Rotator cuff tendinopathy: a model for the continuum of pathology and related management

Jeremy S Lewis

ABSTRACT
Background  Pathology of the soft tissues of the shoulder including the musculotendinous rotator cuff and subacromial bursa are extremely common and are a principal cause of pain and suffering. Competing theories have been proposed to explain the pathoanatomy of rotator cuff pathology at specific stages and presentations of the condition. This review proposes a model to describe the continuum of the rotator cuff pathology from asymptomatic tendon through full thickness rotator cuff tears.

Conclusions  The pathoanatomy of rotator cuff failure is multifactorial and results from a combination of intrinsic, extrinsic and environmental factors. Recently a new and generic model detailing the continuum of tendon pathology has been proposed. This model is relevant for the rotator cuff and provides a framework to stage the continuum of rotator cuff pathology. Furthermore, it provides a structure to identify the substantial deficiencies in our knowledge base and areas where research would improve our understanding of the pathological and repair process, together with assessment and management. The strength of this model adapted for the rotator cuff tendons and subacromial bursa will be tested in its ability to incorporate and adapt to emerging research.

INTRODUCTION
Certain sports place substantial demands on the shoulder. Elite swimmers execute approximately 2 million strokes per year,1 2 and professional baseball pitchers generate ball speeds of up to 165 km/h with associated peak internal-rotation velocities up to 6940°/s.3 4 These data elucidate why pathologies of the musculotendinous rotator cuff and subacromial bursa (SAB) are considered principal causes of shoulder pain. Various theories have been proposed to explain the pathogenesis of rotator cuff tendinopathy. These include tendon compression from extrinsic and intrinsic causes, tendon underuse and overuse,5-11 genetics,12 evolutionary adaptations13 and nutrition.14 15 To date, a definitive understanding of the pathoanatomy of rotator cuff tendinopathy has not been possible because of equivocal and insufficient research evidence. A review of anatomy, function and pathology of the rotator cuff has recently been published.16 Cook and Purdam17 recently presented a generic model to define the continuum of tendon pathology. This new paradigm involves staging pathology chronologically within a clinical, histological and imaging framework. The continuum involves a transition from normal tendon to currently irreversible tendon pathology. Variations of the generic model may be required because of regional anatomical and/or biomechanical considerations. The purpose of this review is to discuss the relevance of this new generic model with regard to rotator cuff tendinopathy and to propose management options for each of the stages described by Cook and Purdam.17

ROTATOR CUFF TENDINOPATHY: A NEW MODEL
The rotator cuff tendinopathy model (detailed in fig 1) is based on the generic model presented by Cook and Purdam17 and involves placing normal rotator cuff tendon as the optimal functional unit. This is defined as a structurally sound tendon that is pain-free and capable of performing the normal functional tasks required by the individual. Within this model, the tendon unit has the capacity to positively adapt to appropriate and graduated stress.

Underloaded tendon occurs when the rotator cuff does not receive appropriate physiological stress. Although this may occur throughout the tendon, its presence will be disproportionate and may affect the region of the rotator crescent and the articular side of the supraspinatus tendon.18 19 With an appropriate stimulus, an underloaded tendon may return to become a normal tendon. Tendon underuse may result in an imbalance of matrix metalloproteinases (MMPs) and their inhibitors (tissue inhibitors of MMP (TIMPs)), which may eventuate in tendon degradation. Imaging (ultrasound (US) and MRI) investigations may reveal age- and activity-related structural pathology, which in this stage of the continuum may remain asymptomatic. The normal rotator cuff tendon and the underloaded tendon, if subject to an activity level in excess of that normally placed on the tendon, may subject the tissue to overload. If the overload is transient, which may be identified on MRI as an increase in tendon volume due to increased bound water content, the tendon may return to its preloaded state. This state termed normal tendon overload is pain-free and is a normal response to loading rotator cuff tissue through activity and exercise.

However, the increased volume under the coracocromial arch may potentially increase the strain in the coracocromial ligament. Because of its trapezoidal shape and the relatively smaller surface area on the acromial side, strain within the ligament may potentially lead to the development of acromial traction spurs. The development of these osteophytes may depend on load and the anatomy of the region.20 Continuous loading in this state may have an either positive or negative effect on the tendon. This will depend on...
Rotator cuff tendinopathy: a model for the continuum of pathology

The intensity, volume and frequency of the load applied to the tendon. If applied in a graduated and controlled manner, the loading will lead to a tendon capable of withstanding greater stress.

