

# Holding on by a thread: the continuing story of rotator cuff tears

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## Abstract

Rotator cuff tears are a common cause of shoulder pain. The incidence of these tears has increased significantly over the years, with the demands of an increasingly active elderly population. Therefore, a detailed understanding of rotator cuff tears will help doctors manage their patients' condition. This field has rapidly advanced over the past decade and this review provided an insight into the latest developments.

**Key words:** Rotator cuff tear; Tendinopathy; Tendon

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## Introduction

The human shoulder is unique in its circumduction motion and throwing ability. It is a powerful and efficient catapult, allowing humans to throw up to five times faster than the nearest primate. This ability was essential in the hunter-gatherer society of early man. However, this powerful throwing action has left the human shoulder more susceptible to rotator cuff disease.

Shoulder tendon disease is related to age and activities. The majority of cases of shoulder pain tend to resolve spontaneously within 6 months. However, some conditions causing pain in the shoulder can take up to 2 years to resolve, with approximately 20% of these cases persisting beyond this point. One of the most common causes of shoulder pain is rotator cuff tears, the supraspinatus muscle particularly. There is a wide spectrum of severity and treatment options for the disease. In 2011, 300 000 rotator cuff repairs were undertaken in the USA (Colvin et al, 2012), with this number increasing year on year. A deeper understanding of this condition is crucial to meeting this ever-increasing demand.

## Anatomy

The ball and socket joint of the shoulder is a complex articulation, with motion occurring at the glenohumeral and scapulothoracic joint in a 2:1 ratio. The socket is shallow and is shaped more like a saucer than a cup. The humeral head contact area is larger than the glenoid, and is supported by the labrum to increase the surface area.

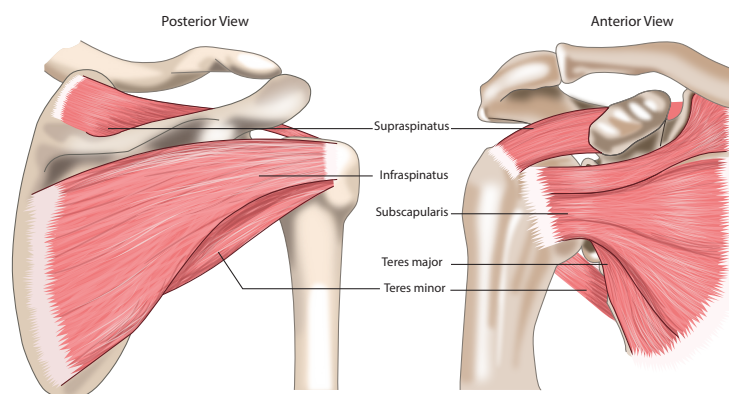
The rotator cuff helps centralise the humeral head in the glenoid and provide a stable fulcrum during shoulder movements, allowing larger muscles, such as the deltoid, to carry out their function. The rotator cuff includes four main tendons (supraspinatus, infraspinatus, subscapularis and teres minor; **Figure 1**), which cover approximately 270° of motion within the ball and socket joint.

The supraspinatus sits above the joint; it originates from the supraspinous fossa of the scapula and inserts on to the superior facet of the greater tubercle of the humerus. Its main aim is to help in shoulder abduction. The infraspinatus is behind the joint; the muscle originates from the infraspinatus fossa and attaches to the middle facet of the greater tubercle. The teres minor is inferior to the infraspinatus, originating from the lateral border of the scapula and inserts to the inferior facet of the greater tubercle. Both the infraspinatus and teres minor help in external shoulder rotation. The subscapularis sits at the front of the joint and attaches to the lesser tubercle, driving internal rotation.

The rotator cuff acts as a dynamic stabiliser of the glenoid humeral joint. When injured, this places increased demand on the static stabilisers of the shoulder. As a result, the capsule

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**Figure 1.** Anatomy of the rotator cuff.

stretches, becoming lax, allowing humeral head migration of the shoulder, which results in impingement and pain. This can also lead to shearing and injury to the glenoid labrum.

## Rotator cuff tear classification

Tear classification is important to the treating physician as it can guide future management. The size of the tear can be useful in classifying the rotator cuff tear – these are described as small (<1 cm), medium (1–3 cm), large (3–5 cm) or massive (>5 cm). Ellman (1990) classified tears by thickness as grade 1 (<3 mm), grade 2 (3–6 mm) and grade 3 (>6 mm). Partial tears can be further classified according to the compartment in which they present, either A: articular, B: bursal-sided tears or C: intratendinous. Cuff tears can also be classified by shape as shown in [Figure 2](#).

