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REVERSE SHOULDER ARTHROPLASTY (E CRAIG AND C CHAMBERS, SECTION EDITORS)

Advances and Update on Reverse Total Shoulder Arthroplasty

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Abstract

Purpose of Review Reverse total shoulder arthroplasty (RTSA) is a procedure that has been increasingly utilized since its inception over 20 years ago. The purpose of this review is to present the most up to date practice and advances to the RTSA literature from the last 5 years.

Recent Findings Recent literature on RTSA has focused on identifying complications, maximizing outcomes, and determining its cost-effectiveness. RTSA has become a valuable tool in the treatment of various shoulder pathologies from fractures to massive-irreparable rotator cuff tears. Maximizing outcomes, proper patient counseling, and limiting complications are vital to a successful procedure.

Summary RTSA can be a difficult procedure; however, when utilized appropriately, it can be an invaluable tool in the orthopedic surgeon's armament. Recent evidence suggests, more and more, that RTSA not only provides value to the patient, but it is also cost-effective.

Keywords Reverse total shoulder arthroplasty · RTSA · Reverse shoulder · Reverse shoulder arthroplasty · Reverse shoulder prosthesis · Outcomes

Introduction

The original Grammont-style reverse total shoulder arthroplasty (RTSA) system was designed to address limitations of anatomic total shoulder arthroplasty (TSA) and hemiarthroplasty (HA) in the setting of rotator cuff arthropathy and pseudoparalysis [1]. Previous attempts to create a shoulder prosthesis that compensates for a non-functioning rotator cuff were nearly abandoned due to unacceptably high rates of glenoid implant failure [2]. In this design, four key elements were incorporated that remain fundamental in current RTSA models: (1) By eliminating the neck, the joint's center of rotation (COR) is in direct contact with the center of the glenosphere, providing a fixed COR and reducing the amount of torque placed on the glenoid component-bone interface; (2) the large-diameter glenosphere improves mobility and stability; (3) medializing the COR recruits more deltoid fibers for elevation and abduction; and (4) distalization of the COR improves the deltoid's moment arm by restoring its length, thereby decreasing the effort necessary for abduction [3–9]. These modifications allow the deltoid to initiate shoulder abduction in the absence of a functioning supraspinatus [8–10].

This article is part of the Topical Collection on *Reverse Shoulder Arthroplasty*

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The overall volume of RTSA has increased over the last two decades since its FDA approval in 2003 [11–13]. The indications for RTSA have expanded greatly to include massive irreparable rotator cuff tears in the absence of arthritis, failed TSA, proximal humerus fractures (PHFs), tumors of the proximal humerus, irreparable rotator cuff tears, and fixed shoulder instability [14–18]. An aging population, improved implant design, and broader indications for RTSA have also been implicated in its increasing utilization [12, 13]. The present article will provide an evidence-based review of RTSA outcomes as a function of patient-specific factors, surgical indications, implant design, and variations in surgical technique focused on the most recent published findings from the last 5 years.

Preoperative Patient-Specific Factors

A variety of patient-specific factors, including both modifiable and non-modifiable factors, impact outcomes following RTSA, including age, sex, and body mass index (BMI). The majority of patients who undergo RTSA are females above the age of 60 [19]. In the current literature, comparisons of RTSA outcomes across age groups are not equivocal. Some authors have reported lower outcome scores but greater improvements in the range of motion in younger patients following RTSA compared to older patients, while others failed to prove a difference in patient-reported outcomes and complication rates between younger and older age groups [20–22]. As with all arthroplasty procedures, it is important to understand the long-term durability of RTSA for the risk-benefit stratification across different age groups. RTSA in patients under 60 years of age has been shown to result in substantial improvements in subjective and functional outcome measures that are maintained beyond 10 years [23]. The implications of BMI as a risk factor for RTSA are also subject to inconsistent reports in the current literature. Satisfactory rates of implant survival, complications, and pain relief have been demonstrated following RTSA in morbidly obese patients at intermediate follow-up [24]. Wiater et al. [25] found no difference in the rate of radiographic or clinical complications in normal weight, overweight, and obese patients. Conversely, increased BMI has been reported as a risk factor for deep infection and dislocation [26, 27]. In the senior authors' experience, morbidly obese patients with a large amount of trunk and upper arm adipose tissue have increased rates of instability and wound issues. Regarding sex-related differences, it has been shown that males experience superior outcomes and lower re-admission rates compared to females [20, 28].

