.

Technically, SR technique is simpler, quicker, inflicts less trauma to tendon margins, cheaper, and easier to revise. On the downside, the SR technique has smaller contact area and pressures, and the repaired tendon is allowed to heal over the smaller area, which theoretically predisposes SR repair to poor healing potential.\(^5,13\)

Despite theoretical short-comings, good clinical and structural outcomes are reported throughout the literature with SR technique.\(^5,149,150\)

Few studies have reported good clinical outcome with SR technique but higher re-rupture at the end of 2 years.\(^5,13,150,151\)

In the context of the single row repair, different techniques have been described:

(a) The single row anchor-simple (SRA-s) repair is 1 line simple stitch repair, achieved using 2 double-loaded suture anchors;

(b) a single row anchor-mattress (SRA-m) provides a horizontal mattress stitch repair, performed using 1 line of 2 double-loaded suture anchors; (c) the single row arthroscopic Mason-Allen configuration (SRA ama) is obtained by placing 1 line of 2 double-loaded suture anchors.\(^{152}\)
Arthroscopic modified Mason-Allen stitch:

Described by Scheibel and Habermeyer,\textsuperscript{22} which is a complex single-row technique that provides biomechanical results superior to those provided by simple or mattress stitches.

Gerber et al.\textsuperscript{140} proposed a modified Mason-Allen suturing technique for transosseous rotator cuff repair which has been originally described in hand surgery. The mechanical properties of this suture grasping technique have been shown to be superior to the single and mattress stitches.\textsuperscript{20}

Habermeyer et al.\textsuperscript{22}, had developed a modified Mason-Allen technique for suture anchor repair that can be used in arthroscopic and open rotator cuff reconstruction. This technique is easy to perform and provides excellent stability to the reattached tendons. They had stated in their article that it can be performed with all currently available suture anchor devices that are loaded with two sutures. The suture anchor they had used was either the Corkscrew or Bio-corkscrew (Arthrex, Naples, FL).

The number of anchors they used was dependent on the length of the tear. They prefer to use 1 anchor per centimeter of tear size. Their modified Mason-Allen suture grasping technique for suture anchor repair follows the principles of the Mason-Allen technique. The combination of a mattress and single suture offers a construct that applies a constant and balanced contact pressure of the tendon to the prepared bony bed (Figure 23 and 24). The mattress stitch is tied first and the single stitch on top of it so it resists the single stitch pull through the tendon. They had not mentioned in their technical note the exact location of the anchor in the footprint.\textsuperscript{22}

However, in Lichtenberg and Habermeyer publication\textsuperscript{153} to study the effect of tendon healing on the clinical outcome after SR MMA, they emphasized that
they place the anchor as far lateral as possible in contrast to Meyer et al. recommendation.\textsuperscript{154}

![Figure 23](image1.png)

\textit{Figure 23: Tendon refixation using the modified Mason-Allen technique for suture anchor repair: The mattress stitch is tied first and the single stitch on top of it so it resists the single stitch pull through the tendon.}\textsuperscript{22}

![Figure 24](image2.png)

\textit{Figure 24: Details of the modified Mason-Allen technique using suture anchors: The combination of a mattress and single suture represents the principles of a modified Mason-Allen technique and offers a construct that applies a constant and balanced contact pressure of the tendon to the prepared bony bed.}\textsuperscript{22}

The modified Mason-Allen suture produces greater force and pressure of the tendon on the bone than the simple repair. Histologically this suture has not yet been studied, but according to the study of Scheibel et al.\textsuperscript{22} no cases of aseptic necrosis of the tendon were observed.
Porto et al.\textsuperscript{155} had reported significant clinical improvement in 79 patients who underwent arthroscopic rotator cuff repair using the Modified Mason-Allen technique regardless of lesion size. A high rate of re-ruptures was found in the larger lesions.

Baums et al.\textsuperscript{148} compared the tendon-bone interface contact pressure of different single- versus double-row suture anchor repair techniques. Their results were that the average contact pressures for the more complex single- and double- row techniques utilizing arthroscopic Mason-Allen stitches were greater than were those of the repair techniques utilizing simple and horizontal mattress stitches.

\textit{Figure 25:} Diagrammatic representation of (A) single row, (B) double row, and (C) transosseous equivalent suture anchor repair.\textsuperscript{34}

**Double row (DR):**

In the “double row” configuration, 2 rows of suture anchors are placed over the articular cartilage margin of the anatomic neck (medial) and along the lateral edge of the tuberosity (lateral) to better restore the native rotator cuff footprint. Usually, a mattress configuration is used to tie the medial suture anchors, and a simple configuration is performed for the lateral anchors.\textsuperscript{10}

DR repair encompasses restoration of a larger medial to lateral footprint area near the anatomical footprint with improved initial strength and stiffness, decreased least gap formation and strain as compared with SR or transosseous repair.\textsuperscript{148,156,157} However, classic DR is criticized for increased operative time, complexity of the procedure, and higher cost of more implants used without having any major added clinical advantage over SR. In addition, presence of excess implant at the footprint renders repair of re-tear
difficult.\cite{14,158-160} Although DR repair is stated to provide superior fixation properties, it can fail at the medial row (type 2 failure) near the musculotendinous junction.\cite{161-163}

The arthroscopic transosseous equivalent suture bridge (TOE-SB) technique:

The suture bridge double-row technique as originally introduced by Park et al.\cite{164} It was developed to maximize tendon-to-bone compression by bridging the medial suture limbs to lateral suture anchors. This results in compression of the tendon onto the rotator cuff footprint. In vitro biomechanical studies demonstrated that the transosseous technique provides more contact and greater pressure over a defined footprint relative to suture anchors alone.\cite{165} Similarly, TOE-SB repair provides significantly more contact area and pressure over a repaired rotator cuff footprint than a double-row suture anchor repair.\cite{164}

\textit{Figure 26: Schematic drawing of the modified double-row suture bridge repair.}\cite{166}
Patients and methods

From October 2013 to August 2015, a prospective case series was done to investigate the functional outcome of arthroscopic modified Mason Allen stitch using single row technique, done for 22 patients (22 shoulders) with symptomatic rotator cuff tears. All selected patients met the following inclusion criteria:

1. Symptomatic complete rotator cuff tear for more than 6 months for degenerative cases.
2. Immediate repair for the traumatic cases.
3. Good rotator cuff muscles with no evidence of fatty infiltration.

Our exclusion criteria were as follows:

1. Massive rotator cuff tears.
2. Partial thickness tears.
3. Evidence of fatty infiltration in the MRI.
4. Severe retracted tendon.
5. Isolated subscapularis tears.

Patients were subjected to the following:

A. Demographic analysis
B. Preoperative evaluation
   1. History and complaint analysis.
   2. Clinical examination and scoring.
   3. Imaging investigation.

C. Arthroscopic repair of the rotator cuff tendon using single row modified Mason Allen stitch and addressing the associated findings accordingly.

D. Rehabilitation program.
E. Follow up evaluation
   A. Range of motion (ROM).
   B. Scoring.
A. Demographics

From October 2013 to August 2015, a prospective case series was done to investigate the functional outcome of arthroscopic modified Mason Allen stitch using single row technique, done for 22 patients (22 shoulders) with symptomatic rotator cuff tears.

The mean duration of follow-up in our series was 10.82 ± 4.15 (range, 2-20 months). There were 17 females (77.3%) and 5 males (22.7%) with a mean age of 47.45 years ± 8.58 (range, 33-62 years). There were 17 dominant (77.3%) and 5 non-dominant (22.7%) shoulders. The mean duration of pre-operative symptoms was 9.6 months ± 8.4 months (range, 3-36 months).

