In the United Kingdom, the prevalence of shoulder problems based on consultations in primary care is estimated to be 2.4%.

Between 30% and 70% of such shoulder pain is due to disorders of the rotator cuff. In their recent review Oh et al. stated that in 2002 in the United States there were 4.5 million physician visits and approximately 40,000 inpatient procedures for problems of the rotator cuff with a mean cost of $14,000 per case. This highlights how common such problems are and what a considerable health burden they present. It is therefore surprising that despite the endeavours of shoulder surgeons and research groups, uncertainty remains as to the best treatment for this common disorder.

There are still many unanswered questions, some of which are not so important and some very important. As yet we do not fully understand the pathogenesis and natural history of tears of the rotator cuff, and do not always know when to operate and when we do operate, which operation to perform.

In the world of evidence-based medicine and scrutiny of surgical outcome, reliable answers to these questions are now overdue. These answers have, however, been elusive for some time mainly because of a multi-factorial pathology. Published studies have usually been small, single-centre and retrospective. Despite our limited understanding of the pathogenesis and natural history of tears of the rotator cuff we have been forced to continue treating this disorder as best we can because of the large numbers of patients involved. The research surrounding some of the more important unanswered questions is discussed here.

What is the pathogenesis and natural history of tears of the rotator cuff?

Originally, mechanical compression and abrasion of the cuff tendons on the subacromial arch were thought to be the initiating factor in such tears. Morphological variations in the acromion were also considered to be important and Neer proposed a continuum from chronic bursitis, to partial tears, to complete tears and then to massive tears.

As might be expected, much of the approach to studying the pathogenesis of tears of the rotator cuff has involved basic-science. Vascular studies have shown a critical, avascular zone within the rotator cuff 1 cm proximal to its insertion, but it is unclear whether the presumed hypoperfusion within this area results in degeneration and ultimately failure of the tendon. Other vascular studies have produced contradictory findings. Goodmurphy et al. showed that the vascularity of the torn edge of a tear was less than that 2.5 mm to 5.0 mm back from the edge. Fukuda, Hamada and Yamanaka noted that in partial-thickness tears, the critical zone of the tendon had relative hyperfusion when compared with that of the more proximal tendon. Laser Doppler flow studies have shown blood flow throughout the rotator cuff and a hyperaemic response at the edge of a tear. Further support for this finding has been provided by the observation that tissue adjacent to the edge of the tear (≤2.5 mm from the edge) appeared to be viable histologically in terms of the microvasculature.

While there has been considerable vascular investigation, genetic research has been limited. In 2004 Harvie et al. identified a significantly increased risk of tears in the siblings of patients with symptomatic tears implying for the first time that genetic factors may play a major role in rotator-cuff pathology. This work was convincing in its methodology and findings, but has not been supported by further studies. Most other basic-science research has been directed at a cellular level with studies beginning to emphasise the importance of intrinsic factors. Some have examined the
process of tendon degeneration and Kannus and Józsa\(^4\) showed characteristic histopathological changes in tendons which ruptured spontaneously. They noted degenerative changes in 97% of cases examined including features of hypoxic degenerative tendinopathy, mucoid degeneration, tendinolipomatosis and calcifying tendinopathy, either individually or in combination. They concluded that these changes could be explained by hypoperfusion and proposed that they were the main contributor to failure of the tendon.

Nirschl\(^7\) described cellular changes in the rotator-cuff tendons, such as disorganisation and fragmentation of the architecture of the collagen and infiltration of fibroblasts and vascular tissue. Hashimoto et al\(^16\) observed different patterns of degenerative change in partial- and full-thickness tears, but were unable to correlate these with the size or extent of the tear. There have also been conflicting studies on the synthetic capability of the tendons.\(^5,18-20\) While some have concluded that the regenerative component of the tissue at the edge of the tear is active with increased cellular synthesis of type-I procollagen\(^6,18\) and type-III collagen,\(^19\) others have suggested that a ruptured supraspinatus tendon, compared with a control tendon, has a reduced ability to heal because of an increased degree of apoptosis and reduced production of type-I collagen.\(^20\)