RTSA for Massive Irreparable Rotator Cuff Tears

Rotator cuff tear arthropathy (CTA), characterized by rotator cuff dysfunction in the setting of end-stage arthritis, is the most common indication for RTSA [19, 29]. Depending on the degree of arthritic change and pattern of the rotator cuff tear, patients typically complain of shoulder pain, weakness, and progressive loss of function [30, 31]. Alternatively, patients may present with pseudoparalysis which is the loss of active arm elevation in the absence of glenohumeral arthritis due to a massive irreparable rotator cuff tear (MIRCT). Pseudoparalysis is the second most common indication for RTSA [19].

In patients with rotator cuff dysfunction, the function of each rotator cuff muscle should be assessed. While RTSA corrects pseudoparalysis of forward elevation (FE), it may not address loss of external rotation (ER) [32]. Prostheses with a more lateral COR or the bio-reverse may more reliably restore external rotation by recruiting more of the rear deltoid. Some authors have shown that active ER following RTSA is correlated with the radiologic integrity of the teres minor muscle [33]. In patients with ER deficits in the setting of RCA, concomitant latissimus dorsi transfer at the time of RTSA has been shown to improve active ER postoperatively, but it may lead to deficits in internal rotation (IR) and increase the risk of perioperative complications [34–37]. Because RTSA relies on deltoid function to restore active elevation, it is contraindicated in patients with absent or severely impaired deltoid contraction [15, 31].

A recent systematic review reporting the outcomes of RTSA for MIRCT and CTA included 7 studies with a total of 408 shoulders [38]. The authors described significant improvements for all reported clinical outcome scores and ROM assessments. The overall complication rate was 17.4%, and revision surgery was required in 7.3% of patients. Among the reported complications, heterotrophic ossification was the most common (6.6%), followed by glenoid radiolucency (2.9%), acromion fracture (2.7%), mechanical failure (2.4%), and failed baseplate (2.2%). Among cases requiring revision surgery, mechanical failure (33.3%) and failed baseplate (30%) were the most common indications. None of the studies included in this review were level I evidence, highlighting a need for high-quality investigations on the outcomes of RTSA for MIRCT and CTA. The authors concluded that RTSA improves shoulder pain, mobility, and function in patients with MIRCT and CTA after a mean follow-up period of 35.3 months.

In patients undergoing RTSA for rotator cuff dysfunction, approximately 31–35% will have undergone a prior rotator cuff repair (RCR) [9, 20]. Patients with a previous RCR have been shown to derive benefit from RTSA [39]. However, there is no consensus on whether a history of RCT is an independent risk factor for inferior RTSA outcomes [39–43].

Prior Surgery

A history of previous ipsilateral shoulder surgery is another important factor to consider in patients undergoing RTSA. RTSA is frequently utilized as a salvage procedure for failed prior shoulder arthroplasty [44]. While RTSA for revision shoulder arthroplasty provides satisfactory clinical and patient-reported outcomes, they are usually lower than those achieved with primary RTSA and complication rates may be higher following revision procedures [45–47]. Risk factors increasing complication rates after revision RTSA include the presence of a stemmed humeral component and conversion from hemiarthroplasty for the treatment of a proximal humeral fracture [46–48].

Prior non-arthroplasty surgery, in general, has also been shown to increase the risk of postoperative complications following RTSA [39]. However, when looking specifically at a patient's history of undergoing a previous RCR, the evidence has shown conflicting results in short-term follow-up studies. The number of RTSAs performed after a failed RCR has been steadily increasing, but it has yet to be established if a previous RCR to the ipsilateral shoulder leads to inferior outcomes [41, 43].

RTSA in the Setting of Trauma

RTSA has been gaining popularity in its use for the treatment of 3- and 4-part proximal humerus fractures. This has been especially true in elderly patients and patients with fracture types that have a significant risk of developing avascular necrosis of the humeral head. Some of these fractures had been previously treated with HA, but the results were heavily dependent on successful tuberosity healing. There has been a growing trend to perform RTSA over HA due to more predictable functional outcomes and pain relief. Recent systematic reviews have shown similar or better clinical outcomes when comparing RTSA to HA in elderly patients, with the HA groups showing a 2.8 times higher risk of having to undergo re-operation [49, 50•]. Cost analysis between the two has also favored RTSA over HA despite the higher initial implant costs, in part due to this increased risk of re-operation for HA [51]. RTSA has similarly been shown to be a valuable salvage option after failure of open reduction and internal fixation with acceptable results still being able to be achieved in the setting of previous surgery [52]. In either case, the senior authors have found that results are improved if the greater tuberosity can be preserved and re-attached to the humeral shaft in RTSA and HA alike.