Seventeen patients were housewives (77.3%), three patients were heavy manual workers (13.5%), and two patients were drivers (9.1%).

Twelve patients had degenerative tears with no history of trauma (54.5%) and ten patients (45.5%) gave history of traumatic event (fall to the ground).

Seventeen patients (77.27%) had no chronic medical conditions, four patients were diabetic (type II diabetes) (18.18%) and one patient had rheumatoid arthritis (4.5%).

Table 2 illustrates the demographics of all the cases.

N.B. The numbers given to the cases were randomly and were not upon their real sequence.
### Patients and methods

**Table 2: Illustrates the demographics of the 22 cases.**

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age</th>
<th>Sex</th>
<th>Occupation</th>
<th>Affected side</th>
<th>Dominant side</th>
<th>H/O of trauma</th>
<th>Duration of symptoms</th>
<th>Medical conditions</th>
<th>Medications</th>
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<td>RA (10 y)</td>
<td>steroids ,MXT</td>
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<td>None</td>
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<td>None</td>
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<td>4 m</td>
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<td>None</td>
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<tr>
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<td>R</td>
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<td>6 m</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
B. Preoperative evaluation:

1. History and complaint analysis

Careful history taking was done for all patients. Special care was given to identification if there was specific traumatic event to the affected shoulder or not, duration of the symptoms, progressive of the symptoms, medical conditions, night pain, trials of physiotherapy, and presence of weakness.

The answers to these questions may depict the type of the rotator cuff tear whether traumatic or degenerative, compensated or not, partial or complete thickness tear. The following sheet was filled in for all patients. (Figure 29)

![Rotator cuff shoulder sheet](image)

*Figure 27: Rotator cuff shoulder sheet*
Seventeen patients (77.3%) had graded their pain as severe and five patients (22.7%) had moderate pain.

Twenty-one patients (95.5%) were complaining of night pain, while one patient (4.5%) had no night pain.

2. Clinical examination and Scoring

The physical examination began with inspection from the front and the back for prior scars, atrophy, or deformity. Then, a comparative analysis of the range of motion, strength, and neurovascular status of both upper extremities was completed. Particular attention was paid to exclude cervical causes of brachialgia.

General examination:

Involved examination of the neck, whole upper limb with the intact shoulder examined before the affected shoulder.

Inspection:

Skin

Scars

Symmetry swelling

Atrophy

Scapular winging

Range of Motion (ROM):

Active ROM was assessed first then passive ROM if active ROM was limited. Using the goniometer, ROM for the following movements was evaluated and documented (for both normal and affected side):

Forward flexion (anterior elevation)

External rotation (ER) at side.

ER at 90° abduction
Internal rotation (IR) at 90° abduction

IR hand to back (spinous process of the highest vertebra reached)

Table 3 illustrates the pre-operative ROM of the 22 shoulders and Figure 28 shows IR hand to back.

**Table 3: Pre-operative active ROM (mean ± SD, range)**

<table>
<thead>
<tr>
<th></th>
<th>Anterior elevation°</th>
<th>Abduction</th>
<th>ER at side</th>
<th>ER at 90° abduction</th>
<th>IR at 90° abduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>81.3° ± 45.2°</td>
<td>80° ± 41.5°</td>
<td>40.6° ±19.2°</td>
<td>35.9° ± 22.3°</td>
<td>20.9° ±14.2°</td>
</tr>
<tr>
<td>Range</td>
<td>30°-170°</td>
<td>30°-170°</td>
<td>20°-80°</td>
<td>10°-80°</td>
<td>5°-45°</td>
</tr>
</tbody>
</table>

**Figure 28: Pre-operative IR hand to back**

**Palpation:**

The following structures were palpated for tenderness:
AC joint, clavicle, acromion, scapular spine
Long head of biceps
Deltoid, trapezius, pectoralis major
Supra and infrascapular fossae

**Muscle testing:**

Serratus anterior, rhomboids, trapezius.

Supraspinatus: Jobe test.

Infraspinatus: resisted ER with arm at side.

Teres minor: resisted ER with arm at 90° abduction.

Subscapularis: Lift off, belly press, bear hug tests.

Biceps tendinitis and Superior labrum: Speed, Yergason’s, O’Briens, Biceps load shift tests.

All patients had positive Impingement and Hawkin’s signs. Other special tests findings summarized in table 4.

*Table 4: Illustrates the pre-operative special tests.*

<table>
<thead>
<tr>
<th>Name of the Test</th>
<th>Test result</th>
<th>Number of patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobe test</td>
<td>positive</td>
<td>20</td>
<td>90.9%</td>
</tr>
<tr>
<td></td>
<td>negative</td>
<td>2</td>
<td>9.1%</td>
</tr>
<tr>
<td>Resisted IR</td>
<td>Intact</td>
<td>20</td>
<td>90.9%</td>
</tr>
<tr>
<td></td>
<td>Weak</td>
<td>2</td>
<td>9.1%</td>
</tr>
<tr>
<td>Resisted ER</td>
<td>Intact</td>
<td>21</td>
<td>95.5%</td>
</tr>
<tr>
<td></td>
<td>tender</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td>Lift off test</td>
<td>negative</td>
<td>22</td>
<td>100%</td>
</tr>
<tr>
<td>Belly press test</td>
<td>negative</td>
<td>21</td>
<td>95.5%</td>
</tr>
<tr>
<td></td>
<td>positive</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td>BHT 45°</td>
<td>Negative</td>
<td>22</td>
<td>100%</td>
</tr>
<tr>
<td>BHT 90°</td>
<td>Negative</td>
<td>20</td>
<td>90.9%</td>
</tr>
<tr>
<td></td>
<td>Positive</td>
<td>2</td>
<td>9.1%</td>
</tr>
</tbody>
</table>
**Scoring System:** (Appendix 2)
The Constant Murley score was used for pre-operative assessment.

We have used a fixed spring balance in our study to measure the strength. The fixed spring balance is a quick and simple method that has been described and validated. The spring balance was fixed at one end, and the reading taken after 5 seconds of maximum effort. The test position consisted of the subject standing, with the arm in 90° of lateral elevation in the scapular plane, the elbow extended, and the forearm pronated, with the device attached to the wrist.

**Pre-operative Constant-Murley score**
The mean total Constant score of the affected shoulders was 26.8 ± 20.5 (range, 10-82).
The mean total Constant score of the normal shoulders was 94.9 ± 3.7 (range, 83-98). Table 5 shows the subdivisions of the Constant-Murley score.

*Table 5: Pre-operative Constant score.*

<table>
<thead>
<tr>
<th></th>
<th>Pain</th>
<th>Activities of daily activities</th>
<th>Strength</th>
<th>Total Constant score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>1.1 ± 2.1</td>
<td>6.6 ± 3.9</td>
<td>3.8 ± 7.5</td>
<td>26.8 ± 20.5</td>
</tr>
<tr>
<td>Range</td>
<td>0-5</td>
<td>4-18</td>
<td>0-25</td>
<td>10-82</td>
</tr>
</tbody>
</table>
**Pre-operative Constant Murley score grading**

The grade is the difference between the normal and affected shoulder Constant scores. The mean difference Constant scores between the normal and affected shoulders was 68.1 ± 20.6 (range, 14-86). Pre-operative Constant grades see table 6.

*Table 6: Grading of the pre-operative Constant Murley score*

<table>
<thead>
<tr>
<th>Grade</th>
<th>Number of patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(Difference &lt; 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>2</td>
<td>9.1%</td>
</tr>
<tr>
<td>(Difference 11-20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(Difference 21-30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>20</td>
<td>90.9%</td>
</tr>
<tr>
<td>(Difference &gt; 30)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3. Imaging investigations:**

All patients had plain X-rays and MRI.