Millstein and Snyder (2003) coined the term partial articular surface tendon avulsion and Conway (2001) introduced partial thickness articular surface intra-tendinous tears. Partial thickness articular surface intra-tendinous tears are more common in overhead athletes where the footprint (attachment) of the rotator cuff on the greater tuberosity is intact and is present in the posterior aspect of the supraspinatus extending into the infraspinatus tendon.

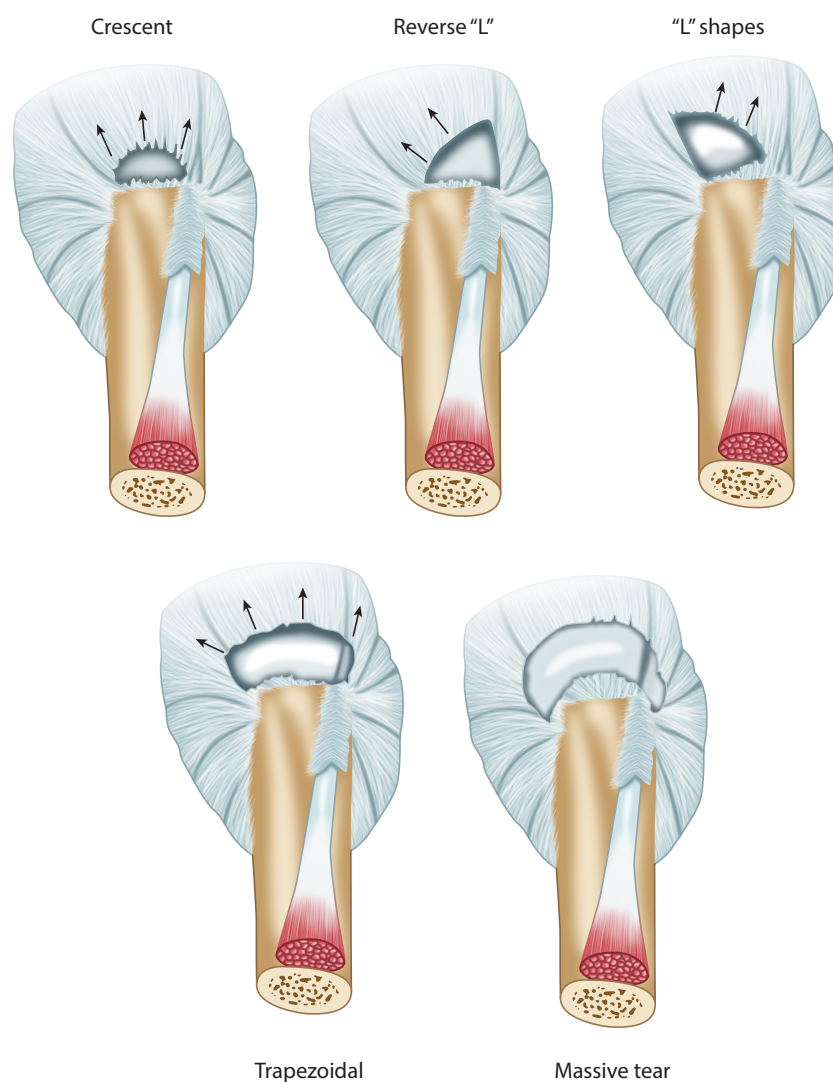
## Epidemiology

Bigliani (1986) conducted a cadaveric study and found 40% prevalence of full-thickness tears in patients over the age of 60 years, with an even higher incidence of partial tears. Several epidemiological studies have confirmed similar numbers.

The UK Chingford study is an epidemiological study of the general population in Chingford, UK (Hinsley et al, 2014). The researchers conducted large epidemiological studies of multiple conditions. A study was conducted on 464 patients between the age of 65 and 87 years. The study involved an interview, clinical examination, strength testing and ultrasound examination. The study found the rate for abnormal tears as follows: 60–69 years = 51.1%, 70–79 years = 61.8% and 80–89 years = 72.5% with an overall rate of 59.3%. The prevalence of full-thickness tears was: 60–69 years = 14.4%, 70–79 years = 26.35% and 80–89 years = 29%, with an overall rate of 22%. They also found that the larger the tear, the more likely the patient was to be symptomatic. In fact, it was only in patients with tears over 2.5 cm that the number in the symptomatic group was greater than the number in the asymptomatic group. Studies in the USA have found similar rates (Raynor and Kuhn, 2016).

