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Rotator cuff repair: a review of surgical techniques, animal models, and new technologies under development

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Rotator cuff tears are the most common musculoskeletal injury occurring in the shoulder. Current surgical repair fails to heal in 20% to 95% of patients, depending on age, size of the tear, smoking, time of repair, tendon quality, muscle quality, healing response, and surgical treatments. These problems are worsened by the limited healing potential of injured tendons attributed to the presence of degenerative changes and relatively poor vascularity of the cuff tendons. Development of new techniques to treat rotator cuff tears requires testing in animal models to assess safety and efficacy before clinical testing. Hence, it is important to evaluate appropriate animal models for rotator cuff research with degeneration of tendons, muscular atrophy, and fatty infiltration similar to humans. This report reviews current clinical treatments and preclinical approaches for rotator cuff tear repair. The review will focus on current clinical surgical treatments, new repair strategies under clinical and preclinical development, and will also describe different animal models available for rotator cuff research. These findings and future directions for rotator cuff tear repair will be discussed.

Level of evidence: Narrative Review

Keywords: Rotator cuff repair; animal models; technologies under development; chitosan; biomaterials; regenerative medicine; tissue engineering; tissue repair

More than 28 million Americans are affected by musculoskeletal injuries, costing more than $254 billion each year.[70] Rotator cuff injury is the second most common musculoskeletal pathology after lower back pain[69] and the most common shoulder condition for which patients seek therapy.[23] In the United Kingdom, the prevalence of shoulder problems based on consultations in primary care is estimated to be 2.4%.[51] Between 30% and 70% of such shoulder pain is due to disorders of the rotator cuff.[62] More than 17 million Americans may be susceptible for shoulder impairment because of rotator cuff tendon deterioration and eventual tearing.[49]

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Cuff tears usually result in shoulder pain, stiffness, weakness, and loss of motion. The shoulder joint can still function with minimal pain despite a rotator cuff tear; however, limited function of the upper extremities often impairs the ability to perform basic activities. Rotator cuff disease may start as an acute tendinopathy, with progressive degeneration leading to a partial-thickness tear and eventually a complete tear.[63] Large tears result in disuse muscle atrophy with fatty accumulation within muscles, which may irreversibly decrease muscle function.[48] Failure to heal after rotator cuff repair occurs in 20% to 95% of patients and has been shown to correlate with tear size, time from injury, tendon quality, fatty atrophy, and surgical repair technique. Degenerative changes in the structure and composition of the tendons make healing very difficult.

The aim of this review is to describe the current clinical surgical treatments for rotator cuff tears, review the different animal models available for rotator cuff research, and summarize new repair approaches that are under development clinically and in preclinical studies. Although previous studies have reviewed accepted clinical treatments and preclinical models, to our knowledge, no existing review has combined both along with technologies under development.

Rotator cuff anatomy and pathology

The rotator cuff is a group of muscles consisting of the subscapularis, supraspinatus, infraspinatus, and the teres minor.[17] All of these muscles are attached to the head of the humerus via their specific tendons and control the rotation and position of the arm.[17] The rotator cuff muscles assist shoulder motion but primarily provide stability by centering and pressing the humeral head on the glenoid[17] through exertion of forces in the coronal and transverse planes.[66] The supraspinatus and the infraspinatus contribute to glenohumeral stability in the resting position, and the subscapularis stabilizes the glenohumeral joint in the position of apprehension.[17]

Rotator cuff tendons respond to excessive loading by inflammation or degeneration.[4] This is usually manifested by pain, formation of lipids, proteoglycans, and sometimes calcified tissues in the tendon lesions, which can lead to the release of various cytokines and to adverse changes in cellular activities.[50] Rotator cuff tendon pathology is also influenced by the microvascular supply of rotator cuff tendons.[66]

Degenerative rotator cuff tears were traditionally thought to begin at the anterior part of the supraspinatus tendon, adjacent to the biceps tendon. The anterior portion was believed to transmit most of the contractile load, and because more stress would be applied daily, this tendon would be at high risk for a tear.[61] However, recent studies suggest that degenerative tears occur about 15 mm posterior to the biceps within the crescent at the junction of supraspinatus and infraspinatus, hence, a more posterior location.[42] These tears then propagate in anterior and posterior directions.[39]

Chronic rotator cuff tears are associated with structural changes, such as loss of muscle volume, fatty accumulation, and retraction, all of which result in muscle remodeling, subtraction of sarcomeres, and profound muscle weakness.[83] Progression of a tear may also lead to superior subluxation of the humeral head and, eventually, dysfunction of the shoulder. Rotator cuff tear pathology is also influenced by the microvascular supply of rotator cuff tendons.[66] Rotator cuff tears can also result from an acute trauma, most frequently a fall onto an outstretched arm. The supraspinatus is, again, the most commonly involved tendon; however, there is a high association with subscapularis tears.[55]

Surgical treatments of rotator cuff tears

Nonoperative treatments can be used to manage most rotator cuff tears, especially in patients with lower demands. Rotator cuff tendons do not heal spontaneously, however, and surgical treatment is often required in patients who have persistent symptoms and functional impairment after conservative treatment. Operative treatment of traumatic and nontraumatic tears can be successful, with some authors reporting better results in younger patients with traumatic tears compared with degenerative tears.[7] Successful results were initially reported with open repair techniques using deltoid detachment and then, subsequently, through a "mini-open" deltoid split. Currently, fully arthroscopic procedures are generally considered to be the standard of care for most tears.

The superiority of arthroscopy vs open or mini-open repair is still unproven and controversial at this point (Supplementary Table S1). Overall, functional outcomes, clinical scores and retear rates are similar between arthroscopy vs mini-open repair patients. However, mini-open repair seems to be associated with more postoperative complications, and decreased short-term pain is seen with arthroscopic repair. Faster recovery, a quicker return to exercise, and better aesthetic results are other potential advantages of arthroscopic repair.

Transosseous tunnels were initially used to perform open rotator cuff repair. This technique uses sutures placed directly into bone tunnels extending from the rotator cuff footprint and exiting laterally on the tuberosity where they are tied. A limitation of this technique can be bone quality, and now, cuff repair is usually performed with suture anchors using different configurations: the single-row, the double-row, and the suture bridge repair, sometimes called the transosseous-equivalent repair technique.

The goal of using suture anchors is to restore the tendon footprint by suturing the tendon directly onto the tuberosity of the humerus. In controlled laboratory studies using cadaveric shoulders, the superior biomechanical performance of the transosseous-equivalent technique over the double-row technique and of the double-row technique over the single-row technique seems clear,[14,41,56,77] but this has not been translated into better clinical or functional outcomes (Sup-