If the applied load exceeds the physiological capacity of the rotator cuff, the effect may be tendon upregulation. The first stage may be reactive tendinopathy and is predominantly seen in an acutely overloaded tendon. This stage may involve the SAB tissue, where abnormal neuropeptide (substance P) and cytokine levels have been reported.21,22

Although there may be no substantial areas of tendon degeneration, there will be increased swelling within the tendon, and it possibly involves bursal effusion. Cook and Purdam17 have suggested that this stage occurs following a burst of unaccustomed activity and exists as a transition phase between normal tendon and tendon disrepair. This stage is probably driven by an increased activation of tenocytes, whose first response is driving a deposition of proteoglycans with larger molecular weight such as aggrecan.

Pain may be present, and this may be constant or intermittent and probably position and activity dependent. Constant pain and/or night pain may further implicate the SAB.23 In this stage, failure of the rotator cuff to control superior translation of the humeral head may lead to a secondary irritation of the superior fibres of the tendon against the coracoacromial ligament and the undersurface of the acromion.24 Because of the upregulation of the vascular endothelial growth factor in the early stages of rotator cuff tendon overuse,16 neovascularity may be present.

Cook and Purdam17 defined the next stage in the continuum as tendon disrepair. This will involve essentially the same spectrum of clinical symptoms as reactive tendinopathy. The symptoms may be more commonly associated with movement and activity. Tendon disrepair may be characterised by substantial areas of swelling, tendon degeneration, hypoechoic areas on greyscale US imaging that correspond with disorganisation of the matrix, increases in ground substance and some separation of the collagen fibres. It will also be observed as swelling and increased signal on MRI. A bursal reaction characterised by effusion and areas of neovascularity within the tendon and bursa may be present. The presence of neovascularity may be more evident if examined with the tendon off stretch, following an activity or after heating.

Cook and Purdam17 have classified the final stage as degenerated tendon, and for the rotator cuff, this will be associated with substantial structural failure in the form of large partial-thickness, full-thickness and massive rotator cuff tears.26 In the late stages, there may also be radiological evidence of glenohumeral and acromial degenerative changes.

STAGING TREATMENT WITHIN THIS MODEL

Patient education, pain reduction, tendon load management (unloading and reloading) and re-injury prevention form the basis of symptomatic rotator cuff tendon rehabilitation. In addition to this, consideration should be given to the possibility of SAB involvement associated with the presenting symptoms. To maintain optimal health and function, tendons require appropriate ongoing mechanical stimulation. Chronically underloaded tendon in a sedentary population may result in asymptomatic degeneration and tears, which will increase with age. This may occur as a result of alterations in the concentrations of the MMPs and TIMPs. It is not currently understood why elite-level athletes develop asymptomatic rotator cuff pathology.26 It may be due to overuse or fluctuating periods of activity and relative rest influencing MMP and TIMP concentrations. It may also be due to the relatively low innervation in tendons that do not produce a pain response in the presence of structural pathology until a specific threshold is reached. Treatment for an underloaded rotator cuff involves a tendon-reloading programme in a controlled and graduated manner. The management for a structurally and functionally normal rotator cuff involves maintenance of physical activity with appropriate controlled and graduated increase in tendon loading as required. To maximise the benefit of tendon-loading
<table>
<thead>
<tr>
<th>State</th>
<th>Underloaded tendon</th>
<th>Normal tendon</th>
<th>Underloaded/normal tendon overload</th>
<th>Reactive tendinopathy (acute phase)</th>
<th>Tendon disrepair (subacute to chronic phase)</th>
<th>Degenerated tendon (chronic phase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td>Essentially normal tendon Asymptomatic degeneration and tears may be present Increasing with age</td>
<td>Normal tendon Asymptomatic degeneration and tears may be present Increasing with age</td>
<td>Oedematous tendon Neovascularity possible Bursal involvement (evidenced by effusion) possible Hypoechoic areas may be present in grey scale (may or may not be cause of pain and symptoms)</td>
<td>Oedematous tendon Neovascularity possible Bursal involvement (evidenced by effusion) possible Degeneration to small PTT present (may or may not be cause of pain and symptoms)</td>
<td>Neovascularity possible – less likely with an increase in size of tear Bursal involvement (evidenced by effusion) possible Large PTT to FTI present involving the rotator cable (may or may not be a cause of pain if present) Fat infiltration may be evident in muscle in CT/MRI</td>
<td></td>
</tr>
<tr>
<td>Cause</td>
<td>Suboptimal mechanical stress (stress shielding) Increase in MMP1 and MMP13 Due to chronic suboptimal tenocyte stimulation</td>
<td>Appropriate mechanical stress Normal tensile and compressive properties</td>
<td>Tendon mechanically overloaded May be beneficial or may lead to reactive tendinopathy</td>
<td>Tendon mechanically overloaded by surpassing physiological capacity of (1) normal tendon or (2) chronically unloaded tendon No certainty where pain is coming from</td>
<td>Substantial tendon overload and incomplete healing No certainty where pain is coming from</td>
<td></td>
</tr>
<tr>
<td>Clinical</td>
<td>Pain-free and suboptimal shoulder function</td>
<td>Pain-free normal shoulder movement and function</td>
<td>Pain-free shoulder function may be normal or suboptimal</td>
<td>Pain increases with activity Persistent pain and night pain suggest bursal involvement</td>
<td>Pain increased with activity Persistent pain and night pain suggest bursal involvement</td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td>Reload tendon in controlled and graduated manner</td>
<td>Maintain physical activity Increase tendon loading in controlled and graduated manner</td>
<td>Relieve pain Relative rest(?) Tendinoplasty(?)</td>
<td>Pain increases with activity Persistent pain and night pain suggest bursal involvement</td>
<td>Pain increased with activity Persistent pain and night pain suggest bursal involvement</td>
<td></td>
</tr>
</tbody>
</table>

