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SYMPOSIUM: CURRENT CONCEPTS IN ROTATOR CUFF DISEASE AND TREATMENT

Indications for Reverse Total Shoulder Arthroplasty in Rotator Cuff Disease

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Abstract

Background Reverse total shoulder arthroplasty (RTSA) was introduced to treat rotator cuff tear arthropathy but is now used to treat a variety of problems. Although its use has expanded substantially since the FDA's approval in 2004, the appropriateness in patients with rotator cuff disease is unclear.

Questions/purposes We review the use of RTSA in patients with rotator cuff disease to (1) describe classification of rotator cuff tear reparability and the concept of a balanced shoulder; (2) explore the theory behind RTSA design relative to rotator cuff arthropathy; (3) discuss the indications and contraindications for RTSA; and (4) review published outcomes of RTSA for rotator cuff arthropathy.

Methods We performed a selective review of the literature on the use of RTSA in the treatment of rotator cuff disease.

Results Modern RTSA designs restore deltoid tension and a functional fulcrum to the rotator cuff deficient shoulder, which allows recovery of active shoulder elevation and effectively restores function in short- and medium-term followup studies.

Conclusions In short-term followup the RTSA relieves symptoms and restores function for patients with cuff tear arthropathy and irreparable rotator cuff tears with pseudoparalysis (preserved deltoid contraction but loss of active elevation). Severely impaired deltoid function, an isolated supraspinatus tear, and the presence of full active shoulder elevation with a massive rotator cuff tear and arthritis are contraindications to RTSA.

Clinical Relevance For properly selected patients who have symptomatic and disabling rotator cuff deficiency, RTSA can result in life-changing improvements in pain, motion, function, and patient satisfaction.

Level of Evidence Level V therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution either has waived or does not require approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
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Introduction

The first cases of glenohumeral arthritis occurring with tearing of the rotator cuff were described by Adams and Smith in the 1850s [18]. Neer et al. labeled this diagnosis "cuff tear arthropathy" nearly 130 years later and described definitive characteristics: a massive rotator cuff tear with superior migration and diminished acromiohumeral distance with erosion of the tuberosities ("femoralization") of

the proximal humerus and other arthritic changes in the glenohumeral joint [40].

Paul Grammont and colleagues modernized the reverse shoulder arthroplasty implant in 1987 to treat this condition [25]. The current iteration reverse total shoulder arthroplasty (RTSA) has been in use in Europe since the late 1980s [24, 25], and was approved by the FDA for use in the United States in 2004 [7]. The RTSA was originally designed to treat a massive irreparable rotator cuff with superior migration of the humeral head combined with glenohumeral arthritis (cuff tear arthropathy [CTA]) [5, 15, 18, 21, 40]. The indications have expanded however, and currently it is being used for multiple diagnoses including fracture sequelae [6, 31, 32, 34, 58], revision arthroplasty [6, 27, 33, 57], instability [57], and tumors [4, 13, 35, 57]. As a result of its success with these problems, its indications are gradually increasing, and many are unsure about its role in the treatment of rotator cuff disease.

Our review of the use of RTSA in patients with rotator cuff disease has several objectives: (1) to describe the ability to classify the reparability of a rotator cuff tear and to distinguish between a balanced and unbalanced shoulder based on the configuration of rotator cuff disease; (2) to review the theory behind RTSA design relative to rotator cuff disease; (3) to discuss the indications and selected contraindications for a RTSA; and (4) to review published clinical and functional outcomes of RTSA for the treatment of rotator cuff disease.

