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# The Rheumatoid Shoulder: Current Surgical Treatments

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Nuri Aydin, Lercan Aslan, Janne Lehtinen and  
Vedat Hamuryudan

Additional information is available at the end of the chapter

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## Abstract

**Background:** Rheumatoid arthritis (RA) is an inflammatory disease resulting in pain and decreased functional outcome. Even though most of large joints are widely discussed in literature, shoulder's surgical treatment options, indications and superiorities to each other were not compared entirely.

**Materials and methods:** Treatment options, such as synovectomy and bursectomy, resection interposition arthroplasty (RIAP), hemiarthroplasty, humeral resurfacing arthroplasty, anatomical total shoulder arthroplasty (TSA) and reverse shoulder arthroplasty (RSA) are examined and compared according to timing, advantages and disadvantages.

**Results:** Age is the primary criteria for decision making. Young-aged patients demand high functionality, also need for revision in the future must be planned. First step is preservation of bone stock as much as possible. For young patient, disabling pain can be candidate for synovectomy and bursectomy or RIAP and also for hemiarthroplasty. As age progresses, priorities change towards rotator cuff status and glenoid bone stock.

**Conclusions:** Age, functional demand, rotator cuff status, adequacy of glenoid bone stock and future planning for possible complications are defined as major criteria for optimal treatment. RA patients will require systemic evaluations with help of rheumatologists. Patient, rheumatologist and orthopaedist should discuss the possible surgical intervention together to achieve high quality of life.

**Keywords:** rheumatoid arthritis, rheumatoid shoulder, surgical techniques, arthroplasty, synovectomy

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## 1. Introduction

### 1.1. Epidemiology

Rheumatoid arthritis (RA) is an inflammatory process that may lead to disability as a result of joint destruction. The prevalence of RA is less than 1% in the general population and women are affected three times more as men but this sex difference weakens in the elderly. The onset of the disease is mostly during the fourth and fifth decades. Family studies have indicated a genetic predisposition with an increased frequency of the disease among the first-degree relatives and twins [1]. An association with human leukocyte antigen (HLA)-DR4 was shown in 70% of the Caucasian and Japanese patients compared to 28% of the controls [2, 3]. The discovery of rheumatoid factor (RF) in 1940s, led to hopes that blood tests could provide gold standard biomarkers in the recognition of the disease [4]. Approximately 70% of RA patients have a positive RF or anti-cyclic citrullinated peptide antibodies (ACPA) along with elevated erythrocyte sedimentation rate (ESR) or C-reactive protein (CRP) [5–7].

New Genome-Wide Association Studies (GWAS) showed a total of 101 single nucleotide polymorphisms (SNPs) associated with immune dysregulation and inflammation. T-reg cells seem to be defective in RA patients [8]. Also, GWAS studies identified potential therapeutic targets. One study showed RA risk in a special pathway, which is called kappa B signaling pathway (NF- $\kappa$ B). Engagement of CD40 is one of the ways this pathway can be triggered and can be targeted for treatment [9]. Another new treatment method focuses on the Janus kinase (JAK) pathway [10]. This pathway is the main signaling mechanism in response to many cytokines involved in RA, including IL-6 [11]. Human leukocyte antigen (HLA) class II locus is associated less with the risk of developing ACPA and more ACPA-positivity to have RA [12]. In the recent years, environmental factors like smoking and pulmonary inflammation was shown to be associated with the emergence of the disease [13]. By using new methods that integrate genetic data with biochemical pathways and cell types involved in the disease, real progress has been made about RA pathophysiology like where and when immune tolerance is broken, which results in synovial inflammation and bone destruction [14]. Environmental factors needs to be recognized and their role in breaking RA tolerance should be investigated further [15].

### 1.2. Diagnosis

Autoimmunity and the overall systemic and articular inflammatory load drive the destructive phase of the disease, which can be detected by conventional radiography or other imaging techniques. But the joint destruction is rarely visible in the early stages of the disease [16]. In the last decade, the use of disease-modifying antirheumatic drugs (DMARDs), particularly methotrexate (MTX) and the availability of new biologic agents have dramatically enhanced the success of RA management [17, 18]. It was shown that early therapeutic intervention improves clinical and radiological outcomes [19]. Up to now it was not possible to effectively investigate the efficacy of early interventions in terms of their ability to prevent later stage RA, since there are not enough data or accepted criteria to group such patients with early disease. In 1987, American College of Rheumatology (ACR) published the criteria for diagnosis [20]. The criteria required four or more of the following: (a) morning stiffness for at least 1 hour for at least 6 weeks,

(b) soft-tissue swelling of three or more joints at least 6 weeks, (c) swelling of the proximal interphalangeal, metacarpophalangeal or wrist joints for at least 6 weeks, (d) symmetric joint swelling for at least 6 weeks, (e) rheumatoid nodules, (f) RF positive blood test and (g) radiographic changes like erosions or osteopenia in hand and wrist joints. These criteria are widely accepted for the diagnosis, but have a limitation in that they were derived for trying to discriminate patients with RA from those with a combination of other rheumatologic diagnosis. Early identification in the patients was not possible with the use of these criteria. In 2010, a joint working group of the ACR and the European League Against Rheumatism (EULAR) was formed to develop a new classification for RA. The newly developed criteria's were designed also as a referral tool for primary care physicians. The number of joints involved, small or large joints, serology (RF, negative or positive ACPA, CRP, ESR) and the duration of symptoms are noted. Every possibility has different points. If the patient has more than six points, the patient has a definitive RA [17] (**Table 1**).

Who should be tested?

Target population

1. Have at least one joint with definite clinical synovitis (swelling)
2. With the synovitis not better explained by another disease

Classification criteria for Rheumatoid Arthritis<sup>\*,\*\*</sup>

A. Joint Involvement	Score
1 Large Joint	0
2–10. Large joints	1
1–3 Small Joints (with/without involvement of large joints)	2
4–10 Small joints (with/without involvement of large joints)	3
>10 Joints (at least one small joint)	5
B. Serology <sup>†</sup>	Score
Negative rheumatoid factor and negative anti-citrullinated protein antibody	0
Low-positive rheumatoid factor or low-positive anti-citrullinated protein antibody	2
High-positive rheumatoid factor or high-positive anti-citrullinated protein antibody	3
C. Acute-phase reactants <sup>†</sup>	Score
Normal C-reactive protein and normal sedimentation rate	0
Abnormal C-reactive protein or abnormal sedimentation rate	1
D. Duration of symptoms	Score
<6 weeks	0
≥6 weeks	1

\*Score-based algorithm: add score of categories A–D.

\*\* A score of ≥6/10 is needed for classification of a patient as having definite rheumatoid arthritis.

†At least one test is needed for classification.

**Table 1.** The 2010 American College of Rheumatology/European League Against Rheumatism classification criteria for rheumatoid arthritis [17].