**Plain X-rays:**

AP and outlet views were done in all cases, no proximal migration of the head was detected. Case no. 2 had ACJ arthrosis. Eighteen cases had type II acromion according to Bigliani et al.36, 3 cases (no. 6, 11and 12) had type I, one case had type III acromion (case no.4).

**MRI:**

Was used in all of our cases, with the average interval between the date of the MRI and the operation was 2 months. However it had poorly identified associated subscapularis (in case no. 8) and biceps tendinopathy (in cases 5, 8, 10, 11and 17).
C. Surgical Technique of Arthroscopic modified Mason Allen rotator cuff repair

All shoulders were first examined under anesthesia before surgery to ensure complete passive ROM and exclude frozen shoulder.

Drawing of the bony landmarks and identification of the sites of the main portals (figure 29).

Figure 29: Drawing of anatomical landmarks (right shoulder). (1) Primary posterior portal. (2) Posterolateral portal. (3) Accessory superior lateral portal. (4) Anterosuperior portal. (5) Lateral portal.

The surgery was performed with the patients in the beach-chair position under hypotensive general anesthesia. Mean blood pressure was 70 mmHg in all cases.

The antibiotic used as a prophylaxis was Ceftriaxone, 2 grams were given 1 hour before the surgery. The pump pressure was between 50-60 mmHg (Conmed, Linvatec 10 K Pump).

A skin traction was applied before draping and traction by 5 kg was applied. (Figure 30)
First Intra-articular examination:

A 30° lens was introduced into the shoulder through the classic posterior portal (1 inch medial and inferior to postero-lateral corner of the acromion).

Saline inflation was then started and anterosuperior portal was established in an outside-in technique for examination of the joint.

Examination of the subscapularis, biceps tendon, supraspinatus and the labrum was done and managed accordingly in every case.

Moving to the subacromial space

Switching the portal to posterolateral portal described by Ellman was done in every case instead of the classic posterior portal.
Patients and methods

Then the lateral subacromial portal was established in outside-in technique, redirecting the anterosuperior portal by inserting a 6.5 mm cannula in AS portal redirecting towards the subacromial space.

Assessment of cuff tear size, location and mobility was made. Using a grasper inserted through a lateral subacromial portal, a trial reduction of the cuff tear to the tuberosity was performed.

Once the tear pattern was identified the number of anchors needed, and the need for release was determined. Inserting 8 mm cannula in the lateral portal was performed at that point.

One anchor per 10 mm diameter of tear size was used.

Preparation of the foot print of the rotator cuff was done by superficial debridement using the shaver and radiofrequency device with preservation of the cortex in order to maximize anchor pull out strength until bleeding bone surface was achieved. (Figure 32)

The tendon edge was also conservatively debrided, but the structural fibers of the tendon was preserved.

Figure 32: (A) extra-articular view of right shoulder from the posterolateral portal showing the foot print preparation using the shaver. (B) Intra-articular view of a right shoulder with the scope in the classic posterior portal show preparation of the foot print using radiofrequency.
Then the location and direction of the anchor was checked carefully with blunt rod or spinal needle from one of the pre-established portal or another additional portal when necessary. (Figure 33)

![Figure 33: Right shoulder viewing from the PL portal, spinal needle was used to check the direction and direction of the anchor.](image)

A double loaded 5.0 mm suture anchor was inserted just lateral to the foot print, we recommend at least 10 mm lateral to the articular surface as to increase the area of bone-tendon contact.

Types of the anchors used were as follow:

- 18 cases Fastin RC (DePuy Mitek, Raynham, MA).
- 2 cases Super Revo (CONMED, linvatec).
- 1 case Paladin (CONMED Linvatec).
- 1 case Cork screw (Arthrex).

The number of anchors used per case and the size of the tear per case summarized in table 7.

The suture anchor was inserted at an angle of approximately 45° (the Deadman Angle). The anchor was inserted midway between the articular cartilage and the lateral end of the foot print. (Figure 34)
Patients and methods

After placing the anchor, the method of suture passing through the tendon was chosen depending on the tear type and the direction needed for passing the sutures.

In all of our cases antegrade method using suture passing devices were used (like Expresso (DePuy Mitek, Raynham), Concept Suture Passer (CONMED Linvatec)). Care was taken during managing the sutures, taking all the sutures into the AS portal to act as a ‘parking portal’ or creating another portal according to the need. (Figure 35)

Performing the modified Mason-Allen technique for grasping the ruptured tendon is a combination of a mattress and a single suture. In the first step the mattress stitch was performed by passing both free ends of the first suture from intraarticular through the tendon into the subacromial space while working from the lateral portal. (Figure 36 and 37)

Figure 34: (A) Left shoulder inserting Fastin RC (DePuy Mitek, Raynham, MA). (B) Right shoulder inserting Super Revo (CONMED, linvatec).

Figure 35: Left shoulder retrieving 3 sutures through the AS portal leaving in that case a tiger free end coming through the lateral portal.
Patients and methods

Figure 36: Passing the anterior limb of the mattress stitch using suture passing device.

Figure 37: passing the posterior limb of the mattress stitch

The sutures were placed approximately 10 mm from the tendon edge and 10 mm next to each other.

Before tying the mattress suture the simple stitch was performed with the second suture. The 1 free end of the second suture was passed in between the previous suture and approximately 1 to 2 mm more medial. (Figure 38)

The mattress suture was tied first so that the single stitch was tied on top of it (figures 39 and 40).
A sliding knot (Duncan, Hangman’s, or Fisherman’s Knot) was used for the primary refixation and 3 reversed-post half-hitches for the locking mechanism of the base knot as was described by S. Burkhart.167 (Final repair figures 41, 42 and 43)
Patients and methods

Figure 40: Tying of the simple stitch.

Figure 41: From the posterolateral portal showing the final repair

Figure 42: From the lateral portal showing the final repair.
Patients and methods

Figure 43: Examination of the repaired tendon with very good coverage of the footprint.

Intra-operative findings:

i. **Regard the tear**
   Twenty two patients had complete tear supraspinatus, according to the classification of DeOrio and Cofield, sixteen patients had medium sized tears, five patients had large tears, and one patient had small sized tear. All patients had crescent shaped tears and were repaired with MMA technique. Sixteen patients had stage I and six patients had stage II tendon retraction according to Patte.

ii. **Number of Anchors**
   A mean of 1.45 anchors were used for the repair (range, 1-2). (More details in table 7).

iii. **Associated pathology**
   - Five cases had **biceps tendinopathy** in which biceps tenodesis was done in 3 cases and biceps tenotomy in 2 cases. In the cases of biceps tenodesis, 2 cases (cases no. 5 and 17) having SS tear (2 cm) with biceps tendinopathy sutures from the anterior anchor were used for the biceps tenodesis then preserved for constructing the mattress component of MMA stitch, 1 case (case no. 8) had subscapularis tear the sutures from the anchor used to repair the subscapularis were used to fix the biceps tendon with the subscapularis.
• One case (case no. 8) had associated subscapularis tear in which repair was done using SR MMA\textsuperscript{168} technique.