## Pathogenesis

The tendon is an organised type I collagen structure that helps to transmit forces from muscle to bone and also acts as energy storage, similar to a spring. After injury in adults, the tendon heals in three stages: inflammation, proliferation and maturation. The tendon normally heals by regeneration; this forms scar tissue in adults, resulting in a weaker construct. The



**Figure 2.** Types of tears.

enthesis is the problem area of the tendon, which is exposed to high mechanical stresses and prone to injury. The exact cause of rotator cuff tears is an evolving subject.

Neer (1972) proposed the acromial irritation or impingement theory, and advocated acromioplasty. Several articles have challenged this theory. Henkus et al (2009) undertook a randomised controlled trial of 57 patients comparing acromioplasty to bursectomy, and found equivocal outcomes. Cheng et al's (2018) meta-analysis of six randomised controlled trials reached the same conclusion. Another issue is that the majority of rotator cuff tears are articular sided rather than bursal sided, because the articular side has half the strength of the bursal side.

Generally, rotator cuff tears occur in a weakened tendon that has been exposed to chronic inflammation. There have been numerous theories proposed for the cause of tendon pathology. The pathology of rotator cuff tears could be the result of a continuum of factors, rather than any one issue. These can be broadly divided into intrinsic and extrinsic factors.

Intrinsic factors include vascularity, mechanical and inflammation (Seitz et al, 2011). The tendon, in particular the tendon–bone interface, has poor blood supply, which may explain the inferior healing. The mechanical theory states that load beyond normal tendon capacity can lead to micro-tears, leading to degeneration of tendon matrix and fibres. This eventually leads to structural failure. The inflammation theory was originally discounted (Khan et al, 1999), but following advances in immunohistochemistry, new evidence confirms its role in the damage and failure of tendons (Rees et al, 2014). Genetics have a strong role, but the actual genes responsible are still under investigation.

Extrinsic factors for rotator cuff tears include local factors such as a subacromial spur, type 2 and 3 acromion, osteoarthritis spurs of the acromioclavicular joint and a thickened coracoacromial ligament (Seitz et al, 2011). Generalised extrinsic factors include high cholesterol levels, steroid use, smoking, diabetes, overhead activities such as throwing or painting, occupation and recreational activities. The pathogenesis is usually a combination of a number of these factors.

## Pain

Pain in patients with rotator cuff tears may be caused by a number of factors, with the pathway being unclear. Several theories of the cause of pain have been proposed, including central sensitisation, local neurochemical changes and inflammation.

Central sensitisation refers to the adaptive changes in the CNS that are present in people with shoulder pain (Sanchis et al, 2015). This is the theory that hyperexcitability of the central neurons leads to activation of pain receptors in the shoulder. Patients with this tend to have a poorer surgical outcome. The solution for the management of this condition is still under investigation.

Persistent shoulder pain may lead to a change in levels of local neurochemical and inflammatory factors in patients with rotator cuff disease. It has been shown that, when there is persistent pain, patients have more monocytes and macrophages within the shoulder joint than those patients that become pain free. Glutamate is also found more abundantly in patients with shoulder pain. The correct polarisation of macrophages determines the amount of scarring in tendon tissue. In patients who are pain free, a larger amount of pro-resolving proteins is expressed. The stromal population phenotype changes when it is injured and as a result becomes more susceptible to pro-inflammatory cytokines. There are different forms of inflammation: one form resolves and the other persists. Within these boundaries, there are forms of inflammation that do not cross the threshold for pain while remaining asymptomatic. Therefore treating the diseased tendon is not just about removing the inflammatory cells but also about reprogramming the resident cell population.

## Progress of tear size

Yamamoto et al (2010) found that partial and full thickness tears are common in patients over the age of 65 years. Many patients with rotator cuff tears are asymptomatic. Fifty per cent of patients with a rotator cuff tear on one side have a rotator cuff tear on the other, which is often asymptomatic. Tears tend to get larger over time, with 22% at 2 years and 50% at 5 years experiencing a >5 mm enlargement of a partial thickness rotator cuff tear (Hsu and Keener, 2015). The quality of muscle deteriorates over time (Hsu and Keener, 2015). Tear size is not an independent predictor of risk of future enlargement, although several studies suggest that the location of the tear is an important factor.