Joint status of the RA patients was needed to be evaluated after biological agent administration for remission of the disease. Joint destruction pattern under biologic agents were widely discussed. Fukae et al. [21] had shown under X-ray imaging of fingers, Yoshimi et al. [22] by ultrasound and Suzuki et al. [23] evaluated the synovitis of the hand by the help of MRI. Yonemoto et al. had chosen the  $^{18}\text{F}$ -fluorodeoxyglucose positron emission tomography for the evaluation of the destruction. They shared the results of the previous studies of the authors mentioned that even though clinical status of the patient may improve, the synovitis thus destruction was only slowed [24].

In multiple-joint involvement type of the disease, shoulder joint is commonly involved. But it is rarely affected in monoarticular fashion. The clinical presentation may be different in every patient. It can be symmetrical, episodic and silent between periods of remission. The clinical presentation may start with musculoskeletal pain, fever, fatigue or malaise. At the same time, other joints may present with erythema, pain and stiffness after inactivity. In the early stages of this disease, inflammatory changes of the subacromial soft tissue like bursitis, tenosynovitis of the long head of the biceps tendon resulting in defects of the rotator cuff. Rotator cuff is affected both by the synovial proliferations of the glenohumeral joint and the synovitis of the subacromial bursa. The starting point of the destruction of the rotator cuff is often a partial defect of the supraspinatus tendon at the attachment side to the humeral head. The intraoperative rate of this pathology lies between 30 and 90% of the cases, intratendinous defects between 20 and 40%, partial defects and simply thinning-out is found 80% of the cases [25]. Glenohumeral joint, at the beginning, is not really painful because of the large intracapsular space. The first cartilage bone change starts from humeral head that leads to deformation of the head [26]. Pain originates from the capsule, that is sensitive to stretch and distension. The increase in the synovial fluid and hypertrophy of the synovium leads to increase in intra-articular pressure. To overcome this condition, the shoulder is positioned in slight flexion and internal rotation. By this way, the capsular volume is increased [1].

The initial presentation around the shoulder is pain and loss of motion. With the progression of the disease, loss of elevation and external rotation are noted. The initial presentation of the disease can be subacromial bursitis with giant rice bodies in some patients, which may mimic impingement syndrome [27]. Villous synovial hypertrophic tissues (pannus) may result in crepitation and pain during motion. At the inflammatory phase, the patient experiences a constant aching even at rest and being worst at night. In rare cases, scapulothoracic bursa can become inflamed and painful [28]. It should be kept in mind that, in rheumatoid shoulder, the affected joint is not only the GH joint, also acromioclavicular joint (AC) is affected. It was found that in RA patients, AC joint is affected more frequently than the GH joint, but in half of the patients both joints are involved. This should be remembered when treating painful rheumatoid shoulder [29].

The shoulder joint is affected in approximately 60% of hospitalized patients with RA [30, 31]. The pain around the shoulder area was reported in 50% of newly diagnosed RA patients [32]. The degree of dysfunction of the shoulder is related to the severity of the rheumatoid disease [33]. It was reported that 48% of RA patients developed glenohumeral erosive changes and 13% developed pathologic joint space narrowing. Plain radiographs of the rheumatoid shoulder are the



primary diagnostic tools for evaluating the glenohumeral joint (GH). According to prospective study of Kojima et al., RA patients were evaluated for their range of motion of large joints and the effect on the daily activities. Disability of daily activities like dressing, arising, eating, walking and personal hygiene was strongly correlated with shoulder abduction limitations [34].

Medial migration and remodeling of the humeral head with medialization of the GH joint due to bony erosion are common radiographic findings in RA [35]. The rotator cuff insufficiency provokes superior migration of the humeral head with medialization.

Larsen defined the widely used radiographic classification of rheumatoid shoulder in 1977. According to this classification, in stage 0: there is no sign on plain X-ray; stage I: arthritic changes with osteopenia and periarticular tissue swelling; stage II: narrowing of the joint space and erosions; stage III: cysts, increased loss of joint space, superior migration of the humeral head because of rotator cuff insufficiency; stage IV: loss of contours of the articular surface, flattening of the humeral head, medialization of the glenoid; and stage V: severe bony deformation with loss of joint contours and superior migration of the humeral head [36]. Ultrasonography (USG) is also a helpful tool in the shoulder joint. Thus radiography gives limited information about the soft tissue changes, USG could show possible pathologies of the periarticular tissues, especially at the beginning of the disease. It is easy to detect inflammatory changes in the subacromial space like bursitis, tendinitis of the long head of the biceps tendon and rotator cuff tears [37]. Magnetic resonance imaging (MRI) and computerized tomography (CT) are not needed for classification of the disease. But they are useful to answer some special questions like tumoral infiltration, fatty infiltration of the muscles and preoperative planning of shoulder arthroplasty [38, 39]. Evaluation of the degree of periarticular soft tissues is important when deciding on the best treatment strategy [33].

Amundsen et al. investigated the arthroplasty mortality rates for various aetiologies. A total of 214 RA patients were included and on the postoperative 90th day and first year, significantly higher mortality rate was encountered. Even though the highest mortality rate was encountered for fracture patients, RA patients' increased mortality rate must be kept in mind for surgical intervention [40].

Best treatment strategy takes into account the overall condition of the patient and the involvement of other joints. There might be need for lower limb surgery and the use of walking aids. Sometimes the involvement of other, distal joints in the upper arm affects the timing of shoulder surgery/reconstruction.

## **2. Current surgical treatments**

### **2.1. Synovectomy and bursectomy**

In RA, synovium produces chemokines and cytokines, which are responsible for pain and swelling of the joint and later for the articular destruction [41]. Synovectomy is a treatment method aimed for pain relief and treatment of joint swelling before bony erosions occur [42].

Indication of synovectomy may be considered when appropriate medical treatment fails after a period of 6–12 months [41]. Open synovectomy and bursectomy was first described by Pahle in 1973 [43]. Schmidt et al. accomplished arthroscopic approach for synovectomy in 1994 [44]. Although the clinical results are not significantly different between open and arthroscopic synovectomy, due to the immunosuppression resulted by medical treatments and disease itself, arthroscopic approach is mostly preferred. Also short hospital stay and lower risk of shoulder motion restriction are the additional advantages of arthroscopic approach [42]. The results of this treatment method for rheumatoid shoulder are widely discussed in the literature [42–46].

Ossyssek et al. reported two-staged synovectomy in rheumatoid knee. In the first stage, synovectomy was performed and the prominent area of synovitis was marked. In the second look, previously marked synovium area was collected and investigated by immunofluorescence. After the first stage, 94% of the patients' pain was relieved and was linked to the results of immunofluorescence which has shown reduced sensory innervations [47].

In Petersson's open synovectomy series, 21 patients who had gradually increased pain and restriction of motion despite medical management and hydrocortisone injections, were included. Three of 21 patients had advanced arthritic changes at the time of surgery and was not excluded. A mean follow-up of 4 years revealed that if joint cartilage is well preserved, the efficacy of synovectomy and bursectomy increases, thus the functional outcome [45]. Also Petersson stated that in spite of Pahle et al.'s report for synovectomy's favorable outcomes in advanced arthritis, synovectomized 2 out of 3 advanced arthritic patients were dissatisfied and required arthroplasty [45, 48].

