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Anatomical and biomechanical framework for shoulder arthroplasty rehabilitation

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ABSTRACT

This article provides an anatomical and biomechanical framework for the postoperative management and progression of treatment for shoulder arthroplasty. The clinical relevance of normal shoulder anatomy, biomechanics, and pathomechanics related to this surgery is emphasized to provide the reader with an understanding of the rationale for treatment. We review the rehabilitation implications of surgical indications and technique for both traditional total shoulder arthroplasty and reverse total shoulder arthroplasty procedures with an emphasis on biomechanical considerations. Relevant factors that affect rehabilitation outcomes are discussed along with supporting evidence from the literature. Principles to guide and progress treatment are highlighted with a discussion on return to sports with the ultimate objective of providing a comprehensive approach for successful rehabilitation.

Introduction

The incidence of both conventional total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA) procedures has been steadily increasing over the last several years, resulting in increased referrals for postoperative rehabilitation.[1] Shoulder arthroplasty is the most common joint replacement after hip and knee reported worldwide.[2,3] In the United States, the number of shoulder arthroplasty surgeries has increased by approximately 3000 cases every year over the past 12 years compared with an increase of 400 per year before 2004.[4] Increased incidence has also led to changes in implant design and surgical techniques. The goal of arthroplasty surgery is to restore or alter shoulder biomechanics and joint kinematics in the diseased and injured shoulder in an effort to decrease pain and improve function.

The purpose of this article is to describe the relevant anatomical and biomechanical principles and related evidence and discuss the clinical implications for rehabilitation to provide the clinician with the underlying rationale for treatment approach and progression. Successful outcomes of arthroplasty surgery depend on several factors, which include the preoperative condition, the design of the prosthetic implant, surgical skill, and the postoperative rehabilitation.[5] Progression of treatment is based on a comprehensive understanding of the underlying biomechanics, physiological healing process, and the individual's pre-existing pathology and tolerance for exercise and activity.

Surprisingly, despite a large body of evidence on shoulder arthroplasty outcomes, there are little published data on the effect of specific rehabilitation programs and approaches. Clinical outcome studies focus on the surgical approach and implant design and not on the contribution of postoperative therapy. Most studies acknowledge rehabilitation but lack details regarding specific exercises and time frames. Published postoperative guidelines are generally based on the original protocol developed by Hughes and Neer[6] with a range of modifications. Readers are referred to specific treatment guidelines and exercises detailed in multiple publications.[6-12] These guidelines are descriptive in nature, are not prospective, do not address differences in treatment approaches or advantages and disadvantages of existing protocols, and do not address the influence of therapy on outcomes.[2,7] Although it is clear that prospective studies are required to establish evidence-based rehabilitation, the purpose of this article is to emphasize the key anatomical and biomechanical considerations for restoration of function.

Shoulder anatomy, biomechanics, and function

Normal functioning of the shoulder is dependent on the interplay of motion, stability, and strength.[13,14] The shoulder functions to position the arm in space for a wide range of daily activities, such as

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using the hand to manipulate or grasp objects, lifting, reaching out in all directions, reaching overhead, and reaching behind the body.[15] The bones, joints, ligaments, and muscles function in a coordinated synchronized fashion that allows for pain-free functional motion of the shoulder.[14] Relationships between the joints, length tension relationships of muscles and soft tissue, as well as the timing and firing patterns of muscles are critical for effective function.[15-18] It is therefore essential for the clinician to understand how injury and surgery alter the biomechanics and kinematics in order to apply effective rehabilitation techniques and treatment progressions after shoulder arthroplasty.

The primary muscles and dynamic stabilizers of the shoulder can be divided into 3 primary groups. The scapulohumeral group includes the deltoid and rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis).[15,19] The axioscapular group comprises muscles that act on the scapula and includes the rhomboids, trapezius, serratus anterior, and levator scapula. The axiohumeral group includes the muscles that originate on the thorax and insert on the humerus and includes the latissimus dorsi and pectoralis major muscles.[15,19] The deltoid muscle is the primary abductor of the arm with supraspinatus contribution for initiation of movement.[13] The rotator cuff muscles collectively act to compress the humeral head in the glenoid fossa providing stability to the joint. Multiple muscles are activated synchronously to move the clavicle, scapula, and humerus to generate smooth movement of the arm. Retraction of the scapula is accomplished by the joint action of the trapezius and rhomboids.[15] Upward rotation of the scapula is achieved by a force coupling of the upper trapezius, lower trapezius, and serratus anterior muscles.[15] Scapular elevation is achieved through a force coupled action of the upper trapezius, levator scapulae, and rhomboids.[15] These force couples work together to rotate the scapula upward and contribute to the elevation of the arm.[15,19] The term scapula-humeral rhythm[19] refers to the 2:1 ratio of glenohumeral to scapulothoracic motion (Fig. 1). Full 180° elevation of the humerus cannot be achieved without 60° of upward rotation by the scapula on the thoracic spine.[19] The role of the rotator cuff is to stabilize the humeral head and counteract antagonist moments from the 3 prime shoulder movers (deltoid, pectoralis major, and latissimus dorsi)[16] at multiple shoulder angles.[20] The supraspinatus compresses, abducts, and generates a small external rotation torque peaking between 30° and 60° of elevation.[16] In the absence of this check, the humeral head translates superiorly during humeral elevation resulting in impingement.[14,16] With rotator cuff pathology, altered kinematics and muscle activity are present,[21] and superior humeral head translation increases and subacromial space decreases.[22] In conditions such as osteoarthritis, cartilage degeneration and a collapsed head further alter the joint kinematics. The goal of conventional TSA is to restore stability, motion, strength, and smoothness; critical characteristics of a healthy shoulder joint.[23] This is accomplished by replacing the humeral head and glenoid with prosthetic implants that are designed to recreate the original anatomy. In the presence of intact rotator cuff and extrinsic shoulder muscles, a TSA is successful in restoring motion and improving function.