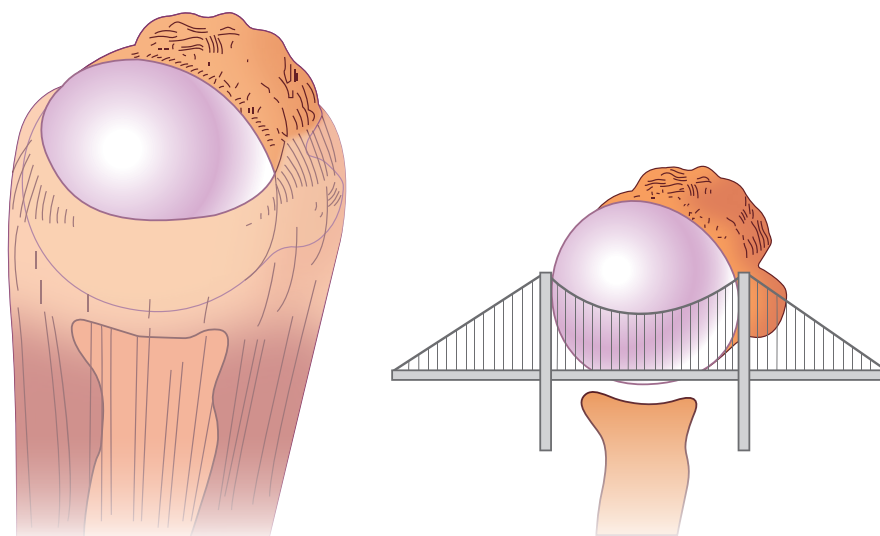
The rotator cuff acts a structural suspension bridge within the shoulder. Burkhart et al (1993) showed that there is a thickened section of the supraspinatus and infraspinatus, which they describe as the cables (**Figure 3**). In front of this area is a thinner, poorly vascularised section of the cuff, called the crescent. They explained how the cable can 'bypass' forces and stresses around the crescent and transfer load between the anterior and posterior aspect of the rotator cuff. Therefore, a tear of the crescent is unlikely to cause much loss of function. Connor et al (2003) showed that 40% of high-class overhead athletes have asymptomatic rotator cuff tears, as this area is largely confined to the crescent area. However, tears of the cable can cause a significant loss of function.

Muscle degeneration is more likely to occur in tears of greater than 15 mm. Recent tear enlargement doubles the risk of muscle degeneration. Disruption of the anterior cable attachment carries a triple risk. The muscle changes are normally seen after 1 year of tear enlargement.

## Features

### History

When taking a history, detailed information of the pain, loss of function and causative events is important. The common complaints in patients with rotator cuff injury are pain, weakness, instability and limited range of motion in the shoulder. There is often no single



**Figure 3.** Suspension bridge mechanism of rotator cuff.

causative event, rather it is a series of events resulting from occupation and recreation, in particular overhead activities. With athletes, it is important to obtain a detailed sports history, including training regimen, appropriate stretching, rest intervals and any change in sporting technique.

Pain in patients with a rotator cuff injury can localise to a general but non-specific area of the shoulder, suggesting a deeper source. Pain radiating from the neck should lead to suspicions of cervical pathology, which can be associated with neurological symptoms secondary to radiculopathy or nerve injury. Night pain is frequently associated with rotator cuff pathology, in contrast to radiculopathy, which typically presents with a diurnal variation. Most patients with rotator cuff tears have tolerated pain at some point, but a loss of function is often the most important presenting symptom.

Functional deficit should be elicited. The patient's occupation and hobbies can highlight risk factors and also lead to a conversation about expectations. Common functional complaints are weakness, swelling, reduced range of motion, instability, popping or catching of the shoulder. Any previous interventions tried by the patient should be elicited.

Raynor and Kuhn (2016) undertook a systematic review of features related to shoulder issues. They found that patients with a past medical history of hypercholesterolaemia, overhead activity, age over 60 years, or a history of cuff tear in the patient or the family are risk factors for cuff disease. Smokers usually present with larger and more degenerate tears. Diabetics often have the worst postoperative outcomes. The patient's attitude and expectations are the most important factors to guide prognosis.

### Examination

There are numerous methods of examining the rotator cuff and diagnosing a tear. Clear execution is important, but the examiner must be aware of underlying conditions that can lead to false positive tests. There is much controversy in this area. Hermans et al (2013) undertook a systematic review to determine the most accurate test and found that the painful arc is the most accurate in diagnosing rotator cuff disease. The drop arm test is more diagnostic of larger tears and is also helpful after rotator cuff repair to see if the patient has re-torn the tendon.