• One case (case no. 2) had AC arthrosis in which arthroscopic distal clavicle excision was done.

iv. **Sub-acromial decompression**

SAD was done in nineteen patients (86.3%), while was not performed in three patients (13.6%) with no radiological or intra-operative acromial spur.
**Table 7: Illustrates the intraoperative data of the 22 cases**

<table>
<thead>
<tr>
<th>Case</th>
<th>Tendons involved</th>
<th>Description of the tear</th>
<th>No. of Anchor s</th>
<th>Associated pathology</th>
<th>Management of the associated pathology</th>
<th>SAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SS and IS</td>
<td>35 mm medium crescent</td>
<td>2</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>AC arthrosis</td>
<td>Arthroscopic distal clavicle excision</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>SS</td>
<td>20 mm medium crescent</td>
<td>2</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>SS and IS</td>
<td>40 mm large crescent</td>
<td>2</td>
<td>Biceps tendenopathy</td>
<td>biceps tenodesis with SS</td>
<td>yes</td>
</tr>
<tr>
<td>6</td>
<td>SS and IS</td>
<td>40 mm large crescent</td>
<td>2</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>7</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>8</td>
<td>SS and Subs Subs (upper 10mm) SS 15 mm</td>
<td>medium crescent</td>
<td>SS(1), Subs (1)</td>
<td>Biceps tendenopathy</td>
<td>biceps tenodesis with subs</td>
<td>yes</td>
</tr>
<tr>
<td>9</td>
<td>SS</td>
<td>15 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>10</td>
<td>SS</td>
<td>8 mm small crescent</td>
<td>1</td>
<td>Biceps tendenopathy</td>
<td>biceps tenotomy</td>
<td>yes</td>
</tr>
<tr>
<td>11</td>
<td>SS</td>
<td>15 mm medium crescent</td>
<td>1</td>
<td>Biceps tendenopathy</td>
<td>biceps tenotomy</td>
<td>no</td>
</tr>
<tr>
<td>12</td>
<td>SS and IS</td>
<td>40 mm large crescent</td>
<td>2</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>13</td>
<td>SS</td>
<td>15 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>14</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>15</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>16</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>17</td>
<td>SS and IS</td>
<td>35 mm large crescent</td>
<td>2</td>
<td>Biceps tendenopathy</td>
<td>biceps tenodesis with SS</td>
<td>yes</td>
</tr>
<tr>
<td>18</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>19</td>
<td>SS and IS</td>
<td>40 mm large crescent</td>
<td>2</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>20</td>
<td>SS</td>
<td>15 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>21</td>
<td>SS</td>
<td>10 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>22</td>
<td>SS</td>
<td>20 mm medium crescent</td>
<td>1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>
D. Rehabilitation program
The shoulder was immobilized in a broad arm sling with an abdominal belt for 6 weeks, during which self-directed rehabilitation including passive ROM was permitted.
The pendulum exercises were permitted on the 3rd week, for 3 times per day. On the 6th week active assisted ROM was permitted and patients were referred to physiotherapist supervised rehabilitation.
No strengthening exercises were permitted before regaining pain free ROM. The patients were permitted to return to their usual activity six months post-operatively.

E. Follow up evaluation

1. ROM
   Active anterior elevation, ER at 90°abduction, ER at side, IR at 90° abduction and IR hand to back were assessed and documented at 2, 6, 12 and final follow-up.

2. Scoring
   Constant-Murley scores were calculated at the final follow-up.

F. Statistical methods
Data were coded and entered using the statistical package SPSS version 22. Data was summarized using mean, standard deviation, median, minimum and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparison of measured parameters in the same individual before and after operation was done using the non-parametric Friedman test and Wilcoxon signed rank test. P-values less than 0.05 were considered as statistically significant.
Results

The mean duration of follow-up in our series was 10.82 ± 4.15 (range, 2-20 months).

Our results can be summarized as follow:

1. Post-operative ROM assessment
   A. ROM at final follow-up

Table 8 illustrates the ROM of the 22 shoulders and figure 44 shows IR hand to back at the final follow up.

Table 8: Post-operative ROM at final follow-up

<table>
<thead>
<tr>
<th></th>
<th>Anterior elevation</th>
<th>Abduction</th>
<th>ER at side</th>
<th>ER at 90° abduction</th>
<th>IR at 90° abduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>162.3 ± 7</td>
<td>161.4 ± 7.2</td>
<td>70.4 ± 16.1</td>
<td>76.9 ± 15</td>
<td>55.9 ± 18.3</td>
</tr>
<tr>
<td>Range</td>
<td>150-170</td>
<td>150-170</td>
<td>30-90</td>
<td>30-90</td>
<td>20-80</td>
</tr>
</tbody>
</table>

Figure 44: Postoperative IR hand to back.
B. ROM at 2\textsuperscript{nd}, 6\textsuperscript{th} and 12\textsuperscript{th} postoperative month.
There was a statically significant difference between the mean of ROM at 2 m, 6 m and 12 m postoperatively (p value < 0.001).

C. ROM at the final FU compared to preoperative ROM
A statistically significant difference was found in the mean increase of the ROM (anterior elevation, abduction, ER at side, ER at 90° abduction and IR at 90° abduction) at final follow-up compared to per-operative ROM (p value < 0.001).

Table 9: The ROM at final FU compared to the pre-operative

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Final</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
</tr>
<tr>
<td>Active anterior elevation</td>
<td>81.3</td>
<td>45.2</td>
<td>30-170</td>
</tr>
<tr>
<td>active abduction</td>
<td>80</td>
<td>41.5</td>
<td>30-170</td>
</tr>
<tr>
<td>ER at 0°</td>
<td>40.6</td>
<td>19.2</td>
<td>20-80</td>
</tr>
<tr>
<td>ER at 90°</td>
<td>35.91</td>
<td>22.34</td>
<td>10-80</td>
</tr>
<tr>
<td>IR at 90°</td>
<td>20.91</td>
<td>14.20</td>
<td>5-45</td>
</tr>
</tbody>
</table>

D. ROM at final FU compared to normal side ROM
Statistically significant difference was found in the mean decrease of 15.2° for anterior active elevation, 15.7° for the active abduction, 13.8° for ER at side, and 13.1° for ER at 90° abduction at final follow-up compared to normal side ROM (p value < 0.001). There was a mean decrease of 6.1° for IR at 90° abduction, however this was not statistically significant.
2. Post-operative functional score assessment at final follow-up

The mean total Constant score of the affected shoulders was 76.05 ± 14.28 (range, 39-98). Table 10 show the subdivisions of Constant score.

Table 10: Post-operative Constant score at the final follow-up

<table>
<thead>
<tr>
<th></th>
<th>Pain</th>
<th>Activities of daily living</th>
<th>Strength</th>
<th>Total Constant score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>12.1 ± 3.7</td>
<td>17.6 ± 4.5</td>
<td>9.3 ± 7.4</td>
<td>76.05 ± 14.28</td>
</tr>
<tr>
<td>Range</td>
<td>5-15</td>
<td>6-20</td>
<td>2-25</td>
<td>39-98</td>
</tr>
</tbody>
</table>

3. Post-operative Constant Murley score grading

The mean total difference between Constant score of the normal and affected shoulders was 18.4 ± 14.1 (Range, 0-57).

Table 11: Grading of the Post-operative Constant Murley score

<table>
<thead>
<tr>
<th>Grade</th>
<th>Number of patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>5</td>
<td>22.7%</td>
</tr>
<tr>
<td>(Difference &lt; 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>6</td>
<td>27.2%</td>
</tr>
<tr>
<td>(Difference 11-20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>6</td>
<td>27.2%</td>
</tr>
<tr>
<td>(Difference 21-30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>3</td>
<td>13.6%</td>
</tr>
<tr>
<td>(Difference &gt; 30)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. **Post-operative compared to the pre-operative Constant score**

Statistically significant difference was found in mean increase of the total Constant score (p value < 0.001). That was a 49.2 increase for the Constant score (figure 55).