On contrary, Kanbe et al. performed arthroscopic synovectomy and capsular release to 54 patients and reported that excellent outcomes can be achieved even if the radiological changes have been occurred. These patients' had shorter disease duration, younger age and lower prednisolone usage. Based on these prognostic factors, a patient even with bone and cartilage destruction might have a good clinical outcome after synovectomy. They also suggested that medical treatment alone will not suffice to stop the progression of inflammation and synovectomy should be performed to obtain improved quality of life before rotator cuff tear occurs [42].

As for late stage rheumatoid shoulders, Wakitani et al. accepted success of synovectomy for pain relief, but pointed out shoulder arthroplasty had better functional outcomes in addition to pain relief, which limited the indications of synovectomy for early stage rheumatoid shoulders [49].

In conclusion, arthroscopic synovectomy and bursectomy is the first line of surgical treatment not a decisive solution in early staged rheumatoid shoulder. But this treatment is mostly symptomatic because of the inability to stop the progression of erosions in the joint. This procedure can delay the need for arthroplasty for the patients approximately 4 years, but as the disease progresses, the need for arthroplasty will be evident. In **Table 2**, the literature is summarized according to functional status and complications. When considering the surgical outcomes, the limitations of this surgery should be widely discussed with the patients [50].

Publications	n	A/O	Follow-up (mean) (months)	Age (mean) (years)	Pain relief <sup>*/**</sup>	Result	Pre-op score	Post-op score	Conversion to arthroplasty	Conclusion
Kanbe et al. [41]	7	A	13 (range 13)	62 (range 49–68)	N/E	Decreased CRP levels, increased efficacy of RA medications	N/A	N/A	—	Combination of medical treatment and synovectomy, slows the progression of arthritis
Smith et al. [46]	16	A	66 (range 12–120)	49 (range 28–71)	13/16	15° increase in ER 34° increase in FF (statistically significant)	ASES: N/A SST: N/A	ASES: 60 (range 47–67) SST: 8 (range 6–11)	1	Good functional results and pain relief in rotator cuff intact shoulders
Kanbe et al. [42]	54	A	60 ± 40.92	53.3 (range N/A)	N/E	30° increase ER 48° increase FF	JOA: 36.65 ± 7.66	JOA: 84.61 ± 12.74	—	Good functional results can be obtained before the tear of rotator cuff
Pahle [48]	54	O	64 (range N/A)	N/A	6/54	%10 increased shoulder functions	N/A	N/A	6	Good functional results in early stages
Petersson [45]	13	O	48 (range N/A)	60 (range 31–73)	5/12	29° increase ER 44° increase FF	N/A	Pain Score: 1.3 (range 1–3)	2	Good functional results in early stages

*Abbreviations:* CRP, C-reactive protein; RA, rheumatoid arthritis; ER, external rotation; FF, forward flexion; ASES, American Shoulder and Elbow Surgeons Score; SST, Simple Shoulder Test; JOA, Japanese Orthopedic Association Score; N/E, not evaluated.

\*Satisfied patients with pain-free or mild pain.

\*\*Total number of participated patients.

**Table 2.** Summary of previous publications about synovectomy and bursectomy in RA patients.



## 2.2. Resection and interposition arthroplasty

When the glenohumeral joint destruction occurs and patient suffers from severe pain, at this point arthroplasty becomes the treatment of choice. But first generation of shoulder arthroplasties had resulted with high rate of loosening, thus patients' morbidity increased [51]. Till the advancement of shoulder prosthesis, resection and interposition arthroplasty was preferred by several authors because of the preservation of glenoid and humeral head bone stock and enabling further revisions [52]. This procedure is mostly selected for high life expectant patients with advanced glenohumeral arthritis suffering from severe pain [51].

Principle of this procedure, damaged cartilages of glenoid and humeral head are resected, radical open synovectomy is performed and soft tissues are interpositioned between articulations, ultimately a new joint is formed [52]. Historically, porcine bladder was used as the soft tissue [53] and in time skin, fascia, tendon, muscle [54] and eventually dura mater [52] were used as membranes for interposition. Porcine bladder was mostly used in temporomandibular joint interposition surgeries and dura mater was used in elbow, temporomandibular joint interposition surgeries [55–57].

Milbrink et al. advocated functional outcome of resection interposition arthroplasty was even better than prosthetic arthroplasty. Although the operation fails in time, as the remaining bone stock was well preserved, conversion to arthroplasty or arthrodesis was still possible [52]. But the advancements in shoulder arthroplasty had nullified this statement [51].

Fink et al. observed 53 shoulders for a mean follow-up of 8.2 years. They stated that after 10 years, the functional outcome of resection interposition arthroplasty decreases dramatically. This phenomenon is explained by the medialization of joint's center of rotation because of progressive resorption of humeral head [51]. As Strauss et al. stated, the medialization of joint center by resection interposition surgery deltoid abduction lever arm decreases by 35% resulting in poor functional outcomes [58]. They supported indication for resection interposition arthroplasty for the group of very young-aged patients because of preservation of bone stock and delay the need for prosthesis [51]. But the pain relief is controversial, maximum active abduction is mostly limited to 60–80° and moderate weakness can persist even though the rotator cuff was sutured [59].

In conclusion; with the advancement of shoulder prosthesis, the indication for resection interposition arthroplasty is declined in time, but theoretically for the young-aged patients with advanced glenohumeral arthritis may be the candidates for resection and interposition arthroplasty due to the preservation of glenohumeral joint and thus delaying the need of prosthetic reconstruction, but practically we saw that newest shoulder resection and interposition surgery literature is from year of 2001, that is because surgeons began to prefer arthroplasty for arthritic patients [50]. The postoperative functional status, complications and revision to arthroplasty are summarized in **Table 3**.

## 2.3. Resurfacing arthroplasty

The idea for resurfacing arthroplasty was to correct deformed humeral head with minimal bone loss. The need for this idea was because of reported high incidence of glenoid loosening with

Publications	n	Age (mean)	Follow-up (mean)	Satisfaction	Pre-op score	Post-op score	Improvement in FF	Improvement in ER	Complication	Conclusion
Milbrink et al. [52]	13	N/A	6 months (prognostic)	%100	N/A	N/A	48	N/A	None	Resection interposition arthroplasty's results are even superior to some endoprosthetic reconstructions and also enable adequate bone stock for total shoulder arthroplasty if revision is needed.
Fink et al. [51]	42	47.9 (range 18–68)	98.4 months (range 42–210)		Constant: N/A SAS: N/A	Constant: 42.33 SAS: 26.43	27.5	2.39	1 (rotator cuff tear, painful shoulder)	Even though functions after resection interposition arthroplasty improve in the long-term deterioration of the scores was witnessed. Young-aged patients may be logical candidates for reserving bone stock for total shoulder arthroplasty revision in the future

*Abbreviations:* ER, external rotation; FF, forward flexion; SAS, Society of American Shoulder and Elbow Surgeons Basic Shoulder Evaluation Form.