None of these studies investigated the cell type and density relative to the size of the tear or the distance from the edge of the tear. This lack of knowledge about the capability of the torn tendons to heal has been reflected in the variations in surgical practice with some, but not all, authors recommending excision of the edge of the tear before repair.\(^21-23\) Matthews et al\(^24\) recently examined this uncertainty about the viability and potential of rotator-cuff tears to heal after surgical repair. They used histochemical and immunocytochemical techniques to describe patterns of cell and tissue changes associated with inflammation and repair in relation to the stage of the disease process, and compared their findings with those of healthy tissue. They found histological changes indicative of repair and inflammation which were most evident in small tears noting increased fibroblast cellularity and intimal hyperplasia, together with an increased expression of leucocyte and vascular markers. These reparative and inflammatory changes decreased as the size of the tear increased. Marked oedema and degeneration were seen in large and massive tears, which more often showed chondroid metaplasia and deposition of amyloid. Their findings suggest that small tears retain the greatest potential to heal and that tissue from large and massive tears is of such a degenerative nature that healing may be improbable and that this may be a significant cause of rupture after surgical repair.

In a further study, Matthews et al\(^25\) performed an in\textit{vivo} assessment of tissue metabolism and cellular activity of the edges of different tears and compared this with a control group of normal tendons. All of the torn tendons had lower levels of cellular activity than those of the control group. This activity was lower still in the tissue nearest the edge of the tear with larger tears showing the lowest activity. This work supported their earlier findings\(^24\) and further suggested that surgical repair of torn tendons should include the more proximal viable tissue. It also helped to explain further the higher rate of ruptures seen in larger tears.

While basic-science research is improving our understanding of the genetic, vascular and cellular influences on rotator-cuff pathology, the clinical evidence available regarding the natural history and management, remains limited and conflicting. There are no long-term longitudinal studies. MRI and ultrasound studies have shown that the prevalence of asymptomatic full-thickness tears is from 15% to 23% overall,\(^26-27\) 4% to 13% in patients under 59 years of age and 28% to 51% in those between 60 and 80 years of age. This has been supported by cadaver studies in the elderly which estimated the prevalence of full-thickness tears to be between 5% and 30%,\(^28,29\) What is clear is that there appears to be considerable variation in the functional deficit associated with tears with some patients having full movement and others having considerable limitation, even pseudoparalysis of the limb.

Yamaguchi et al\(^30\) examined the natural history of asymptomatic tears by following patients over a period of five years. They observed that 51% became symptomatic, but not all returned for ultrasound examination and it was therefore unclear if there was always progression of the tear. In 2006 Yamaguchi et al\(^31\) followed this up further and examined 588 patients with unilateral symptomatic shoulder pain. There was a high correlation between increasing age and the presence of a tear. Asymptomatic tears in the contralateral shoulder were common, but generally smaller than on the symptomatic side.

The pathogenesis of tears and the progression of asymptomatic tears to symptomatic tears remains unclear. It is likely to involve a number of factors such as a genetic predisposition, extrinsic impingement from structures surrounding the cuff and intrinsic degeneration from changes within the tendon itself. The order of importance or sequence of events remains unknown but useful information about the viability of the edges of a tear is now becoming available and may influence decisions about the timing of surgery, the way in which a tendon should be repaired and whether attempted repair in some cases is in fact a sensible option.

**When to operate?**

In orthopaedics the decision to operate is usually based on a combination of symptoms, signs, investigative findings, previous treatment, a knowledge of the pathology and evidence about the likely outcome after surgical intervention. Surgery of the rotator cuff should be no different, but there is often great variation in examination findings, tear sizes, co-morbidities, the type and duration of previous treatment and available evidence about outcome.
Although sizes of tear vary, imaging of the shoulder has greatly improved and these tears can now be accurately defined (Fig. 1)\textsuperscript{32-35} thus aiding the surgeon in his decision-making about surgery. MRI has been regarded as the procedure of choice for shoulder imaging and its accuracy in diagnosing tears of the rotator cuff has been studied extensively.\textsuperscript{32,36-39} MR arthrography has also been used,\textsuperscript{40} but is interventional and will have to prove that it has significant advantages over the new 3.0 Tesla MR scanners which are highly sensitive and specific for both full- and partial-thickness tears.\textsuperscript{41} The diagnostic accuracy of ultrasound has not been extensively evaluated, but many studies have shown its high accuracy in the diagnosis of full-thickness tears.\textsuperscript{33-35,42-44} Its great advantage is that it remains a focused examination providing a rapid diagnosis with a complete examination of the rotator cuff often being carried out in the time that it takes to do one MR sequence. Many shoulder surgeons therefore now perform their own ultrasound examination in the shoulder clinic;\textsuperscript{33,45,46} this is further described in a paper in this issue.\textsuperscript{47}