Background

The first description of a ruptured rotator cuff was credited to J.G. Smith, who in 1834 described the entity in the *London Medical Gazette* [51]. Codman is credited for the first cuff repair in 1909 [11]. Since that time, Neer modernized treatment of rotator cuff arthropathy and provided the indications for acromioplasty [39]. Arthroscopic shoulder surgery became popular in the 1980s and, like many new techniques, was initially looked upon somewhat skeptically [46]. Debates continued throughout the 1990s, comparing open versus arthroscopic rotator cuff repair [9, 28, 30, 48, 49, 59, 62]. The millennium ushered in a new brand of surgeons who, during their residencies, made the transition to arthroscopic shoulder surgery [10, 19, 38, 42]. Arthroscopic surgery reportedly provides similar functional scores, pain relief, clinical tests of motion and strength, and patient satisfaction to open rotator cuff repair [28, 30, 38, 42, 44, 49, 55, 59, 62]. Two recent reviews of the arthroscopic and mini-open rotator cuff repair literature reported that both techniques resulted in similar UCLA scores, mean ASES scores, patient satisfaction ratings, complications, active elevation, and active external rotation [38, 42].

Surgeons now have tools at their disposal that were not present 20 years ago. The introduction of magnetic resonance imaging has allowed surgeons to evaluate the rotator cuff to determine size, retraction, and fatty infiltration staging based on the data by Goutallier et al. [22]. It is currently much easier to determine if a rotator cuff tear will be irreparable or reparable based on MRI findings [23, 36, 41]. Large (> 5 cm) tears that involve two or more rotator cuff tendons with atrophy and a high degree of fatty infiltration (stage 3 or 4) are unlikely to benefit from attempts at surgical repair [23, 36, 41]. Thus, we consider reparable tears to be those that have stage 0, 1 or 2 fatty infiltration [22, 23]. Interval slides and release of adhesions either arthroscopically or open are often indicated in retracted tears with minimal or no fatty infiltration of the associated musculature.

The goal of all cuff surgery should be to repair the rotator cuff if possible and restore a balanced shoulder [43, 47], in which the rotator cuff tendons maintain the humeral head within the center of the glenoid during elevation of the extremity to allow motion while maintaining joint stability. On the other hand, if the anterosuperior cuff (supraspinatus, subscapularis) is compromised, dynamic and/or static anterosuperior subluxation may occur, resulting in an unbalanced shoulder [2, 29, 53]. Ultimately this may lead to a decreased coracohumeral distance and pseudoparalysis. Similarly, if the posterosuperior cuff is compromised, superior subluxation may occur. If a balanced shoulder cannot be restored through a standard rotator cuff repair, alternative treatment options should be considered. If the patient is young and active without pseudoparalysis, tendon transfers may be warranted to balance the shoulder [61]. If the muscle is of good quality (ie, minimal or no fatty infiltration) but insufficient tendon exists for repair, some consideration may be given to a human or porcine dermal allograft that may augment the repair and enhance healing [1, 8], although the benefits of allografts relative to other treatment options is uncertain at present [37, 52]. If painful arthritis and pseudoparalysis develops with an irreparable rotator cuff tear, RTSA may be the best treatment option [18, 21, 61].

A RTSA resurfaces the glenohumeral joint to treat arthritis, and also restores deltoid tension (Fig. 1). Normally when the deltoid contracts, the rotator cuff compresses the humeral head within the glenoid, creating a fulcrum on which the deltoid can lever to elevate the arm. When an irreparable rotator cuff tear is present, the musculotendinous unit retracts and loses its ability to compress the humeral head. When this scenario develops, as the deltoid muscle fibers contract, the humeral head translates superiorly. In doing so, the fulcrum is lost and the deltoid no longer has a lever to elevate the arm. By restoring deltoid tension and moving the center of rotation within the