Intraoperative Factors and Newer Implant Options

Since the inception of the RTSA, there has been much debate about what the optimum management of the subscapularis tendon is between no repair and repair once the RTSA has been implanted. Recent literature on the subject has shown variable and conflicting results in regard to repairing of the subscapularis [49, 50•, 53–55]. Reviews have been mixed on whether or not subscapularis repair decreases dislocation rates postoperatively with some favoring repair [53] and some showing no differences in final outcomes [54, 55].

Closed drainage systems have also been under scrutiny. Recently, there has been a trend away from using drain systems postoperatively as a benefit has not been shown in the reduction of hematomas or complications, even in patients with known risk factors [56]. Conversely, blood management using tranexamic acid (TXA) has been shown to be beneficial in RTSA. In a prospective double-blind randomized trial, TXA was shown to have significantly lower blood loss and less postoperative hemoglobin drop when compared to placebo [57].

New developments in implant designs have led to cementless implants and those with shorter humeral stems. While there is limited long-term data for their use, short- to mid-term data has shown promising results [58, 59].

Complications

Complications for RTSA have been a unique emphasis in the latest literature. Among all shoulder arthroplasty surgeries (HA, TSA, RTSA), RTSA was shown to have the highest re-admission rates of the three [60]. Eighty-two percent of re-admissions, however, were due to medical complications, and only 18% were due to surgical. The most common causes of surgical re-admission were infection and dislocation [60]. In a national database study comparing the complications of TSA to RTSA, RTSA was shown to have increased perioperative complications, but also increased rates of preoperative morbidity (i.e., history of pneumonia, deep vein thrombosis (DVT), cardiac issues, and urinary tract infections), likely due to the significantly increased age of the RTSA group [61]. Elderly patients undergoing all shoulder arthroplasty had statistically increased rates of 30-day complications, overall length of stay, and unplanned re-admissions [62]. Likewise, worker's compensation status preoperatively was independently associated with inferior outcomes and increased complication rates [63]. In long-term follow-up (10+ years), complication rates have been found to be 29%, with a significant majority (90%) occurring within the first 2 years [64•]. While in that same study, 42% to 73% of patients showed some form of scapular notching, very little is found to be clinically relevant [32, 64•].

Dislocation, in particular, has been a source of increased scrutiny in recent years. As stated above, the decision to repair the subscapularis or not has been heavily analyzed with mixed results and no definitive answer as to whether repair decreases dislocation events [53–55]. Dislocation events have generally been divided into early (less than 3 months) and late (greater than 3 months). Early dislocations are uncommon, but of those with early dislocations, the mean time to dislocation has been found to be 3 weeks to 4 weeks and the most common risk factors were BMI greater than 30, male gender, previous subscapularis deficiency, and previous shoulder surgery [65]. In contrast, asymmetric wear of the polyethylene has been implicated in 60% of late dislocations [66]. Even despite appropriate treatment, recurrent instability is an ongoing issue for 29% of early dislocators and 40% of late dislocators [66]. Current research is focused on version and rotation as a potential cause of instability, even in the obese patient. In a classic Grammont-style prosthesis with a medialized COR and a 155° humeral component, repair of the subscapularis may decrease rate of dislocation.

C. Acnes

Recent studies have shown infection rates for RTSA to be from 2.2 to 6.4% at mid-term follow-up [67, 68]. Of particular concern in the shoulder arthroplasty population is *Cutibacterium acnes* (*C. acnes*), formerly named *Propionibacterium acnes* (*P. acnes*). It is an aerotolerant, anaerobic, gram-positive bacterium that has been implicated in an increasing number of infections. There has been a recent and growing recognition of this bacterium as a source of chronic or indolent infections of the shoulder. *C. acnes* is not only difficult to diagnose but also to treat as it generally takes 10–21 days to culture [69–72]. It generally leads to a low-level, indolent infection without gross purulence, erythema, or drainage.