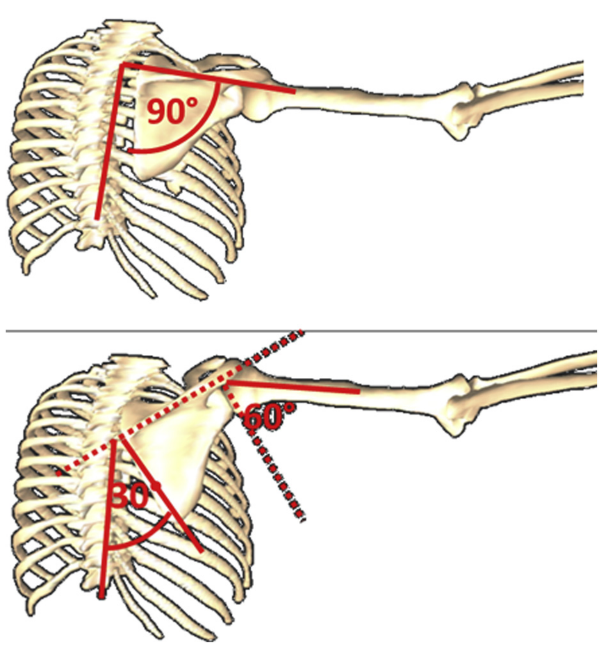

Fig. 1. Scapulohumeral rhythm. In a healthy shoulder joint, 90° of abduction of the humerus relative to the thorax (*top*) is achieved by 30° of scapular motion and 60° of glenohumeral motion.

Total shoulder arthroplasty

Indications

TSA is indicated for complex humeral head fractures, advanced osteoarthritis, or rheumatoid arthritis that results in persistent pain or impairment with loss of function despite all conservative measures. TSA is contraindicated in cases of rotator cuff insufficiency, deltoid paralysis, or infection. In addition, TSA may not be indicated in patients who are unable or unwilling to participate in the extensive rehabilitation required after the procedure.[24]

Surgical overview

A thorough understanding of the surgical procedure and implant design is required to ensure proper protection of healing structures. TSA (Fig. 2) is usually performed via a deltopectoral approach to expose the glenohumeral joint.[8,24] An alternate and less common technique is the anterior approach where the deltoid is split, allowing for better glenoid exposure. An interscalene regional block is performed in the beach chair position, range of motion is assessed, and a deltopectoral incision is made to retract and/or release the pectoralis major. The short head of the biceps, coracobrachialis, and pectoralis minor are retracted, and the coracoacromial ligament is released.[24] To access the glenohumeral joint, the subscapularis must be released from its insertion on the lesser tuberosity. Violation of the subscapular tendon has serious ramifications for postoperative treatment, demanding vigilant protection of the healing tendon. Once the shoulder joint is dislocated, the humeral head along with any diseased bone and osteophytes are removed, and the implant is selected to be fit. Recent advances to prosthetic design include modular components that allow for trial components to be fit for size. Sizing of the humeral head is important to balance stability with range of motion.[24] Intraoperative assessment of prosthetic size is determined by several factors, including lateral humeral head offset, rotator cuff tissue tension, intraoperative range of motion, and stability of the shoulder. After the correct size is determined, the implant components (a titanium alloy stem, humeral head, and polyethylene glenoid) are inserted, and the humeral head and glenoid morphology are restored for the best balance of stability and range of motion.[24] New systems are introducing a metal back glenoid that is fixed with screws to the glenoid. The polyethylene cup is then inserted to the metal back. Any significant changes in the size of the humeral head or length of the stem could alter the length of the rotator cuff, potentially leading to shoulder impingement, dysfunction, and ultimately failure of the procedure.[14] Surgical