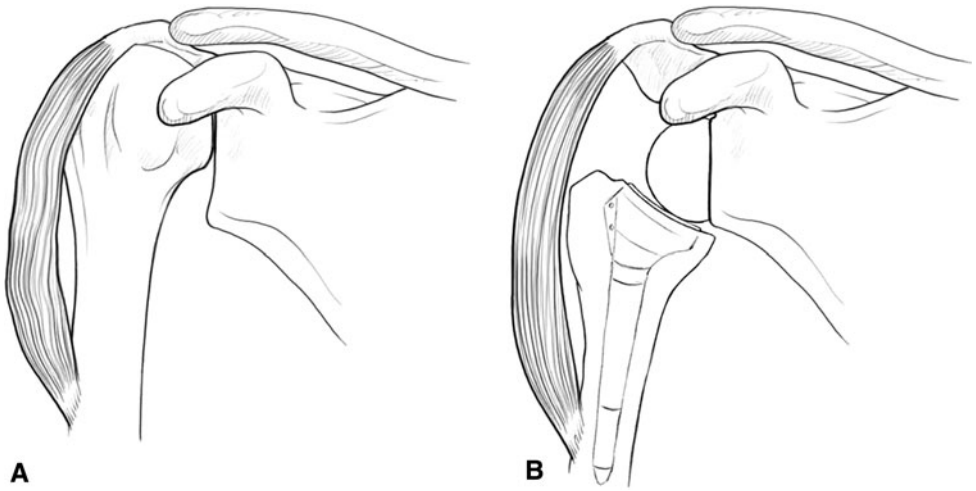

Fig. 1A–B (**A**) Superior migration of the humerus associated with rotator cuff failure results in loss of deltoid tension; contraction of the deltoid produces superior translation of the humeral head rather than humeral elevation. (This figure was published in Gartsman GM, Edwards TB. *Shoulder Arthroplasty*. Philadelphia, PA: ©Saunders; 2008:219–221.) (**B**) The reverse prosthesis restores deltoid tension and creates an appropriate fulcrum for the deltoid to produce humeral elevation. (This figure was published in Gartsman GM, Edwards TB. *Shoulder Arthroplasty*. Philadelphia, PA: ©Saunders; 2008:219–221.)

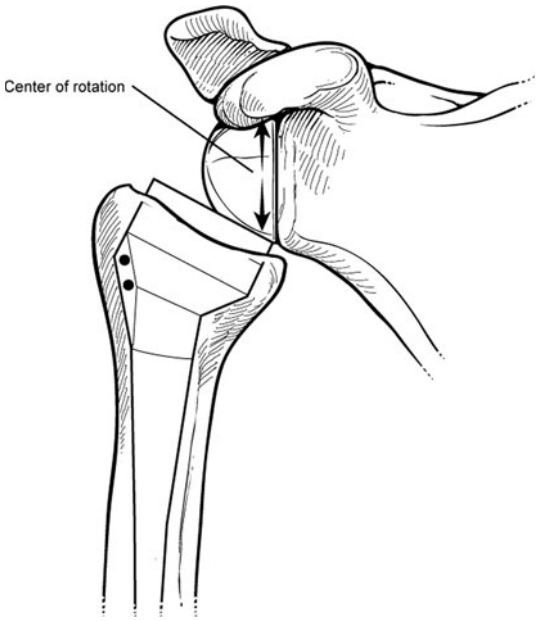

Fig. 2 The Grammont reverse prosthesis design maintains the center of rotation within the glenoid vault, which creates an appropriate fulcrum for the deltoid to produce humeral elevation while reducing the risk of glenoid loosening observed with earlier reverse prosthesis designs. (This figure was published in Gartsman GM, Edwards TB. *Shoulder Arthroplasty*. Philadelphia, PA: ©Saunders; 2008:219–221.)

glenoid, as described by Grammont and Baulot (Fig. 2), not only is the fulcrum recreated, but loosening of the glenoid component, which plagued the early designs of RTSA, is substantially reduced [24].