Standard surgical preps are also not effective at eliminating *C. acnes* preoperatively, and a significant amount of *C. acnes* burden persists despite standard skin preparation with up to 70% of skin cultures remaining *C. acnes* positive [69, 70]. After a shoulder procedure has begun, persistent *C. acnes* has even been shown to grow on the surgical instruments being used in the case leading to another source of possible infection [72]. *C. acnes* infection/colonization is significantly associated with males more so than females. Males have shown a significantly higher odds of being colonized by *C. acnes* preoperatively, as well as intraoperative cultures being found positive [71, 72].

Torrens et al. looked at *C. acnes* infection in primary RTSA specifically [73•]. They showed *C. acnes* to be isolated in 5.7% of all cultures taken with over 1000 cultures sampled in that series [73•]. Sixty-five percent of the cultures were positive for *C. acnes* after the time of implant placement. This highlights not only the difficulty in identifying *C. acnes* colonization/infection but also that *C. acnes* persists and has the potential to infect as a shoulder procedure progresses.

Prevention and treatment of *C. acnes* colonization/infections has also been of significant interest. Unfortunately, adjustment to preoperative antibiotics has not been shown to decrease *C. acnes* culture positivity. The addition of preoperative doxycycline was especially not proven to be effective in reducing postoperative joint infections of the shoulder [74]. However, because of *C. acnes* anaerobic properties, peroxide preps, both hydrogen peroxide and benzoyl peroxide, have been shown to be effective in the eradication of *C. acnes* [75]. This has led many to look at the addition of a peroxide prep to the standard preoperative regiment of shoulder arthroplasty patient. A benzoyl peroxide preparation of a patient's skin has been shown to yield significantly less positive *C. acnes* cultures when administered both consecutively for 3 days preoperatively and immediately preoperatively [76, 77]. Likewise, hydrogen peroxide use during skin preparation has also been shown to decrease *C. acnes* colonization and positive cultures [78]. Both benzoyl peroxide and hydrogen peroxide have been suggested to be a "low-cost" and "low-risk" addition to the preoperative regimen for shoulder arthroplasty and is routinely used in our surgical practices [76–78].

Return to Work and Return to Sport

Return to work following RTSA was reported from 63 to 65% with a mean time ranging from 1.4 to 4.0 months [79•, 80, 81]. Patients with sedentary work returned significantly faster (1.4 month vs 4.0 months) than those with light duty work [80]. Heavy, labor-intensive work status was rarely reported but was associated with a lower return-to-work status following RTSA [79•, 80]. Recent systematic reviews have shown no difference in return-to-work status between patients undergoing RTSA and those undergoing HA and TSA [79•, 81]. Worker's compensation status also did not affect return-to-work rates in that series [79•].

Postoperative activity level and sports participation are also important factors to consider when counseling patients for a RTSA. Return to at least one sport postoperatively has been reported from 60 to 85% in both case series and reviews [80, 82–84]. The average time to return to sport has been reported to be around 5 months [80]. Of those that returned to sport, 30–41% of patients reported they were performing at a higher level than preoperatively, while about 65% reported no change in their level of play [80, 83]. Patients report returning to either high-, moderate-, or low-intensity activity levels at 23%, 48%, and 28% of the time, respectively, with 71% of patients reporting they returned to at least moderate-intensity activity [85]. Of those not returning to sport, 59% were attributed to declining medical issues not related to the shoulder and only 29% were attributable to their RTSA surgery [85]. Most patients can reliably expect to return to at least one sport, and the majority return to moderate-intensity activities such as swimming, biking, jogging, and golf following RTSA [84].

Rate of Improvement and Long-Term Outcomes

When counseling patients preoperatively on the decision to undergo RTSA, it is important to be able to tell them their expected outcomes and activity levels following surgery. Most patients can expect their outcomes to dramatically increase within 6 months of their surgery [86]. Large case series and a recent review have shown that maximum improvement, or maximum medical improvement, is generally achieved within 1 year to 2 years [86, 87•]. Significant improvements in the range of motion and patient-reported outcomes were seen by the 1-year mark, but less so thereafter [87•]. Indicators of poor improvement (change in American Shoulder and Elbow Scores (ASES) below the minimum clinical difference) have been shown to be male sex, intact rotator cuff tear at the time of RTSA, the number of comorbidities, and a diagnosis of depression.