A potential advantage of MRI is its ability to assess the muscle belly of the rotator cuff for fatty infiltration. Some authors feel that such a finding which is often seen in chronic large and massive tears, suggests that attempted repair is not an option since functional recovery would be unlikely.\textsuperscript{48,49} Improved imaging techniques have also prompted another area of debate, that is whether to operate on partial-thickness tears. These are now being observed pre-operatively more commonly than hitherto. There is again a lack of evidence about how best to treat these findings in symptomatic patients. Most agree that there are usually a number of factors responsible for partial tears,\textsuperscript{50} but decision-making about their management is complicated.\textsuperscript{4}

Although imaging techniques are proving to be reliable, the other variables mentioned above and the limited evidence regarding the natural history and surgical outcome make the decision to operate not as straightforward as might be thought. This has been highlighted by Dunn et al\textsuperscript{5} and Oh et al\textsuperscript{4} and the indications for surgery on the rotator cuff have been extensively reviewed over the last 12 months. Dunn et al\textsuperscript{5} examined differences in opinion about the decision to proceed with repair of the rotator cuff and found significant variation in surgical decision-making and lack of clinical agreement between orthopaedic specialists in the American Academy of Orthopaedic Surgeons. They found a positive correlation between the performance of a high volume of procedures and the surgeon’s perception of outcome.

This has led to a recent systematic review on the indications for repair.\textsuperscript{4} It is extensive, but in summary highlights the fact that most of the ‘best papers’ were single-centre retrospective or non-comparative cohort studies. Although it should be expected that most surgeons would consider a move to surgery after a period of failed conservative treatment, the type and duration of such treatment vary. Furthermore, ‘higher-volume’ surgeons were generally less enthusiastic about conservative care.

Overall, the indications for repair are not straightforward. The conclusion of the review by Oh et al\textsuperscript{4} was that there was a need for further research to answer the question as to when to operate on the rotator cuff, but they also highlighted the difficulty in designing an appropriate randomised, controlled trial. Many would suggest that because of this difficulty, it would be more sensible to pursue a line of research to ‘understand the problem’ and then consequently to ‘understand when to operate’. In the author’s view, further research into the pathogenesis and natural history, especially with good longitudinal studies, is an easier route to follow to provide the answer to this particular question.
What type of operation should be performed?

Once a decision to proceed with surgery has been made, there are further choices about the type of surgery. Options include arthroscopic subacromial decompression with mini-open repair, arthroscopic subacromial decompression with arthroscopic repair, arthroscopic subacromial decompression alone, arthroscopic cuff repair alone and open subacromial decompression and open cuff repair. To many the biceps tendon is also an important consideration and some advocate routine biceps tenodesis with rotator-cuff repair or tenotomy if a massive tear proves irreparable. There is also much debate about the best treatment of partial-thickness tears with a number of proposed options including conservative treatment, arthroscopic surgical debridement coupled with arthroscopic subacromial decompression, arthroscopic conversion to a full-thickness tear with repair and arthroscopic repair without conversion to a full-thickness tear. The major debating point, however, is whether repair of full-thickness tears should be by a mini-open or an arthroscopic technique.

A variety of methods and suture anchors has been developed to re-attach the torn tendon to bone. Arthroscopic repair can use either a single- or double-row of suture anchors. Mini-open repair essentially means that an arthroscopic subacromial decompression is first performed which then allows for an open repair through a smaller approach without detachment of the deltoid from the anterior acromion. This has come to be regarded as the procedure of choice and the method to which arthroscopic repair is now compared. Proponents of arthroscopic surgery suggest that the procedure may have advantages over standard open procedures including less trauma to the shoulder muscles, less pain, decreased morbidity and an earlier return of normal movement.