![Total Constant Murley score](image)

*Figure 45: Pre-operative compared to the post-operative Constant score at final follow-up*

Also statistically significant difference was found in mean increase of the subdivisions of the Constant score (pain, ADL and strength) with the post-operative at final FU compared with the pre-operative (figures 46-48).

![Pain subdivision of the Constant score](image)

*Figure 46: Pain subdivision of the Constant score pre-operative and at the final follow-up.*
Results

Figure 47: ADL subdivision of the Constant score pre-operative and at final follow-up

Figure 48: Strength subdivision of the Constant score preoperative and at the final FU.
5. Difference between the pre-operative Constant score of the normal and affected shoulders compared to that at final follow-up

![Bar chart showing the difference between the normal and affected Constant score](image)

*Figure 49: Showing statistical difference between the pre-operative Constant score grade to that at final follow-up.*

6. Postoperative ROM at 2, 6, 12 and final FU compared with the preoperative ROM
Figures 50-54 show the changes of ROM at different time periods.

![Graph showing active anterior elevation](image)

*Figure 50: Anterior elevation; preoperative, postoperative at 2m, at 6m and 12m and final Follow-up.*
Results

Figure 51: Abduction pre-operative, post-operative at 2m, 6m, 12m and final FU.

Figure 52: ER at side pre-operative, post-operative at 2m, 6m, 12m and final FU.
Results

**Figure 53:** ER at 90° pre-operative, post-operative at 2m, 6m, 12m and final FU.

**Figure 54:** IR at 90° pre-operative, post-operative at 2m, 6m, 12m and final FU.

### 7. Patient satisfaction

At the final follow-up twenty-one patients (95.4%) were satisfied by the results and one patient (case number 10) (4.5%) was not satisfied.
Complications

There was one case (case number 10) of serious complication in the form of uniocular blindness that was not directly related to the surgical procedure. The patient was not known to be diabetic nor hypertensive. Severe hypotension was reported intra-operatively, the patient was transferred to the ICU post-operatively due to respiratory center depression causing her to be hypoxic on the room air so, she was intubated.

The tube was removed next day and ipsilateral side blindness was discovered associated with proptosis, and ophthalmoplegia. The patient was referred to the ophthalmology department where CT scan and MRI orbit, fundus examination, IV fluorescein angiography were done. The only positive finding were neovascularization in the retina detected by fundus examination. The exact cause was not known, but ocular stroke by severe hypotensive event was suggested.

One patient (case number 5) reported severe pain and showed no improvement on regular follow-up for 6 months, diagnostic scope was done that revealed healing of the tendon to the greater tuberosity and presence splitting between the supra and infraspinatus, side to side repair was done using additional anchor. The patient showed progressive improvement after that.

No cases of iatrogenic nerve injuries, anchor migration nor wound infections.
Discussion

Our study evaluates the clinical and functional results after arthroscopic single row modified Mason Allen repair of supraspinatus tendon tears. Our hypothesis that the MMA leads to good clinical and functional outcome had been confirmed.

The results of our study showed a statistically significant improvement in the mean of the post-operative total Constant score and its components at the final follow-up compared to that of the pre-operative (p value <0.001). Also there was a statistically significant improvement in the mean of the post-operative ROM compared to that of the pre-operative (p value <0.001), on the other hand when comparing the mean ROM at final follow-up to that of the normal shoulder statistically significant decrease in flexion, abduction, ER at side and ER at 90% abduction. This may be attributed to that most of our patients (17 patients, 77.3%) were housewives, and were not compliant to regular physiotherapy.

Comparing our results with other studies using the same or similar technique, our mean total Constant score at final follow-up was slightly lower than that reported in Christian Gerhardt et al.169 and Sven Lichtenberg et al.153 (See table 12)

Regarding Lichtenberg et al. our pre-operative mean total Constant was remarkably lower, the pre-operative Constant score was not reported in Gerhardt et al. study, also our mean follow-up period was shorter than both studies. (See table 12)

However, our total mean Constant score was 10 points higher than that in Castagna et al. study.170 That may be attributed to differences in the tear sizes as it was only described as >2 cm in their series which may include any tear larger than 2 cm, the repair in their series was done with only one anchor in all cases irrespective of the tear size, finally the modified technique used in their study forming two simple sutures from the anchor loaded sutures, and the mattress component of the Mason-Allen stitch formed using a free ethibond suture, lacking the compressing component when the mattress suture is attached to anchor.
The mean age in our study was relatively low for the rotator cuff diseases as its prevalence increases with age, however that might be attributed to regional differences and small study sample size.

Mason-Allen stitch has higher tensile load, tensile strength, pull out strength, and tissue holding power compared with other repair techniques.

It was also known to have a lower chance of strangulation and necrosis of tissue when compared with other stitches.

Although the Mason-Allen stitch has many advantages, it was difficult to perform arthroscopically, and recently there have been an increasing number of studies attempting to perform it arthroscopically.

Nelson et al reported in their biomechanical study that biomechanical strength in single-row modified Mason-Allen repair was a little higher or almost similar to double-row repair even though double-row repair had better tendon-bone contact.

Given that the weakest point of the repair is the suture tendon interface so, increasing the holding power by the configuration in which the horizontal mattress suture serves as a “rip stop stitch” and theoretically reduces the possibility of the simple sutures cutting out, especially in a degenerative tendon. Also using single row reduces the cost and the operative time.

**Our surgical approach**

We always debrided the footprint only until bleeding was created using a shaver or radiofrequency. The anchors were inserted in the middle of the footprint as to avoid the weak area of the greater tuberosity in contrast to Haybermeyer and Lichtenberg that had described inserting the anchor as far lateral as possible.

A modified Mason-Allen stitch consisting of a horizontal mattress and a vertical single suture was used in all cases. We believe with that technique good footprint area contact can be achieved and that it will reduce slippage out of the sutures and off the
bony bed as demonstrated by Ma et al.\textsuperscript{171} when they showed no significant elongation of the construct and the highest load-to-failure strength.

It has been described a weak zone creation using retrograde suture passing instruments, causing greater holes through the rotator cuff.\textsuperscript{162,172} To avoid increased damage during suture passage, an Expresso, Scorpion, or Concept Needle, as an antegrade suture passer, was used in most of the patients.

Christian Gerhardt et al. had performed a comparative studies between arthroscopic single-row modified Mason-Allen repair and double-row suture bridge reconstruction for supraspinatus tendon tears.\textsuperscript{169} In which they used the same technique of our study described by Peter Haybermeyer for the first group of his study. In which there were no significant differences between patients done using SR MMA and patients done with double-row suture bridge reconstruction in the overall CS (P > 0.05). There were no significant differences between both groups in the CS for pain, activities of daily living, range of motion, and strength. Neither results for the subjective shoulder value (SSV) nor for the Western Ontario Rotator Cuff Index (WORC). No significant differences were detected with regard to muscular atrophy or fatty degeneration and tendon integrity between both techniques. However, the CS values revealed a significant difference between patients with intact tendon and patients with re-tears. Separated into its sub-items, the CS only showed significant differences in “strength”. Patients with intact tendon had significantly better results in the strength category. Also they found different pattern of recurrent defects between the 2 groups, they found lateral cuff failure in 5 of 6 patients with re-tears in SR group, whereas in DR group cases of re-tear predominantly displayed a medial cuff failure.\textsuperscript{169}