Continued
Table 1 Continued

<table>
<thead>
<tr>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>No high-load elastic or eccentric exercise(?)</td>
</tr>
<tr>
<td>No exercise that involves energy storage and release(?)</td>
</tr>
<tr>
<td>Concentrate on rhythmic arm movements(?) (short lever if required)</td>
</tr>
<tr>
<td>Nutritional supplements/dietary changes(?)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bursectomy + acromioplasty(?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair(?) – important to consider amount of muscular fat infiltration prior to repair</td>
</tr>
<tr>
<td>The future</td>
</tr>
<tr>
<td>Pharmacological modification of cytokines/MMP/TIMP/ADAMTS activity(?)</td>
</tr>
<tr>
<td>Stem cells(?)</td>
</tr>
<tr>
<td>Platelet-rich plasma injections(?)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutritional supplements/dietary changes(?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
</tr>
<tr>
<td>Lavage(?)</td>
</tr>
<tr>
<td>Bursectomy(?)</td>
</tr>
<tr>
<td>Bursectomy + acromioplasty(?)</td>
</tr>
<tr>
<td>Repair(?) – important to consider amount of muscular fat infiltration prior to repair</td>
</tr>
<tr>
<td>The future</td>
</tr>
<tr>
<td>Pharmacological modification of cytokines/MMP/TIMP/ADAMTS activity(?)</td>
</tr>
<tr>
<td>Stem cells(?)</td>
</tr>
<tr>
<td>Platelet-rich plasma injections(?)</td>
</tr>
<tr>
<td>Tendon grafts(?)</td>
</tr>
</tbody>
</table>

ADAMTS, a disintegrin and metalloproteinase with thrombospondin motifs; CS, corticosteroid; ESWT, extracorporeal short-wave therapy; FTT, full-thickness tear; GTN, glyceryl trinitrate; MMP, matrix metalloproteinase; PTT, partial-thickness tear; RC, rotator cuff; TIMPs, tissue inhibitors of MMP; US, ultrasound; US, therapeutic ultrasound; VAS pain, visual analogue scale for pain; ↓, decrease; ↑, increase; ?, uncertainty – research required.
attempt a surgical repair of the tear should be informed on an assessment of the (1) individual patient’s functional requirements, (2) size of the tear and (3) the amount of fat infiltration into the muscle because the presence of fatty streaks has been associated with negative surgical outcomes.\textsuperscript{43, 44}

Future advances in pharmacology, stem cell research and tendon grafts may lead to advances in the management of degenerated tendons and other aspects of the continuum of rotator cuff pathology. Table 1 summarises the continuum of rotator cuff pathology, with possible imaging findings, clinical presentations and management options.

**CONCLUSION**

Recently, a new and generic model detailing the continuum of tendon pathology has been proposed. This model is relevant for the rotator cuff and provides a framework to stage the disease. Furthermore, it provides a structure to identify the substantial deficiencies in our knowledge base and areas, where research would improve our understanding of the pathological and repair process, together with assessment and management. Cook and Purdam\textsuperscript{17} have suggested that the strength of their generic model will be tested in its ability to incorporate and adapt to emerging research. This also applies for the rotator cuff tendinopathy continuum model presented in this paper.

**Competing interests** None.

**Provenance and peer review** Not commissioned; externally peer reviewed.

---

**What is already known on this topic**

- Rotator cuff tendinopathy is common and associated with substantial morbidity. Conflicting theories pertaining to the pathogenesis of rotator cuff tendinopathy and bursal pathology exist.

---

**What this study adds**

- The review is presented attempting to describe a model for the continuum of rotator cuff tendinopathy. The continuum involves a transition from normal tendon to currently irreversible tendon pathology. The stages involve asymptomatic tendon, normal tendon overload, reactive tendinopathy, tendon disorder and degenerative tendinopathy. The model describes a corresponding aetiological, clinical, histological and imaging framework for the various stages, together with a framework for management.

---

**REFERENCES**