Most studies have not been comparative or controlled. Burkhart, Danaceau and Pearce found that arthroscopic repair achieved good and excellent results in a large percentage of patients with the results being independent of the size of the tear. Gartsman, Khan and Hammerman obtained satisfactory results as assessed by a number of orthopaedic outcome measures and the short-form 36 health survey. Different outcome tools are often used in different studies which may help to explain why the clinical outcome is inconsistent between studies. Lee et al made the same conclusion in their study of their own retrospective series of arthroscopic repairs in which they found a reliable improvement in function and pain. A criticism of many papers which examine both techniques is the lack of post-operative independent imaging to assess the integrity of the repair. Galatz et al used ultrasound at 12 months in their study which confirmed a rate of re-rupture of almost 100% when large and massive tears were repaired arthroscopically. Despite this, however, many patients maintained that pain had improved. By contrast, Boileau et al used CT arthrography and MRI to assess 67 patients undergoing arthroscopic rotator cuff repair and found a ‘watertight repair’ in 71% of cases, but that patients over 65 years of age or those with associated delamination into other tendons had significantly lower rates of healing.

In arthroscopic repair the main question is whether to perform a single- or double-row repair on to the greater tuberosity. Recently, an in vitro study suggested that a double-row repair gives better resistance to formation of a gap. This appears to be supported in vivo with less re-tears when compared with the use of a single-row technique, although the clinical outcome did not appear to be affected. Sugaya et al reported a series of 106 arthroscopic double-row repairs. Of those which were followed up, there was an overall rate of re-rupture of 17% and of 40% in large and massive tears. Huijsmans et al also reported an overall rate of re-rupture of 17% and a higher percentage in large (22%) and massive tears (53%). There was better strength if the repair was intact at follow-up, but there were no differences in pain scores between patients with an intact repair and a ruptured repair.

Some studies have attempted to compare arthroscopic with mini-open surgery. Most are retrospective comparisons and none is both prospective and randomised. Some have only examined clinical outcome and some, clinical outcome and integrity of the cuff. All suggest similar clinical results for both types of repair, but Bishop et al identified a rate of re-rupture for larger tears repaired arthroscopically which was twice that for those with a mini-open repair.

While there have been some randomised, controlled trials, these are few and have only studied arthroscopic repair with or without subacromial decompression. They concluded that decompression did not appear to change the short-term outcome after arthroscopic repair. Another systematic review has recently been published comparing arthroscopic and mini-open repair. The conclusion was that they were both effective treatments, but of the large number of studies initially identified only 17 were deemed to be appropriate for final analysis. There were no randomised trials or prospective studies among these 17. This supports the findings of the author’s own review and further highlights the conclusions of this section which is the lack of reliable evidence about the best type of surgical intervention. Decision-making is therefore influenced by personal preferences, past experiences, surgical volumes and perceived results. The study by Dunn et al reinforces this conclusion further by showing the marked variation in the surgical management of tears between members of the American Academy of Orthopaedic Surgeons; 36.6% performed open surgery, 46.2% mini-open repair and 14.5% arthroscopic surgery. Surgeons who performed higher volumes of surgery, however, were more likely to undertake arthroscopic surgery and had a greater expectation of outcome. Considerable variation in surgical decision-making was found. This included the type of surgery (open or arthroscopic) and the surgical techniques (the use of anchors and type of suture).
The issue of post-operative integrity of the cuff and imaging requires further comment. Both ultrasound and MRI have shown a high sensitivity and specificity (85% to 95%) in the detection of full-thickness tears. An important aspect to our understanding of this difficult and variable clinical outcome.

A number of authors have reported high rates of re-rupture (20% to 54%), with some showing a significant correlation between re-rupture and poorer outcome and some less so. The assessment of the integrity of a repair is a critical component of the evaluation of the effectiveness of surgery, whether open or arthroscopic and most papers have no radiological follow-up. This allows sceptics to argue that it might be the arthroscopic subacromial decompression component of the procedure which improves the pain rather than the repair of the torn tendon itself. In regard to this, Massoud, Levy and Copeland found a satisfactory outcome in 74.6% of patients overall, but a lower satisfaction rate (59.3%) in those under 60 years age. Others have also reported documented re-ruptures after surgery without deterioration in clinical outcome.

Although most surgeons and shoulder units have evolved guidelines for treating tears of the rotator cuff, these are based on previous experiences and the best evidence available. The latter, however, does not stand up to scientific scrutiny. Answers to some of these questions are only going to be obtained from well-designed large multicentres, randomised studies. This will require careful planning and the enthusiasm and co-operation of shoulder surgeons and the specialist societies as well as health organisations, hospital administrators and managers. We need to meet this challenge if we are to facilitate further improvement in the care of patients with tears of the rotator cuff.

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References