Sven Lichtenberg et al. performed a study to investigate the influence of tendon healing after arthroscopic rotator cuff repair on clinical outcome using single-row Mason-Allen suture technique, it was a prospective study using MRI. They used a sex and age related Constant-score. Therefore, the results of the total score were percent and not absolute points. Statistical significant difference in the strength component of the
Constant score was reported in patients with re-tears. The size of the tear did not influence the chance to suffer a re-tear because the different tear sizes were equally distributed in the intact group and the re-teared group.\textsuperscript{153}

Alessandro Castagna et al. had described modified Mason-Allen technique using triple loaded suture anchor (Alex stitch) in 2007.\textsuperscript{173}

In 2008, Alessandro Castagna et al performed a study to investigate the mid-term clinical and ultrasound outcomes of arthroscopic repair of rotator cuff repair using modified Mason-Allen stitch. However he used another method to reproduce the Mason-Allen stitch in which he used for the mattress stitch a free horizontal side-to-side stitch using a no. 2 ethibond (Ethicon) suture, while 2 simple sutures passed medial to the mattress were the anchor loaded sutures.\textsuperscript{170}

The technique was similar to that described by John D. MacGillivray, that was called the Mac stitch.\textsuperscript{23}

Sang-Hun Ko et al. had described arthroscopic repair with a modified mattress locking stitch (MMLS), which was a simple, clever modification of the modified Mason-Allen stitch. In which they connect the horizontal mattress suture loop with the vertical single loop arthroscopically. They believe that the use of an MMLS was a good way to decrease the occurrence of suture failure in rotator cuff tears. They linked the vertical simple suture and the horizontal mattress suture, so there was only 1 knot in the repaired rotator cuff with the MMLS.\textsuperscript{174}
Several studies have reported comparisons of different single- and double-row reconstruction techniques. In a prospective cohort study, Charousset et al\textsuperscript{175} evaluated the clinical and radiographic outcome of single-row and double-row rotator cuff repair. Although computed tomography arthrography performed 6 months after surgery showed significantly better tendon healing in the double-row group and more retears in the single-row group (22.5% vs 40%), clinical follow-up at 24 months did not show any significant difference between groups in clinical results. These data confirm several studies that showed no differences in clinical results between the single-row repair and the double-row technique.\textsuperscript{14,15,158,176}

Interestingly, often a simple stitch configuration, which results in a quite weak biomechanical construction, is compared with highly stable double-row techniques. Modified suture configurations for single-row techniques reveal improved biomechanical properties: Biomechanical studies point out that the number of sutures passing the tendon might be a fundamental factor determining initial stability.\textsuperscript{147,177–179}

To potentially increase the healing rate, the transosseous equivalent or suture bridge technique as introduced by Park et al\textsuperscript{164} showed significant improvement in the 2-dimensionally pressurized contact area when compared with regular double-row

\textit{Figure 55: Diagram of modified mattress locking stitch MMLS.} \textsuperscript{174}
techniques. Concerning clinical and radiologic results, Frank et al\textsuperscript{180} reported an intact reconstruction site of 89% after a follow-up of 12 months.

A higher recurrent insufficiency rate of 28.9\% was reported after a prolonged follow-up by Voigt et al\textsuperscript{181}; that study still achieved good clinical results, represented by a mean CS score of 94\%.

Comparing the primary biomechanical, stable single-row method (massive cuff stitch) with the double-row suture bridge technique, Pennington et al\textsuperscript{182} were among the first authors evaluating 2 groups of patients in a prospective, nonrandomized assessment. There were no differences concerning the clinical results but the investigators found an unexpected, lower re-tear rate for the single-row technique (20.5\% vs 30.8\%; \( P = .017 \)). The reason for this mentioned by the authors was the inhomogeneity of the tear size between the 2 groups. A more homogeneous subset of patients with tears between 2.5 and 3.5 cm showed a significantly improved healing rate for the double-row repair (\( P < 0.03 \)).

The double-row technique seems to be superior in reconstruction of large to massive rotator cuff tears (tear size \( \geq 3 \text{ cm} \)).\textsuperscript{182–184} However, we have four patients in our series with large tears (4 cm) their final outcome were two cases had fair, one had good and one had poor outcome, a larger group is needed to make a conclusion about the validity of the technique for large tears.

We had a serious complication in our case series which was unilateral blindness of the right eye after rotator cuff repair and SAD of the right shoulder, however it was not related to the technique. The same case scenario was reported as case report in 2003 and the cause was idiopathic.\textsuperscript{185}

The strength of our study is the prospective design and its clear-cut inclusion and exclusion criteria, same technique, good quality follow-up, we also have compared the post-operative ROM to both pre-operative and normal side ROM, we had estimated the
normal side Constant score and calculated the difference between the normal side and the affected pre- and postoperatively.

Our study has several limitations including the lack of a control group in which either a mini-open procedure was performed or a group in which only debridement/sub-acromial decompression was carried out, small number of patients, short term follow-up, non-digital measuring of the ROM, and non-digital measuring of the strength (instead we used a fixed spring balance with the patient standing, with the arm in 90° of lateral elevation in the scapular plane, the elbow extended, and the forearm pronated, with the device attached to the wrist)\textsuperscript{82}.

In addition, our study lacked post-operative imaging to confirm rotator cuff healing. Lastly visual analogue score to estimate the pain points was not convenient for our patients, instead we used the terms (no pain, mild, moderate and severe) to score the pain points.

**Future work**
The following issues should be investigated:

1. Comparing the results of the strength component of the Constant score using a fixed spring balance and dynamometer.
2. Evaluation of the incidence of re-tear and repair integrity of the rotator cuff after 2 years postoperatively using MRI and US for the cases with SR MMA.
3. Compare the results of SR MMA in small, medium and large tears.
4. Compare the results of SR MMA with DR MMA.
5. Compare the results of SR MMA repair of the supraspinatus with biceps tenodesis with and without tenotomy.
Table 12: Demographics and results of various rotator cuff repair using SR MMA and similar techniques.