Driving performance has a significant decline 2 weeks postoperatively but can reliably return to pre-op performance around the 6-week mark. By 12 weeks, most patients actually demonstrated improved driving performance as compared to preoperative testing [88]. Older age, less driving experience, and higher pain scores at the time of testing were negative predictors of driving performance. If these factors are present in the postoperative period, it was recommended to return to driving closer to the 12-week mark rather than 6.

Long-term outcomes of 10 years or more show an overall survivorship of the original Grammont-style RTSA to be 93% with revision as the primary outcome [64•]. Mean absolute constant scores and relative constant scores were still significantly improved from preoperative levels but showed a decline from the mid-term follow-up in a series of the same patients reported previously [64•]. Likewise, patients undergoing RTSA specifically for rotator cuff dysfunction showed that improvements of constant scores and the subjective shoulder value remained elevated at the long-term follow-up with lasting results [29, 32]. Active elevation and abduction also continued to remain improved from preoperative levels; however, similar to short-term outcomes, there can be little improvement expected in external rotation [32].

Patient-Reported Outcome Measures

Patient-reported outcome measures (PROMs) have become increasingly important in the reporting of orthopedics in general; however, limited recent data is available in regard to RTSA specifically. One of the difficulties with PROMs is establishing what improvement is a significant benefit to the patient. Unfortunately, there has not been a significant correlation found between objective physician findings and subjective PROMs [88]. The most significant correlation between objective findings and subjective outcomes is forward elevation. Strength in forward flexion, abduction, and external rotation was positively correlated but weakly so [88]. Factors that have been shown to be predictive of better PROMs are ASA class I, shoulder complaints that are not work related, and no previous surgery to the shoulder in question [89].

Werner et al. [90] set out to determine the minimum clinically important difference (MCID) and substantial clinical benefit (SCB) levels that are needed following RTSA to obtain a successful outcome by comparing overall satisfaction and activity levels with ASES and Short-Form 12 (SF-12) scores. The MCID was established at the level where the patient was at least "somewhat satisfied" with their final results, and the SCB correlated to patients being "very satisfied" or better. In order to reach the MCID level, patients needed to show an improvement of at least 8.4 points on the ASES and 13.9 points on the SF-12 scales, respectively. In reaching a SCB level, patients needed to show improvement of 32.1 points on the ASES and 14.3 points on the SF-12 [88]. These levels can be used as goals or benchmarks for both patients and surgeons to assess how patients are performing postoperatively.

Cost Analysis and Effectiveness

Due to the high cost associated with RTSA implants, recent work has gone into analyzing the costs and value associated with the RTSA procedure. An analysis of short-term hospital costs (less than 90 days) of all shoulder arthroplasties performed at a single institution showed that younger patient age, use of bone graft, less common indications for surgery (i.e., not for osteoarthritis, rotator cuff arthropathy, or previous failed arthroplasty), and implant brand/choice were independent predictors of increased costs [90]. While this analysis did also include anatomic TSA and is thus not completely specific to RTSA, 66% of the 361 included patients underwent RTSA in that study.

RTSA has also been shown to be significantly cost-effective in quality-adjusted life years (QALY) metrics

[91–93, 94•, 95•]. However, in part due to high implant costs, it has not reached the same level of QALY as the *gold standard* of total hip replacement at this time [92]. Similarly, while both arthroscopic RCR and RTSA have shown to improve QALY, RCR was found to be the more cost-effective treatment in repairable large and massive tears leading the authors to recommend RCR when physiologically possible [95•].

Conclusion

RTSA has been shown to be an effective procedure with expanding indications. The most recent data supports its use for a variety of indications. With growing concerns on long-term results, cost-effectiveness, value-based care, and reduction of complications, maximizing outcomes has become a significant priority. Proper patient selection, preoperative counseling, and technique are imperative to successful outcomes.

Compliance with Ethical Standards

Conflict of Interest Dr. Stephen Thon declares that he has no conflict of interest.

Dr. Adam Seidl reports personal fees from DJO and from Medacta, outside the submitted work.

Dr. Jonathan Bravman reports other from DJO, Smith & Nephew, Shukla Medical, and null, outside the submitted work.

Dr. Eric McCarty declares that he has no conflict of interest.

Dr. Felix Savoie III declares that he has no conflict of interest.

Dr. Rachel Frank declares that she has no conflict of interest.

Human and Animal Rights and Informed Consent All reported studies/experiments with human or animal subjects performed by the authors have been previously published and complied with all applicable ethical standards (including the Helsinki Declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

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