**Table 3.** Summary of previous publications about resection and interposition arthroplasty in RA patients.

unpredicted bony erosion during revision surgery after stemmed arthroplasty. Also the application of stems with cement intraoperatively might result in cracking osteopenic humerus shaft of rheumatoid patients. Postoperatively as intramedullary stem leads to stress rise at the tip of the prosthesis, RA patients are prone to fractures around the stem of prosthesis and are hard to manage [60, 61].

The advantages of resurfacing arthroplasty are short operative time, low risk of intraoperative or postoperative periprosthetic fractures and minimal bone resection. The disadvantages are difficulty in correction of the anatomical fitting in cases with extremely deformed humeral head [62, 63].

Rydholm and Sjögren published their mid-term clinical results in 72 rheumatoid shoulders with 94% pain relief and 82% improved mobility. Patients were followed-up for 4.2 years and were evaluated radiographically and functionally. About 25% of patients had shown loosening of the cup. But interestingly, no relationship was found between the position of the cup and the clinical outcomes of the patients. Neither superior migration of the humeral head in 38% nor central attrition of the glenoid in 22% showed any relation to gain of mobility, pain nor functional scores [64]. A counter-argument against resurfacing arthroplasty is that progressive erosion of the glenoid will make future arthroplasty more difficult and the need for total shoulder arthroplasty (TSA) will be earlier and harder as would be advocated for hemiarthroplasty. But in this series of patients they found no relation between the central glenoid erosion and the patient clinical outcomes [64].

Ålund et al. published their 2–6 year results in 33 RA patients. Their findings also showed no correlation between clinical results and radiographic superior migration of the humeral head with or without glenoid erosion. About 25% of the patients showed radiographic signs of cup loosening. They found good pain relief in 27 of the shoulders. The remaining six shoulders were still painful at follow-up [65].

Levy and Copeland published their results with the Copeland Mark-2 Prosthesis with 5–10 year results. In this series, 41 patients out of 94 were RA. There was no difference between the RA and primary osteoarthritis patients in terms of functional clinical scores. Only one RA patient revised to TSA due to loosening. About 93.9% of the patients were satisfied by this procedure [61, 66]. RA patients had better functional results when compared to groups of rotator cuff tear and instability arthropathy.

Fink et al. published the results of 45 RA patients. The patients were divided into three groups according to the cuff pathology: intact, partial tear and total tear. In all three groups, there was significant increase of the functional scores. But the least increase was observed in total rotator cuff tear group. They experienced no complications like component loosening or change in the cup position. Therefore, cup arthroplasty was stated as a good alternative to other arthroplasty solutions in rheumatic patients [67].

Thomas et al. reported their outcome of 56 patients followed-up for at least 2 years. A total of 26 out of 56 patients were RA patients. They reported good clinical outcomes in RA patients when compared to the other indications. The survival analysis showed no variance from acceptable standards for shoulder arthroplasty during the study period. The preservation of

the bone stock for a possible revision surgery and enabling to restore the individual height, version and offset are important advantages for surface arthroplasty [68].

Fuerst et al. published their results of 35 shoulders for a follow-up of at least 5 years in patients with RA. Three revisions were mentioned. These were due to need of conversion to a larger implant, glenoid erosion and loosening. Over the 5-year follow-up, superior migration of the humeral head encountered in 63% and the glenoid depth increased in 31%. Clinically, no difference between the patients with massive rotator cuff tear and smaller tear or no tear was found. Also they suggested magnetic resonance imaging prior to surgery, not only to evaluate soft tissues like rotator cuff, but also to detect the quality of bone, cysts, necrotic areas and other defects of the humeral head [69].

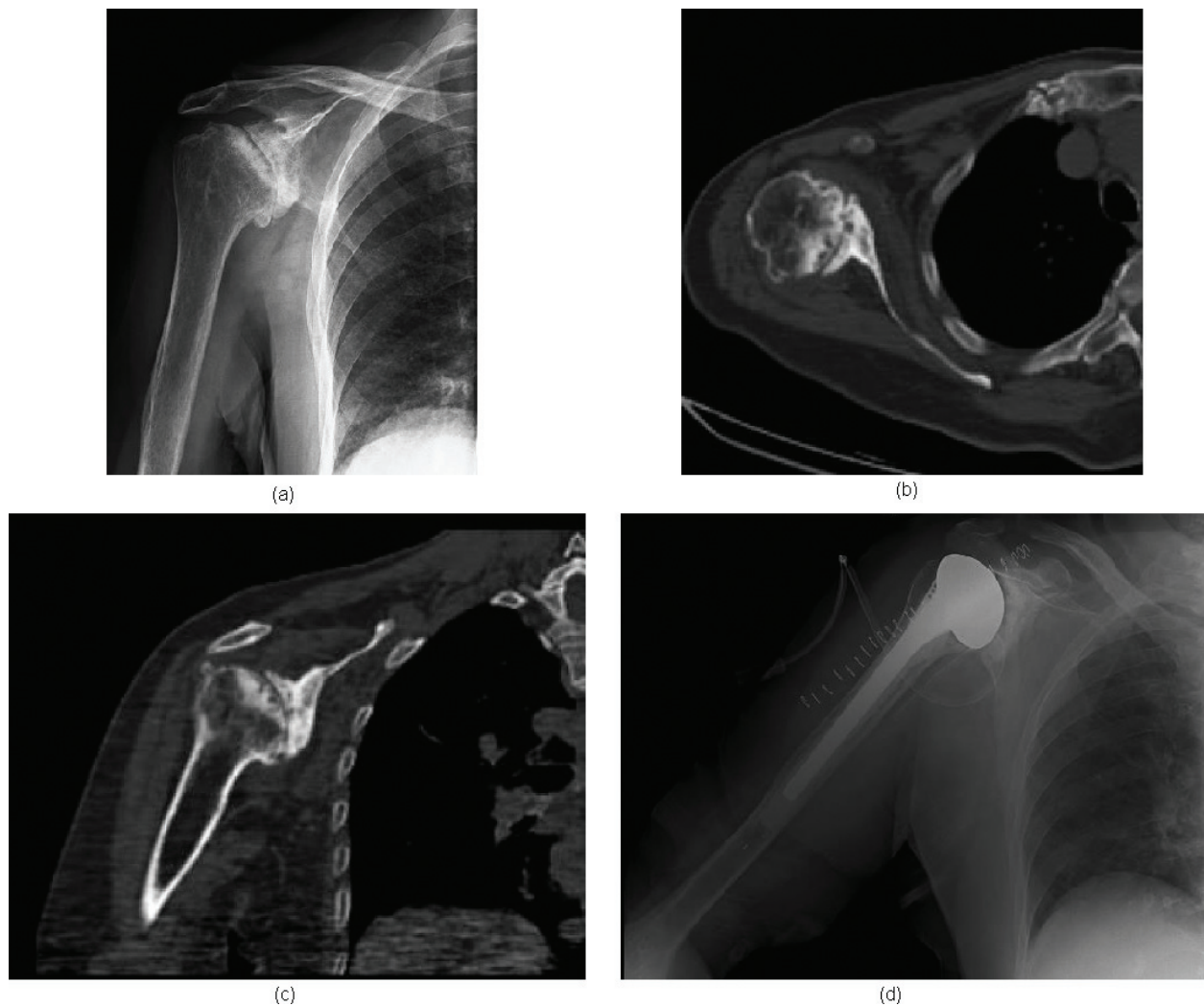
Although most of the results of RA patients with resurfacing arthroplasty are good in the literature given above, Mansat et al. reported worst results in RA patients. In his group of mixed patients, four rheumatoid shoulders gave worst results among them. And concluded that, the resurfacing arthroplasty does not resolve the problem of long-term results of hemiarthroplasty, even it mimics the normal anatomy [70].