<table>
<thead>
<tr>
<th></th>
<th>Our study</th>
<th>Gerhardt et al.(^ {169} )</th>
<th>Sven Lichtenberg et al.(^ {153} )</th>
<th>Castagna et al.(^ {170} )</th>
<th>Ko et al.(^ {174} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>22 shoulders</td>
<td>20 shoulders</td>
<td>53 shoulders</td>
<td>29 shoulders</td>
<td>39 shoulders</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>47.4 y (range, 33-62)</td>
<td>61.5 y</td>
<td>60.9 y (range 46-74)</td>
<td>59.3 y</td>
<td>53.4 y (range, 39-68)</td>
</tr>
<tr>
<td>Mean duration of symptoms prior to surgery</td>
<td>9.6 m</td>
<td>Not reported</td>
<td>11.7 m</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Mean FU (months)</td>
<td>10.8</td>
<td>16.8</td>
<td>26</td>
<td>30.2</td>
<td>31.1</td>
</tr>
<tr>
<td>Tear size</td>
<td>1.9 cm (mean) (range, 1-4 cm)</td>
<td>Range , 1-3 cm</td>
<td>Bateman I in 9, II in 38, III in 6. (range, &lt;1-&lt;5 cm)</td>
<td>&gt;2 cm</td>
<td>1.5-3 cm</td>
</tr>
<tr>
<td>Number of anchor used</td>
<td>1.45 (range, 1-2)</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Using one anchor in every case.</td>
<td>1.7 (range, 1-3)</td>
</tr>
<tr>
<td>ROM</td>
<td>Compared to the preoperative: Flexion +81.02 (&lt;0.001) Abduction +81.4 (&lt;0.001) ER at 0° +29.8 (&lt;0.001) ER at 90° + 40.9 (&lt;0.001) IR at 90° + 35.04 (&lt;0.001) Compared to the normal shoulder: Flexion - 15.2° (&lt;0.001) Abduction - 15.7° (&lt;0.001) ER at 0° - 13.8° (&lt;0.001) ER at 90° - 13.1'(&lt;0.001) IR at 90° - 6.1’( non- significant)</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Preoperative functional score (mean) of affected shoulder</td>
<td>Total CS 26.8</td>
<td>Not reported</td>
<td>Total CS 53.4% (Range, 23–80%)</td>
<td>Total CS 37.2 ± 19.5 UCLA 14.4 ± 5.2</td>
<td>VAS of pain 6.5 ADL 11.0 UCLA 13.4</td>
</tr>
<tr>
<td>Constant score of the normal shoulder</td>
<td>94.9 ± 3.7</td>
<td>88.8 ± 5.3</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Postoperative functional score of affected shoulder</td>
<td>CS 76.05 (Range 39-98) SSV 91.0% CS 82.2 WORC 96.5%.</td>
<td>CS 84.3% (Range, 62.5–99.3%)</td>
<td>Total CS 66.1 ± 8.2 UCLA 30.8 ± 4</td>
<td>VAS 0.9 ADL 27.0 UCLA 32.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Our study</td>
<td>C. Gerhardt et al. [169]</td>
<td>Lichtenberg et al. [153]</td>
<td>Castagna et al. [170]</td>
<td>Ko et al. [174]</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------</td>
<td>--------------------------</td>
<td>---------------------------</td>
<td>------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Method used to measure the strength</td>
<td>Fixed spring balance</td>
<td>Not reported</td>
<td>ISOBEX dynamometer</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Complications</td>
<td>1 case Ipsilateral blindness. 1 case needed another operation.</td>
<td>Not reported</td>
<td>Nil</td>
<td>Nil</td>
<td>Not reported</td>
</tr>
<tr>
<td>Postoperative imaging</td>
<td>Plain X-ray No change in the anchor position</td>
<td>MRI done for 19/20 Re-tear rate in 6 patients (31.6%)</td>
<td>Standardized open MRI. Re-tear in 13 patients (24.5%)</td>
<td>Ultrasound Re-tear in 11 patients (38%)</td>
<td>MRI Re-tear in 6 out of 36 patients had postoperative MRI</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>21 patients were satisfied (95.4%).</td>
<td>Not reported</td>
<td>All patients were satisfied 100%</td>
<td>25 patients were satisfied (86.2%)</td>
<td>37 cases were satisfied (94.9%)</td>
</tr>
</tbody>
</table>
Summary and Conclusion

Recurrent defects are one of the most common complications of arthroscopic rotator cuff repairs.\textsuperscript{3,5} The most frequent cause of early failure, both in open and arthroscopic cuff repairs, is the pull out of the suture through the tendon.\textsuperscript{19}

Mason-Allen stitch has higher tensile load,\textsuperscript{171} tensile strength,\textsuperscript{142} pull out strength, and tissue holding power compared with other repair techniques.\textsuperscript{140} Recently many studies had described technique to perform the Mason-Allen stitch.

From October 2013 to August 2015, 22 shoulders (22 patients) with rotator cuff tear met our inclusion criteria and underwent arthroscopic SR modified Mason-Allen repair. The mean duration of follow-up in our series was 10.82 ± 4.15 (range, 2-20 months). There were 17 females (77.3%) and 5 males (22.7%) with a mean age of 47.45 years ± 8.58 (range, 33-62 years). There were 17 dominant (77.3%) and 5 non-dominant (22.7%) shoulders. The mean duration of pre-operative symptoms was 9.6 months ± 8.4 months (range, 3-36 months). Seventeen patients were housewives (77.3%), three patients were heavy manual workers (13.5%), and two patients were drivers (9.1%). Twelve patients had degenerative tears with no history of trauma (54.5%) and ten patients (45.5%) gave history of traumatic event (fall to the ground). Seventeen patients (77.27%) had no chronic medical conditions, four patients were diabetic (18.18%) and one patient had rheumatoid arthritis (4.5%). Pre-operatively, the ROM was observed and recorded for both the diseased and normal sides. The Constant Murley score was documented for both the diseased and normal sides pre-operatively and post-operatively. ROM was assessed at 2 months, 6 months, 12 months, and at the final follow-up.
The results of our study showed a statistically significant improvement in the mean of the post-operative total Constant score and its components at the final follow-up compared to that of the per-operative (p value <0.001).
Statistically significant improvement was found in the mean of the post-operative ROM compared to that of the pre-operative (p value <0.001).

We had a case of idiopathic postoperative unilateral blindness that was not related to the technique, 8 cases (36%) with residual pain that occur during exertion.

Single row modified Mason-Allen technique is an arthroscopic technique that is easily performed to establish Mason-Allen stitch that was described by Gerber for the open repair.

Our short term results are encouraging but long follow-up and comparing with other techniques is needed.
Rotator cuff tears should be inspected as a fracture in which no single method of fixation is adequate only.

The optimal arthroscopic repair of supraspinatus tendon tears is still a matter of debate. Many authors have developed novel techniques for arthroscopic reconstruction of the rotator cuff to optimize the biomechanical features of the construct or to allow “anatomic” reconstruction of the tendon insertion area.

‘We are still running in the race to reach our target which is the optimal rotator cuff repair.'
Case presentation

Case 1

A. Personal History

Name: S M A
Case number: 3
Sex: Female
Age at surgery: 59 years.
Occupation: House wife
Dominance: right
Affected shoulder: left
Medical conditions: Diabetic
Medications: Oral hypoglycemic drugs
History of Trauma: Fall to the ground
Duration of symptoms: Pain and weakness for 3 months
Night pain: yes
Previous surgeries: none
Special habits of medical importance: none
Physiotherapy period: none
Follow-up period: 15 months

B. Pre-operative Evaluation

1. Special Tests

i. Impingement sign positive
ii. Hawkin's sign positive
iii. Jobe test positive
iv. Resisted IR intact
v. Resisted ER intact
vi. Subscapularis tests negative
vii. Biceps tests negative
viii. Drop arm sign positive

2. Imaging

   Plain X-ray

   Plain X-ray: AP view on the right and outlet view on the left. No ACJ arthrosis and type 2 acromion.

MRI

   MRI coronal T1
C. Intra-operative data:
1. Complete tear of the supraspinatus, 1 cm crescent shaped tear repaired by one double loaded suture anchor by single-row modified Mason-Allen.
2. SAD was done.

D. Final Follow-up

1. ROM

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior elevation</td>
<td>60°</td>
<td>160°</td>
</tr>
<tr>
<td>abduction</td>
<td>60°</td>
<td>160°</td>
</tr>
<tr>
<td>ER side</td>
<td>30°</td>
<td>80°</td>
</tr>
<tr>
<td>ER 90° abduction</td>
<td>30°</td>
<td>90°</td>
</tr>
<tr>
<td>IR side</td>
<td>Buttock</td>
<td>L3</td>
</tr>
<tr>
<td>IR 90° abduction</td>
<td>10°</td>
<td>50°</td>
</tr>
</tbody>
</table>

2. Constant score

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>ADL</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Strength</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>82</td>
</tr>
</tbody>
</table>
Case presentation

Active anterior elevation at final Follow-up

Internal rotation at 90° abduction and at side at final follow-up.
External rotation at 90° abduction at final follow-up.
Case 2

A. Personal History

Name: S M A
Case number: 7
Sex: Male
Age at surgery: 34 years.
Occupation: Carpenter
Dominance: right
Affected shoulder: right
Medical conditions: None
Medications: None
History of Trauma: No
Duration of symptoms: pain started 36 months before the operative intervention run a progressive course and was associated with weakness 1 month before the operative intervention.
Night pain: yes
Previous surgeries: none
Special habits of medical importance: Smoking 10 cigarettes /day.
Physiotherapy period: 6 months.
Follow-up period: 9 months

B. Pre-operative Evaluation

1. Special Tests

i. Impingement sign positive
ii. Hawkin's sign positive
iii. Jobe test positive (tender)
iv. Resisted IR intact
v. Resisted ER intact
vi. Subscapularis tests negative.

vii. Biceps tests negative.

viii. Drop arm sign negative.