Rotator cuff tear arthropathy is the single most common indication for RTSA [57]. Clinical findings are variable and depend largely on the degree of arthritis and the specific rotator cuff tendons torn. Patients may complain of severe shoulder pain, weakness of the shoulder or arm, and progressive disability, including the inability to raise their arm [15, 18, 40]. These symptoms are reported to worsen over several years' time, although there may also be recent trauma that precipitated or accelerated the symptoms [18, 40]. Patients may demonstrate glenohumeral or acromiohumeral crepitus with some degree of stiffness. Testing of the rotator cuff will demonstrate specific deficiencies of the posterosuperior rotator cuff, anterosuperior rotator cuff, or both. Additionally the long head of the biceps is often diseased or ruptured [3, 21, 40]. Plain radiography shows loss of the glenohumeral joint space with or without humeral head osteophytes. If the anterosuperior cuff is compromised often only static anterior subluxation will be apparent on the axillary radiograph (Fig. 3). If the posterosuperior cuff is involved, superior subluxation may occur (Fig. 4). Insufficiency fractures of the acromion may be caused by the repetitive wear; however this does not contraindicate the use of a RTSA.

Alternatively, patients may present with a massive rotator cuff tear with pseudoparalysis and no glenohumeral arthritis (Fig. 5) [41, 57, 60, 61]. These patients have full passive forward elevation but a loss of active elevation as a result of the inability of the rotator cuff to provide a fulcrum for the deltoid during elevation.

Indications for Reverse Total Shoulder Arthroplasty

The indications for RTSA have expanded over the last few years and include CTA [15, 18, 26, 50, 57, 61],

Fig. 3 Compromise of the anterosuperior rotator cuff results in static anterior subluxation (anterior escape) that is apparent on the axillary radiograph. (This figure was published in Gartsman GM, Edwards TB. *Shoulder Arthroplasty*. Philadelphia, PA: ©Saunders; 2008:219–221.)

Fig. 4 Compromise of the posterosuperior rotator cuff results in static superior subluxation that is apparent on the anteroposterior radiograph. (This figure was published in Gartsman GM, Edwards TB. *Shoulder Arthroplasty*. Philadelphia, PA: ©Saunders; 2008:219–221.)

inflammatory arthropathy with massive rotator cuff tear [26, 45], proximal humeral nonunion or malunion [6, 34, 57], acute fractures [34, 57, 58], fixed glenohumeral dislocation [57], posttraumatic arthritis [26, 57], tumor [4, 13, 35, 57], revision arthroplasty [6, 27, 33, 57], and chronic pseudoparalysis without arthritis [41, 57, 60, 61]. We will limit our discussion to problems dealing with the rotator cuff.

Fig. 5 This anteroposterior radiograph of a patient with a massive cuff tear without glenohumeral arthritis shows no evidence of superior migration or subluxation of the humeral head. (This figure was published in Gartsman GM, Edwards TB. *Shoulder Arthroplasty*. Philadelphia, PA: ©Saunders; 2008:219–221.)

Cuff Tear Arthropathy

This entity is characterized by rotator cuff dysfunction and end stage glenohumeral arthritis [15, 18, 40]. Physical exam will elicit pain and imaging studies confirm the presence of an irreparable rotator cuff tear and associated arthritis. For this diagnosis, resurfacing of the glenohumeral joint and restoration of deltoid tension can be accomplished with a reverse ball and socket design.

Chronic Pseudoparalysis with a Massive Rotator Cuff Tear and No Arthritis

Chronic pseudoparalysis with a massive rotator cuff tear develops secondary to loss of the fulcrum when the rotator cuff fails [41, 57, 60, 61]. As the deltoid muscle contracts, the humeral head dynamically translates superiorly, and the deltoid loses its lever to elevate the arm. Patients present without evidence of glenohumeral arthritis and are frustrated with the inability to use their upper extremity

Fig. 6 This patient is attempting to raise both arms, demonstrating pseudoparalysis of the right shoulder with associated anterosuperior escape.

(Fig. 6). The first line of treatment should be rehabilitation to strengthen the remaining shoulder musculature to discover if the patient can recruit enough accessory muscles to elevate their arm. The RTSA can restore active elevation through restoration of a fulcrum for deltoid function but we believe is indicated only after physical therapy has failed.