Available data on the long-term survival of shoulder arthroplasty is limited. Because of high functional demands of the younger patients; prosthesis may result in a limited life span and the need for a revision surgery during their lifetime is probable [50]. Recently, Levy et al. published their minimum 10 year results of surface replacement arthroplasty in patients younger than 50 years. This is the longest follow-up result of young-aged RA patients' series. Twenty of 49 patients have RA and 4 of 10 revisions were performed in RA patients. The superior migration of the humeral head was more prevalent in these patients. The revisions were done due to rotator cuff failure and loosening at 8–14 years after surgery [71]. They found decreased pain, high satisfaction, good percentage of back to work and sporting activities. As of our own clinical experience and literature review had shown, resurfacing arthroplasty is more demanding for the surgeon, with its advantages of minimal resection and functional outcomes in rotator cuff intact patients, making it a favorable choice.

#### **2.4. Hemiarthroplasty**

The first hemiarthroplasty series were published by Neer. They reconstructed three and four part humerus proximal fractures and took the attention to good functional outcomes [72]. In the following years, hemiarthroplasty was begun to be preferred for osteoarthritis, RA, cuff tear arthropathies and fracture sequelae (**Figure 1**). But superior migration (**Figure 2**) due to cuff tear arthropathies led to diminished functions which had shown that hemiarthroplasty was not the optimal solution for cuff tear arthropathies, thus reverse shoulder arthroplasty (RSA) was designed [73].

Still there is no consensus on preference of hemiarthroplasty or TSA especially in the cases of young-aged rheumatoid patients. The main complication of hemiarthroplasty is glenoid erosion which results in medialization of the joint which was seen in 98% of the patients in a study by Sperling et al. with a mean follow-up of 11.3 years [74], but the risk of glenoidal component

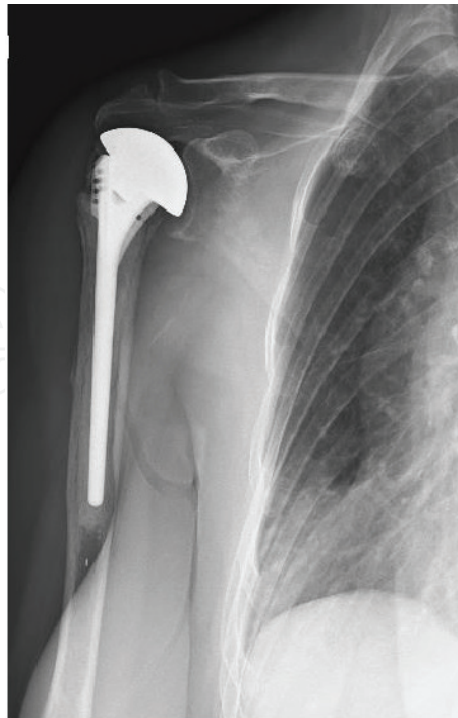


**Figure 1.** Hemiarthroplasty surgery to a defective glenoid. (A) Preoperative AP plain radiography. (B) Preoperative axial CT scan. (C) Preoperative coronal CT scan. (D) Early postoperative AP plain radiography.

loosening in TSA and decreased glenoidal bone stock is another concern for the indication for young-aged patients. Thus, hemiarthroplasty is widely accepted for patients with intact rotator cuff and minimal glenoid erosion [73].

As for RA, indications of arthroplasty are glenohumeral joint destruction with severe pain and restriction of movements [75]. But this must be kept in mind that, the RA in shoulder differs from osteoarthritic patients in many ways, such as glenoid is osteopenic, rotator cuff is torn or thinned and internal rotation is increased due to medial side of glenoid is eroded rather than posterior as seen in osteoarthritis [75]. Smith et al. described the changes and effect on functional outcomes of arthroplasty performed on rheumatoid shoulders. They mentioned that TSA was mostly preferred in their practice, because of the prevention of medial erosion of glenoid by resurfacing and better comfort. Although the advantages of TSA seemed to be better, due to mentioned changes in glenoid might cause an obstacle for insertion of glenoid component, thus hemiarthroplasty might be performed which had a similar functional outcome and pain relief. Also they supported the cementation of humeral component in Sneppen et al.'s





**Figure 2.** Plain radiography of hemiarthroplasty superior migration.

TSA series performed on rheumatoid arthritic shoulders. Because the press-fit technique had shown 40% (5 in 12 patients) loosening, in comparison to cemented humeral components had shown none (0 in 50 patients) [76, 77].

Because of rotator cuff insufficiency to overwhelm superior migration of the prosthesis, Rozing et al. conducted a study of rotator cuff repair for shoulder arthroplasty in 1998 including 40 patients (11 were hemiarthroplasty). The follow-up was ranging from 2 to 13 years. They stated that rotator cuff repair was effective because proximal migration was seen in only 6 of 40 patients. For the surgical technique, if rotator cuff repair is planned, posterosuperior incision should be preferred because the osteotomization of the posterior acromion was not restricting the postoperative rehabilitation in contrast to superior approach which requires an osteotomy including large portion of acromion [75].

Cofield et al.'s study of hemiarthroplasty included 32 rheumatoid shoulders and 35 osteoarthritis shoulders and followed up for 9.3 years. They stated that pain relief was achieved in 78% of the patients, external rotation and forward flexion range increased by 26° and 24°, respectively. Although the functional results seemed to be satisfying, the patients' self-evaluation had shown that 49% of the patients were satisfied. About 12% of the patients required a revision to TSA because of intractable pain of glenoid arthritis and postoperative pain relief evaluations were satisfying. They supported the indication of hemiarthroplasty in inadequate glenoid bone stock which cannot bear an implant and young aged or active life expectant patients [78, 79].

Sperling et al. compared the hemiarthroplasty and TSA patients below 50 years of age between the years of 1976 and 1985. Hemiarthroplasty was performed in 74 shoulders, TSA was performed in 34 shoulders. The radiolucent line adjacent to TSA was 53% for humeral, 59% for



glenoid component in spite of 24% which was seen in humeral component of hemiarthroplasty. In contrary, prosthesis survival analysis revealed at 10 year of follow-up, revision rates of hemiarthroplasties were increased significantly (17% for hemiarthroplasties, 3% for TSA). Pain and functional outcome comparison revealed no significant results [80].