For impingement the two most common tests are the Hawkins test, which is 75% sensitive and 49% specific, and the Neer's test, which is 85% sensitive and 44% specific (Hermans et al, 2013). Hermans et al (2013) showed that the Jobe's test is 53% sensitive and 82% specific for rotator cuff disease.

There is a large range of tests for shoulder examination because the perfect highly accurate test is yet to be designed or realised. Rather than one test, the general consensus is that a number of positive examination findings should be used as a guide for further investigations.

## Investigations

The aim of investigation is to exclude other differential diagnoses. Radiographs are required to investigate arthritis and to review the subacromial space. Further soft tissue imaging options include ultrasound and magnetic resonance imaging.

The optimal imaging for the rotator cuff is controversial. De Jesus et al (2009) undertook a systematic review of 65 articles, and found no difference in sensitivity and specificity between magnetic resonance imaging and ultrasound in the diagnosis of rotator cuff tears. However, they found that magnetic resonance arthrography was superior to both magnetic resonance imaging and ultrasound in diagnosing full and partial thickness rotator cuff tears. Roy et al (2015), in their systematic review, found no difference between any of the modalities.

Ultrasound has the advantage of being dynamic, quick, cost effective, avoids claustrophobia and can guide simultaneous therapeutic injections. The disadvantage is that it is operator dependent and interpretation can be difficult. Moreover, ultrasound is not able to accurately define subtle degenerative soft tissue changes. Magnetic resonance imaging offers the advantage of high interobserver reliability (Okoroha et al, 2017) and all images can be reviewed by the treating physician. Therefore, although ultrasound is cost effective and convenient, it may be best used to identify a tear, whereas magnetic resonance imaging is superior for use for surgical planning in larger tears.

## Treatment

### Conservative

#### Non-steroidal anti-inflammatory drugs

Boudreault et al (2014) undertook a systematic review of 12 studies looking at the use of non-steroidal anti-inflammatory drugs to treat rotator cuff tendinopathy. They found that oral non-steroidal anti-inflammatory drugs can reduce short-term pain, but do not necessarily improve function. The study also found that pain relief was equivalent to that obtained from corticosteroid injections.

#### Physiotherapy

Kuhn et al (2013) conducted a multicentre prospective cohort study looking at the effectiveness of physiotherapy in patients with atraumatic rotator cuff tears. Four hundred and fifty-two subjects were enrolled on a programme guided by a therapist, and their Western Ontario Rotator Cuff index improved from an average of 47.5 to an average of 69.4 over 12 weeks (a score of 80 is within normal range). For non-traumatic supraspinatus tears, surgery has similar outcomes to physiotherapy. Moreover, there is no strong evidence supporting long-term benefits of arthroscopic acromioplasty compared to physiotherapy for the treatment of shoulder impingement. The success of physiotherapy in the treatment of non-traumatic rotator cuff tears is strongly linked to the patient's attitude and compliance, so patient education is crucial to maximise the benefits and achieve a successful outcome. Rehabilitation may involve avoidance of activities which require the patient to lift the arm above their head. An aggressive programme is prescribed with rotator cuff and scapular stabilisation and strengthening over a 3–6-month period.

### Steroids

Studies have compared glucocorticoid injection, rotator cuff repair and acromioplasty. It has been shown that the larger the tear, the more severe the disorganisation of cells. Karthikeyan et al (2010) conducted a randomised controlled trial for subacromial impingement and found a short-term benefit of corticosteroid over non-steroidal anti-inflammatory drug injection, which was confirmed by a meta-analysis (Burger et al, 2016).

### Surgery

#### Indications

Oh et al (2007) conducted a systematic review of indicators of surgery that affect outcome. They found that age and gender are not good indicators for good outcomes from surgery. Patients with acute tears may benefit from early surgery. Those with significant weakness

or functional disability may have better outcomes from surgery. Dunn et al (2014) found that operating just based on the symptom of pain by itself is not a strong indication for achieving good surgical outcomes, as the severity of the tear is unrelated to the level of pain experienced. The study also found that pain is more likely to be associated with comorbidities, lower education level and race. Wylie et al (2016) showed that mental health has a stronger association with patient-reported shoulder pain and function than tear size in patients with full thickness rotator cuff tears.