2. Imaging

Plain X-ray

Plain X-ray AP view

Plain x-ray outlet view showing type II acromion.
Case presentation

MRI

MRI T1 showing the tear in the anterior part of SS.

MRI fat saturation T2
C. **Intra-operative data:**
   1. Complete tear of the supraspinatus, 1 cm crescent shaped tear repaired by one double loaded suture anchor by single-row modified Mason-Allen.
   2. SAD was done.

D. **Final Follow-up**

1. **ROM**

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior elevation</td>
<td>100°</td>
<td>160°</td>
</tr>
<tr>
<td>abduction</td>
<td>100°</td>
<td>160°</td>
</tr>
<tr>
<td>ER side</td>
<td>60°</td>
<td>80°</td>
</tr>
<tr>
<td>ER 90° abduction</td>
<td>60°</td>
<td>80°</td>
</tr>
<tr>
<td>IR side</td>
<td>L3</td>
<td>T12</td>
</tr>
<tr>
<td>IR 90° abduction</td>
<td>45°</td>
<td>80°</td>
</tr>
</tbody>
</table>

2. **Constant score**

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>ADL</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Strength</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>98</td>
</tr>
</tbody>
</table>
Case presentation

**Case 3**

**A. Personal History**

Name: N A S  
Case number: 5  
Sex: Female  
Age at surgery: 45 years.  
Occupation: House wife  
Dominance: right  
Affected shoulder: right  
Medical conditions: None  
Medications: None  
History of Trauma: No  
Duration of symptoms: Pain and weakness for 24 months  
Night pain: yes  
Previous surgeries: none  
Special habits of medical importance: none  
Physiotherapy period: none  
Follow-up period: 14 months

**B. Pre-operative Evaluation**

1. **Special Tests**
   i. Impingement sign positive  
   ii. Hawkin's sign positive  
   iii. Jobe test positive  
   iv. Resisted IR intact  
   v. Resisted ER intact  
   vi. Subscapularis tests negative  
   vii. Biceps tests positive
viii. Drop arm sign negative

2. Imaging

Plain X-ray

*Plain x-ray AP view (pre-operative).*

MRI

*MRI coronal view showing complete tear of the SS*

*MRI coronal view showing involvement of the anterior part of IS*
C. Intra-operative data:
1. Complete tear of the SS and anterior part of IS, 4 cm crescent shaped tear repaired by two double loaded suture anchor by single-row modified Mason-Allen.
2. Biceps tendinopathy was managed by biceps tenodesis with anterior anchor used for the SS.
3. SAD was done.

Arthroscopic intra-articular view of a crescent shaped tear involving the SS and anterior part of the IS.
D. Follow-up at 6 month after the repair

1. ROM

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative ROM at 6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior elevation</td>
<td>90°</td>
<td>90°</td>
</tr>
<tr>
<td>abduction</td>
<td>90°</td>
<td>90°</td>
</tr>
<tr>
<td>ER side</td>
<td>45°</td>
<td>45°</td>
</tr>
<tr>
<td>ER 90° abduction</td>
<td>45°</td>
<td>45°</td>
</tr>
<tr>
<td>IR side</td>
<td>Buttock</td>
<td>Buttock</td>
</tr>
<tr>
<td>IR 90° abduction</td>
<td>10°</td>
<td>20°</td>
</tr>
</tbody>
</table>

2. Constant score at 6 month

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative at 6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ADL</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Strength</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

At 6 months postoperative follow up the patient had no improvement as regard the ROM and constant score. The patient was admitted and another shoulder arthroscopy was done.
E. Intra operative findings at the second operation
1. Complete healing of the SS and IS to the footprint was found, with the presence of splitting between SS and IS.
2. Repair was done by additional anchor and side to side repair was performed.

Intra-articular view showing healed SS anterior to the probe and IS posterior to the probe with the presence of splitting in between.

F. Final Follow-up (8 months from the second operation)
1. ROM

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative ROM at 8 m after 2nd operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior elevation</td>
<td>90°</td>
<td>160°</td>
</tr>
<tr>
<td>abduction</td>
<td>90°</td>
<td>150°</td>
</tr>
<tr>
<td>ER side</td>
<td>45°</td>
<td>60°</td>
</tr>
<tr>
<td>ER 90° abduction</td>
<td>45°</td>
<td>70°</td>
</tr>
<tr>
<td>IR side</td>
<td>Buttock</td>
<td>L3</td>
</tr>
<tr>
<td>IR 90° abduction</td>
<td>10°</td>
<td>30°</td>
</tr>
</tbody>
</table>
### 2. Constant score

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative at 8 m after 2\textsuperscript{nd} operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>ADL</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>Strength</td>
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<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>58</td>
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References


References


الملخص العربي

إرتجاع القطع في أوتار الكفة المدورته هو أكثر المضاعفات شيوعا بعد جراحات إصلاح الأوتار.
و يكون نزع الخيوط من الوتر هي أكثر الأسباب حدوثا سواء كانت الجراحة عن طريق المنظار أو الفتح.
ماسون ألين هي حياكه للوتر تعطي قوة وتمزق الوتر بالخيوط . قد وصفت في حالات الجراحة بالفتح.
و حديثا قام باحثين عديدين بوصف تقنيات لعمل حياكة ماسون ألين بالمنظار.
تم إدراج 22 حالة في هذه الدراسة لإصلاح الوتر بطريقة ماسون ألين إحادي الصف المعدل من أكتوبر 2012 وحتى أغسطس 2015.
كان هناك 17 حالة من الإناث مقابل 5 من الذكور. كان متوسط عمر الحالات عند الجراحة 67 سنة وكان متوسط المتابعة 10 أشهر. وكان متوسط فترة الشكوي قبل الجراحة 9 شهور. تم تقييم المدى الحركي للكتف في كل من الجهة المعتلة و السليمة مع تدوين النتيجة لتقييم الوظيفي باستخدام المؤشر كونستنت مع مقارنة النتيج قبل و بعد الجراحة.
وجد اختلاف ذو دلائل إحصائية في زيادة ملحوظة في المدى الحركي و أيضا في درجات المؤشر كونستنت عند المتابعة النهائية مقارنة بالحالة قبل العملية.
يعتبر ماسون ألين المعدل إحادي الصف بالمنظار طريقة بسيطة لعمل حياكة ماسون ألين القوية التي قد وصفها جربر في الجراحة المفتوحة.
و على مدى المتابعة قصيرة الأمد ، فإننا نرى النتائج مشجعة تحتاج للمتابعة لفترات أطول و المقارنة بينها وبين تقنيات أخرى للوصول إلى الإصلاح الأمثل.
إصلاح اوتار العضلة الدوارة بالكتف بتقنية آحادي الصف المعدل باستخدام المنظار
رسالة توطئة للحصول علي درجة الدكتوراه في جراحة العظام

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2015