In contrary, Collins et al. published a prospective multi-centered study for the comparison of arthroplasties in RA patients. They stated the hemiarthroplasty indication as young aged, high activity level anticipated, osteopenic, rotator cuff tear already present, extensive poorly controlled systemic disease. A total of 61 shoulder arthroplasties were included (36 hemiarthroplasty, 25 TSA) and followed up for 38 months for hemiarthroplasty, 39 months for TSA. The results of functional scores and pain assessments had shown a slight advantage for TSA, but patient selection criteria were worse for hemiarthroplasty. The choice for TSA was advised for the patients with intact or reparable rotator cuff and adequate glenoid bone stock. Because even the patients' condition was worse for selection of hemiarthroplasty, functional outcome and pain relief were increased when compared to preoperative status. Also another concern for better functional outcome and pain relief criteria was stated as the glenohumeral alignment which could be achieved better in TSA [81].

Sperling et al.'s 195 TSA and 108 hemiarthroplasty included with 11.3 year follow-up is the largest patient population. Their comparison of hemiarthroplasty and TSA revealed important factors for decision. For hemiarthroplasty and TSA, the results for pain relief and functional outcome were significantly improved. But if the results were evaluated for rotator cuff intact or reparable and rotator cuff torn patients separately, the rotator cuff intact patients' survival of prosthesis, pain relief, functional outcome results were superior to hemiarthroplasty. But for the rotator cuff deficient shoulders, the results remained the same. As for the main complication of the prosthesis choice, TSA's glenoid loosening rates were lower than hemiarthroplasty's painful glenoid arthritis [73].

Rees et al. investigated the primary shoulder hemiarthroplasties for osteoarthritis and RA, but they subgrouped RA so that the results were clear. Thirty-one patients were evaluated with Oxford Shoulder Score and transition and satisfaction questions. As for Oxford Shoulder Scores, a statistically significant improvement was seen, but for the patient satisfaction test the results had shown that 33.3% of the RA patients were worse or the same and 29.6% were not pleased [82].

Roizing et al. conducted a study to describe the prognostic factors in arthroplasty for rheumatoid shoulders. They included 66 TSA and 75 hemiarthroplasty. They stated that hemiarthroplasty was affected by the preoperative acromioclavicular joint arthrosis and medial migration. But as for the rotator cuff repair status, proximal migration progression hemiarthroplasty's Hospital for Special Surgery clinical score were not affected as much as TSA. Also they stated that 11 patients who had both hemiarthroplasty and TSA, in their 2nd year follow-up score functional results had shown no significant difference. They concluded that in the patients with poor glenoid bone stock and moderate or lower quality rotator cuff repair, hemiarthroplasty was a good treatment choice [83].

Etiology-based evaluation study by Gadea et al. for hemiarthroplasty resulted with improved Constant-Murley score and 100% survival of prosthesis [73]. Although this study had a minimum

Publication	N	Age (mean)	Follow-up	Satisfaction	Pre-op score	Post-op score	Improvement in ER	Improvement in FF	Complication	Conclusion
Cofield et al. [78]	32	N/A	9.3	%49	N/A	N/A	26	24	N/A	Patients with inadequate glenoid bone stock or high-level activity expectancy might be proper candidates for hemiarthroplasty
Watson et al. [79]	4	71 (range 70–73)	5.9 (range 2.5–10)	%100	HSS: 13	HSS: 41.75	25	30	None	Bipolar spacer prosthesis might be a good surgical option for the treatment of advanced glenohumeral arthritis, but the eventually encountered loss of low-friction properties of the sleeve might restrict joint movements.
Sperling et al. [80]	28	39 (range 19–50)	11.7	%66	VAS: 4.6	VAS: 2.4	24	44	N/A	Shoulder arthroplasty provides long-term pain relief and motion improvement, but in young-aged patients (<50) care should be taken to assess the appropriate choice due to low survival of prosthesis.
Collins et al. [81]	36	58 (range 30–84)	3.1 (range 2–6)	N/A	N/A	N/A	15	N/A	N/A	By hemiarthroplasty, pain relief and improved range of motion are expected when sufficient glenoidal and humeral bone stock are present
Sperling et al. [74]	95	54 (range 21–77)	12.1	N/A	Pain score: 4.8	Pain score: 2.4	18	32	10 (8 glenoid erosion, 2 loosening)	Shoulder arthroplasty in rheumatoid arthritis relieves pain and improves shoulder joint range of motion, but with the presence of intact rotator cuff, total shoulder arthroplasty's results had shown superiority
Rees et al. [82]	31	63.5 ± 11.9	4.37 (range 3–8)	%70.4	OSS: 13.7	OSS: 28	N/A	N/A	N/A	Rheumatoid arthritis patients less likely satisfied with their hemiarthroplasty operation. This fact may be rectified by their systemic pathology where the joint pain improved but bodily and limb function did not.

*Abbreviations:* ER, external rotation; FF, forward flexion; OSS, Oxford Shoulder Score; HSS, Hospital for Special Surgery Score; VAS, Visual Analogue Scale; N/A, not available.

**Table 4.** Summary of previous publications comparing hemiarthroplasty and total shoulder arthroplasty in RA patients.

8 year follow-up, Sperling et al.'s study for survival of prosthesis was more dependable because of its large numbers but as the survival of hemiarthroplasty decreased, after 20th year, it seized to deteriorate and the lines of hemiarthroplasty and TSA intersected [80]. Thus, they concluded that hemiarthroplasty was a better treatment option for the young patients (<50 years of age) [73].

In conclusion, hemiarthroplasty provides a painless shoulder with good functional outcomes. But the literature about comparison of TSA and hemiarthroplasty confirmed that its survival rate is inferior to TSA. Glenoid bone stock preservation which is enabling future revision surgeries, good functional outcomes and survival of prosthesis according to Gadea et al. [73] minimum 8 year and even same survival rate as TSA in long-term as supported by Sperling et al. [74] are in favor for young RA patients, but the conflict of optimal treatment between the use of TSA and hemiarthroplasty in recent literature, mostly limit the indication to elderly patients with insufficient glenoid bone stock and rotator cuff deficient patients [50]. The literature comparing hemiarthroplasty and TSA are summarized in **Table 4**.