Patients with diabetes have poorer outcomes because of their hyperglycaemic state and it is critical that their haemoglobin A<sub>1c</sub> level is under control before considering surgery. Smokers often present with larger and more degenerate tears and outcomes are up to five times worse than in non-smokers. Park et al (2015) showed that older (over 65 years) patients also have worst outcomes.

Predictors of good outcomes are small tear size, younger patient and good preoperative status.

### **Surgical options**

For a low-grade partial articular side tear, the current recommendation is rotator cuff debridement and subacromial decompression. For bursal-sided tears >3 mm or 25% of depth, it is advised to release the remaining tendon and debride the degenerative tissue. The decision to repair partial articular surface tendon avulsion with >7 mm exposed bony footprint will depend on the age of both the tear and the patient. For younger patients and acute tears, in-situ repair is recommended. In older patients with degenerative tears, tendon release, debridement and repair is recommended.

Following surgery, 88% of patients are able to return to a sport and 70% were able to go back to their original sport. The length of time before they are able to return to sports is on average 6 months.

### **Platelet-rich plasma for surgical repair**

Platelet-rich plasma contains autologous blood-derived growth factors and has been used to enhance rotator cuff repair (Ahmad et al, 2012). Hurley et al (2019) conducted a meta-analysis of 18 randomised controlled trials and found that platelet-rich plasma improved healing rate, pain levels and functional outcomes. They also discovered that platelet-rich fibrin did not show any benefit compared to control. This area is still being heavily investigated; further studies are needed before this becomes established practice.

### **Tendon augmentation graft**

Bailey et al's (2019) meta-analysis of five studies showed that use of a tendon augmentation graft can result in lower re-tear rates and better shoulder scores. Ono et al (2016) reached similar conclusions following a meta-analysis of six studies, which found that the use of certain augmentation grafts is superior than repair without the graft.

### **Open vs arthroscopic rotator cuff repair**

The UKUFF (UK rotator cuff surgery trial) study is a randomised multicentre controlled trial comparing the effectiveness of open and arthroscopic rotator cuff repair (Carr et al, 2017). The study included 256 cuff repairs performed in over 19 centres. The study found no benefit of one approach over the other. Imaging at 12 months showed a failure of repair of 30% in small tears and 50% in large tears, with a 40% rate overall. A comparable rate of failure was shown between open and arthroscopic repair. They also found that patients with rotator cuff tears that were found during surgery or from imaging to be unrepairable can still have a reasonable range of function with appropriate conservative treatment options, such as physiotherapy.

### **Double row vs single row**

Two common methods of repairing the rotator cuff using suture anchors are available. One option is a single row, where a single set of suture anchors are present lateral to the attachment of the rotator cuff. The second is where two rows of suture anchors, one medial and one lateral to the footprint, are included. The decision of which method is superior to the other is an area of controversy, with differences of opinion in the literature. Mascarenhas et al's

(2014) systematic review found that double row was superior to single row. Ying et al (2014) found no significant difference in outcomes between two methods, a finding that was also confirmed by Spiegl et al's (2016) meta-analysis. However, competence in the technique and experience were more likely to lead to a better outcome than the number of rows.

### Subacromial decompression

The CSAW (Can Shoulder Arthroscopy Work?) study was a multicentre randomised trial undertaken conducted at 32 centres for 313 patients. Patients were randomised either to arthroscopic subacromial decompression, diagnostic arthroscopy or no surgery (Beard et al, 2018). The study showed no significant benefit to surgery, or to shoulder decompression over diagnostic arthroscopy. This brings into question the use of this approach although some flaws in the methodology have been identified. As such, further studies are needed to validate these results before drawing a definitive conclusion.

## Conclusions

The management of rotator cuff tears is an area of controversy because of the rapidly evolving field with new knowledge and techniques being continuously introduced. Compared to fields such as osteoarthritis, it is still in the early stages. Further high quality investigations and randomised controlled trials are required to reach definitive conclusions on how to best manage rotator cuff tears.

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### Conflicts of interest

The authors declare no conflicts of interest.

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### Key points

- Rotator cuff tears can be caused by recurrent microtrauma that can lead to degenerative tissue.
- Magnetic resonance imaging and ultrasound are equally useful investigations, but magnetic resonance imaging gives surgeons the added ability to plan surgical repair.
- Surgical repair is a viable option in older patients and cases should be referred to the upper limb surgeon for an opinion and consideration of repair.

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