Selected Contraindications

Deltoid function is required to restore active elevation following RTSA. Absence or severe impairment of deltoid contraction is therefore a contraindication to RTSA [18, 21]. We believe implantation of a RTSA in the presence of CTA or massive rotator cuff tear when paralysis of the deltoid or substantial deltoid dysfunction is unlikely to result in an acceptable functional outcome.

A potential pitfall is to place a RTSA in a patient with glenohumeral arthritis and an isolated supraspinatus (SST) tear. An isolated SST tear with associated arthritis will not produce an unbalanced shoulder. If the shoulder is balanced, we believe an unconstrained total shoulder arthroplasty is appropriate. In a study of over 500 cases with an average followup of 43 months, patients with glenohumeral arthritis and an isolated SST tear who were treated with an unconstrained total shoulder arthroplasty were reported to have functional (Constant) scores, active range of motion, patient satisfaction, radiographic outcomes, and complication rates that were equivalent to patients without a rotator cuff tear who were treated with an unconstrained total shoulder arthroplasty [16].

Another potential error is to place an RTSA in a patient with a painful massive irreparable rotator cuff tear without arthritis and full or nearly full active elevation. If a patient has nearly normal active elevation and an associated tear, he or she likely has a balanced shoulder. We believe nonoperative modalities such as nonsteroidal anti-inflammatories and corticosteroid injections are appropriate. If these fail, imaging studies should be used to confirm the presence or absence of the biceps tendon. If the long head of the biceps tendon is intact, an arthroscopic joint débridement and biceps tenotomy can result in improved functional (Constant) scores and good patient satisfaction, although tenotomy does not appear to affect the development and progression of glenohumeral arthritis [56]. In the rare scenario that a patient with an irreparable rotator cuff tear has disabling pain in the absence of a biceps tendon, an arthroscopic débridement may be performed, although we have observed highly variable functional and clinical outcomes in this situation.

Results of RTSA in Rotator Cuff Disease

We previously published a large series reporting the outcomes of reverse total shoulder arthroplasty [57]. Reverse total shoulder arthroplasty was performed in 186 patients with an average age of 71.8 years by two surgeons. This included 59 cases of cuff tear arthropathy and 34 cases of massive rotator cuff tear with pseudoparalysis and no arthritis. Data were collected prospectively and patients were followed up at an average of 39.9 months (range, 24–118 months). The patients with cuff tear arthropathy and massive rotator cuff without arthritis had substantial improvements in Constant scores, active elevation and external rotation (Table 1). There were 38 complications in 36 patients, including dislocation, infection, fractures of the glenoid or humerus, and hardware failure. Risk of complication was nearly three times higher in revision arthroplasty cases. The magnitude of improvements in functional scores and active elevation and the complication rate were similar to those reported in other series of RTSA for rotator cuff arthropathy [6, 12, 20, 54, 60]. These data demonstrate that with proper use in rotator cuff deficient shoulders, patients can obtain excellent clinical function following implantation of a RTSA.

Table 1. Preoperative and postoperative scores in patients with cuff tear arthropathy and massive rotator cuff tear without arthritis

Variable	Cuff tear arthropathy		Massive rotator cuff tear	
	Preoperative	Postoperative	Preoperative	Postoperative
Constant score	22	65	28	63
Active elevation	76	142	94	143
External rotation	5	7	14	8

Discussion

Grammont's RTSA was originally designed to treat a massive rotator cuff combined with superior migration of the humeral head and glenohumeral arthritis, a condition termed cuff tear arthropathy by Neer [5, 15, 18, 21, 40]. The indications for RTSA have expanded considerably since its introduction, but its most common use remains conditions involving severe rotator cuff disease [57]. In this paper, we described the concept of a balanced and unbalanced shoulder in relation to rotator cuff disease, reviewed RTSA design, discussed the indications and selected contraindications for a RTSA, and reviewed published outcomes of RTSA for the treatment of rotator cuff disease.