### 2.5. The ream and run technique

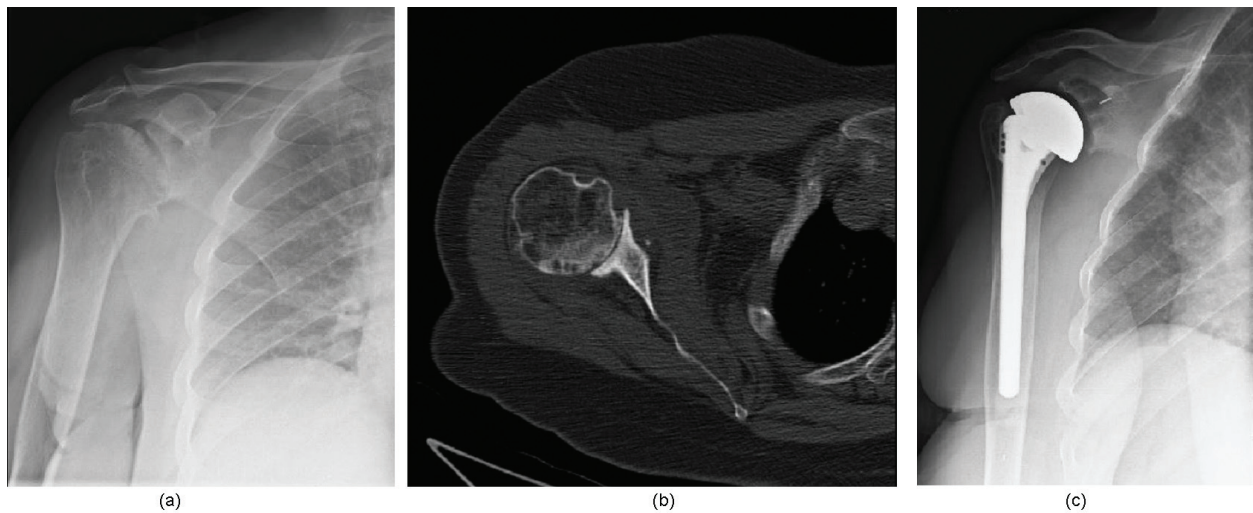
The glenoid component complications of the TSA created concerns about the indications for young-aged active patients [80, 84]. The Ream and Run technique, first described by Clinton et al., is a form of hemiarthroplasty with the reaming of the glenoid. This technique is also called non-prosthetic reconstruction of the glenoid [85, 86]. Reamed glenoidal surface was examined on canine model and demonstrated that the reamed glenoid articular surface heals with smooth and concentric fibrocartilage [86].

One of the advantages of this technique is the preservation of the labrum during the periglenoid capsular release that results with improved glenohumeral stability and concentrically loading of the joint. If there is a need for a correction of glenoid version, this may also be done by ream and run procedure. But if there is severe posterior wear, this condition may not be appropriate for Ream and Run technique [87, 88].

Ream and run technique is suitable for primary glenohumeral arthritis patients who agree on slow recovery to avoid glenoid loosening and medial erosion in the long-term. Even though, the results were satisfying, due to the requirement of healing process in the glenoid for 12–18 months in non-RA patients, rheumatoid shoulders with destructive pattern are not seemed to be suitable candidates, but this assumption was not proven according to our best of our knowledge because the Ream and Run technique's functional outcome has not been evaluated on rheumatoid shoulders yet [87–91].

### 2.6. Anatomical total shoulder arthroplasty

Indications for TSA in rheumatoid shoulders are for the patients with intractable pain, end-stage disease with extensive glenohumeral joint destruction, intact rotator cuff and yet with sufficient bone stock and soft tissue balance to stabilize the prosthetic articulations (**Figure 3**) [92]. The presence of mentioned factors makes the TSA superior treatment choice rather than hemiarthroplasty. Because medial erosion of the glenoid which affects glenoid bone stock may complicate the revision surgeries of hemiarthroplasty. Also the glenohumeral alignment can be



**Figure 3.** Total shoulder arthroplasty surgery. (A) Preoperative AP plain radiography. (B) Preoperative axial CT scan. (C) Postoperative 6th month AP plain radiography.

achieved superiorly in TSA, especially in the patient group whose age is older than 50 which was accepted as a predictor of pain relief and better functional outcome [92–94].

The assessment of rotator cuff status preoperatively is essential to avoid proximal migration and consequently the rocking horse phenomenon. The survival of the glenoidal component has a strong negative correlation with the fatty degeneration of the rotator cuff that can be seen by ultrasonography and magnetic resonance imaging or decreased subacromial space seen in the plain x-ray [33].

Neer's nonconstrained TSA had achieved pain relief and low complication rates in rheumatoid shoulders. But the poor bone stock, irreparable rotator cuff tears, soft tissue constraints demonstrated an underestimated potential risk for arthroplasty [95–97]. Due to these factors of rheumatoid shoulder, high rate of radiographic lucent lines, ranging from 30 to 93% which was correlated with physical loosening of the components, created concerns about the long-term survival of the TSA [95, 98]. Hambright's study of perioperative status comparison between rheumatoid and non-rheumatoid shoulders that had undergone TSA revealed no significant difference among mortality and complications. Also, interestingly, even the hospital costs per day were higher in rheumatoid shoulder patients; due to low hospital stay, overall in-hospital costs were lower in comparison to non-rheumatoid patients. This fact was tried to be explained by the RA patients' experience of managing chronic disease and the pain [31, 99, 100].

Boileau et al. [101] and Martin et al. [102] studied the results of metal backed hydroxyapatite covered uncemented glenoidal components for osteoarthritic patients with a follow-up of 3 and 7.5 years, respectively. Glenoidal component loosening was encountered in 20% of Boileau et al.'s and 11% of Martin et al.'s patients, so considered as unfavorable and uncemented glenoidal component was abandoned. Against these statements, Clement et al. investigated the results of hydroxyapatite covered metal backed glenoid components in rheumatoid patients. A total of 36 shoulders were evaluated for 132 months and 1 out of 5 complication was seen as glenoidal loosening and survival of prosthesis in 10 years was found



for 89%. Their findings showed that the use of pegged which is more stable than keeled component, thin metal back with thicker polyethylene because the polyethylene wear was stated as the major factor for revision surgeries [103].

Also, Betts et al.'s study included 14 rheumatoid shoulders with a follow-up of 19.8 years. They reported their functional outcomes, pain relief and complication rates. With the increase in follow-up duration, radiolucencies around glenoidal and humeral component and rotator cuff deficiency were progressed. But even with the presence of these radiological findings, functional outcomes and satisfactory pain relief were especially achieved in elderly, non-demanding patients. They managed their personal care and their sleep was undisturbed. Additionally, they stated that proximal humeral migration was strongly relevant to glenoidal component loosening. This phenomenon was explained by the rocking horse movements of the humeral component on the glenoidal component which causes the eccentric loading on the glenoid component. The exacerbating factors of the proximal migration were described as instability and rotator cuff deficiency. Even the rotator cuff repair was performed; in the long-term, rotator cuff deficiency was stated as inevitable [104].

In 1987, Kelly et al. reported their experience in Neer's TSA in rheumatoid shoulders. After a follow-up of 36 months; even the patients' forward flexion ( $75^\circ$ ) and abduction ( $68^\circ$ ) were moderate; because of the improvement in external ( $40^\circ$ ) and internal rotation, patients managed their daily living, thus the functional scores were satisfactory. But the main concern was the glenoidal radiolucent lines that started to happen after 2 weeks of operation [105], but their second updated publication in 1997 with a 9.5 year follow-up, revealed that even 23 of 37 glenoidal components had shown radiolucencies, only 24% were progressed and required further evaluation for revision. The range of motion in the long-term was not significantly different from their previous study [106].