The available medical literature provides strong evidence of the effectiveness of RTSA for CTA and massive, irreparable rotator cuff tears. The effectiveness of RTSA for other shoulder conditions, however, are less clear in part because there are fewer published reports, usually involving smaller sample sizes and shorter followup than presented in the rotator cuff arthropathy reports. In addition, reported complication rates vary widely, in some series up to nearly half of cases. This variability may be related to modifiable factors, such as surgical approach and technique [18], and is a topic worthy of further investigation. Given the relatively new widespread use of the RTSA, there are no long-term followup studies of patients with rotator cuff disease. Therefore, we cannot speculate on its long-term effectiveness.

With massive (> 5 cm) rotator cuff tears, maintaining the humeral head in the center of the glenoid becomes difficult and may result in an unbalanced shoulder [2, 29, 53]. This lack of balance puts the deltoid at a mechanical disadvantage, impairing the ability to raise the arm (pseudoparalysis). While rotator cuff repair techniques have advanced considerably in the last 10 years [10, 19], irreparable tears, characterized by involvement of at least two tendons and fatty infiltration of the rotator cuff muscles, cannot be treated successfully using standard rotator cuff repair procedures [23, 36, 41]. An irreparable tear may allow migration of the humeral head and produce severe glenohumeral arthritis, which is the clinical entity known as CTA [5, 15, 18, 21, 40].

The modern RTSA was designed to restore balance to a shoulder with a massive, irreparable rotator cuff tear and CTA [24, 25]. Balance is reestablished by component design that restores deltoid tension and locates the center of rotation within the glenoid. The RTSA thus recreates the fulcrum required to allow active elevation by the deltoid [24].

With advancements in technology and indications expanding, proper patient selection for the reverse prosthesis can be difficult. The RTSA is not indicated for all types of rotator cuff disease; however, it does demonstrate good function when treating CTA and massive rotator cuff tear with chronic pseudoparalysis and no glenohumeral arthritis [6, 12, 15, 20, 57]. Severe deltoid impairment is a contraindication to RTSA [18, 21]. An isolated SST tear does not require treatment with a reverse prosthesis [16]. Caution is advised when treating anyone who has good active range of motion with a reverse prosthesis. Hemiarthroplasty with an extended humeral head ("CTA head") has been described for patients with large rotator cuff tears and arthritis who have good active shoulder motion, but improvements in active motion and functional scores may be somewhat limited [18, 61]. We prefer nonoperative treatment including therapeutic exercise and joint injections, followed by arthroscopic joint débridement with or without biceps tenotomy or tenodesis if necessary to obtain symptomatic relief [56]. When no arthritis is present, an alternative etiology for pain should be sought.

The RTSA effectively relieves symptoms and restores function for patients with CTA and irreparable rotator cuff tears [6, 12, 15, 20, 57]. Although the RTSA has improved treatment options for various problems associated with the rotator cuff, its use is not without problems. Complication rates have been reported from 10% to 47% [12, 14, 20, 26, 32, 54, 57, 60] and the dislocation rate is reportedly 0% to 9% [12, 26, 32, 50, 54, 57]. The dislocation rate is nearly doubled in patients without a subscapularis tendon [17]. Scapular notching can be frequent with RTSA, although in most instances it does not appear to cause any clinical problems [6, 7] and at least one series has reported no incidence of notching at two years after surgery [12]. For these reasons surgeons should remain cognizant of limitations and potential problems of the RTSA prior to recommending its use.

Although RTSA has revolutionized treatment of the rotator cuff deficient shoulder, its use must be tempered toward the appropriate patient. Complication rates are high and potentially devastating for the patient. Even seemingly trivial complications such as a dislocation can ultimately lead to a resection arthroplasty. With proper patient selection however, the function can be excellent and life changing for the patient.

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