Sneppen et al. published the long-term results of TSA in terms of complications in a rheumatoid patient group. Sixty-two shoulders were included and followed up for about 7 years. In the total group, 54% of the patients showed proximal migration. Especially the patients with preoperative Larsen grade V lesions had shown 69% proximal migration. But interestingly, the occurrence of proximal migration did not influence the functional outcome of the patients. About 89% of the patients achieved acceptable pain relief. Forward flexion and abduction were significantly increased according to the preoperative state. They also stated that because of the glenoid's poor bone stock, the glenoidal component's keel might be trimmed to achieve a proper fitting. Thus, the use of metal back components might not be the suitable choice for these patients. The authors also advised the use of cemented humeral component because even the perioperative state of humerus was seemed to be in good shape, 5 out of 12 patients had shown humeral component loosening in contrary of 50 patients with cemented humeral component which had shown no sign of radiolucency [107]. In contrary, Trail et al. supported the uncemented humeral component in their study ( $n = 144$ ) because 13% of the patients had shown the radiolucent lines around the humeral component but it was neither progressive nor symptomatic [108]. Barlow et al.'s updated study about arthroplasty series in rheumatoid shoulder included largest patient population in literature. A total of 195 anatomical total shoulders and 108 hemiarthroplasty was included in study and followed up for 13.8 years.

The radiographic evaluation of TSA revealed that 72% of the patients had radiolucent lines around glenoid component, in contrast to hemiarthroplasty's glenoid erosion which occurred in 98% of the patients. Even the presence of radiolucency rates was higher for TSA, in the 10th year of follow-up; TSA's survival was 92.9% and with an intact rotator cuff survival was increased to 96.7%. In contrary, hemiarthroplasty's 10 year survival was 87.9% but with an intact cuff survival was decreased to 75.8%. They stated that even the glenoidal component loosening is a catastrophic complication; with the presence of an intact rotator cuff, the survival of the prosthesis is superior to hemiarthroplasty [109].

Glenoid loosening also depends on the morphology of the glenoid. Walch et al. identified five types glenoid morphology (A1, A2, B1, B2, C) in 113 patients' computed tomography scans. A1, A2 and B1 represents a lesser risk for glenoid component insertion and long-term loosening in contrast to B2 and C type glenoids. Key feature of the morphology of B2, C glenoids is the excessive retroversion [110]. Surgical techniques vary depending on the morphology but all technique has its disadvantage. Anatomical glenoid correction by reaming may be performed but as a result, the joint will be medialized, thus the lever arm of the surrounding muscle will decrease [111]. Also due to excessive reaming, glenoid bone stock will be lost and while inserting the component, the pegs may perforate the cortex which will result as loosening, fracture and in the long-term the revision surgery will be complicated. To protect the bone stock, glenoid may be reamed retrovertly without correcting version, but this technique represents a threat for perforation of anterior cortex by the inserted pegs and also more than 10° of retroversion increases the subluxation and instability of the prosthesis. To fill the defect of eroded area by bone graft in the posterior glenoid is another choice, but cemented glenoid components carry the risk of graft osteolysis. Metal backed hydroxyapatite covered components may be chosen. The advancement of prosthesis technology created posterior augmented glenoid designs. This component's augment fits on the defected glenoid, thus the reaming of anterior glenoid will be prevented [111, 112]. Kersten et al. compared the standard glenoid component with wedge and stepped posterior augmented glenoid component. Posterior augmented glenoid components confirmed that bone loss in glenoid is decreased significantly according to standard type glenoid components. Also comparison of the subgroups of posterior augmented components, the wedge-shaped required lesser reaming, thus bone stock removal was lesser than the stepped glenoid component and as a result lower risk for glenoid loosening might be achieved with wedged-shaped posterior augmented glenoid component [111]. Also Greiner et al. investigated the radiolucent line occurrences according to morphology. B2 and C glenoid types showed significantly higher radiolucent lines around glenoidal component after a follow-up of approximately 5 years [112]. Although these studies were performed on mostly primary osteoarthritis, surgical technique choices may give clues about patient specific approach.

In conclusion, as the advancement in prosthesis and improvement in surgical techniques, recent literature supports TSA for young- and old-aged patients with an intact or repairable rotator cuff. Rotator cuff deficiency and poor glenoid bone stock are the main perioperative challenges of TSA, but with the repair of rotator cuff and adjusting the glenoidal component by trimming had shown statistically significant pain relief and also improved functional outcomes. The identification of the glenoid morphology carries great importance to assess the



surgical technique for overwhelming the most common complication of the TSA. In the long-term follow-up, the radiolucencies around components had created concerns about loosening, but the progression of radiolucencies is more trustworthy for this diagnosis [50]. Summary of the literature for TSA can be found in **Table 5**.

## 2.7. Reverse shoulder arthroplasty

Although hemiarthroplasty and TSA had shown superiorities to each other in the absence of rotator cuff, instability, superior migration, weakness of the arm and limited range of motion created concerns [113–116]. Van de Salde et al. correlated the joint space obliteration with rotator cuff fatty infiltration [117]. Grammont et al. in 1993 designed an anatomically inverse implant. Humeral cup became concave and glenoid became convex. Thus, the rotator cuff's altering muscle vectors against the deltoid could be neglected and the implant would become deltoid dependent. Also for its design joint movement center was medialized and located inferiorly, thus increased the moment arm of the deltoid and eliminated the forces applying to glenoidal component [118]. Because of the deltoid dependency, perioperative assessment of deltoid tension after insertion of the implant carries great importance (**Figure 4**) [116].

Rittmeister et al. published their experience with RSA in 2001. Seven patients (eight shoulders) were included and inclusion criteria was determined as joint pain, restricted joint movements which deteriorates daily living, evaluation of irreparable rotator cuff and advanced destructive pattern in radiological examination. Their mean follow-up duration was 54.3 months. Their main concerns were the glenoidal component and cuff pathology. Because of the inclusion criteria, advanced staged patients' glenoidal bone stock was not ideal for the insertion of the screws, thus loosening of the glenoidal component and perioperative glenoid fractures were encountered. Additional concern in rheumatoid shoulder, teres minor, infraspinatus were damaged in addition to supraspinatus, which created stability issues for the implant [116]. Another study by John et al. included 20 patients with 22 advanced staged rheumatoid shoulders. The evaluation of the patients was made by patient orientated and a clinical assessment with a mean follow-up of 24.3 months. They concluded that in patients with torn rotator cuff and advanced radiological changes, RSA improved the quality of life. Only complication mentioned was scapular notching which did not progress after 1 year of follow-up and also did not significantly change the functional outcome of the patients [119].

In contrast, Tiusanen et al. included 76 RSA patients who needed to be revised after hemiarthroplasty failure. In their retrospective natured study, evaluations were made preoperatively and 1, 3, 6, 12, 36 months after surgery. They stated that even though the results were from a revised patient group, their range of motions increased gradually till their postoperative first year, after that a steady state was encountered. Patient satisfaction was achieved for 90% of the patients and no major complications were seen [120].

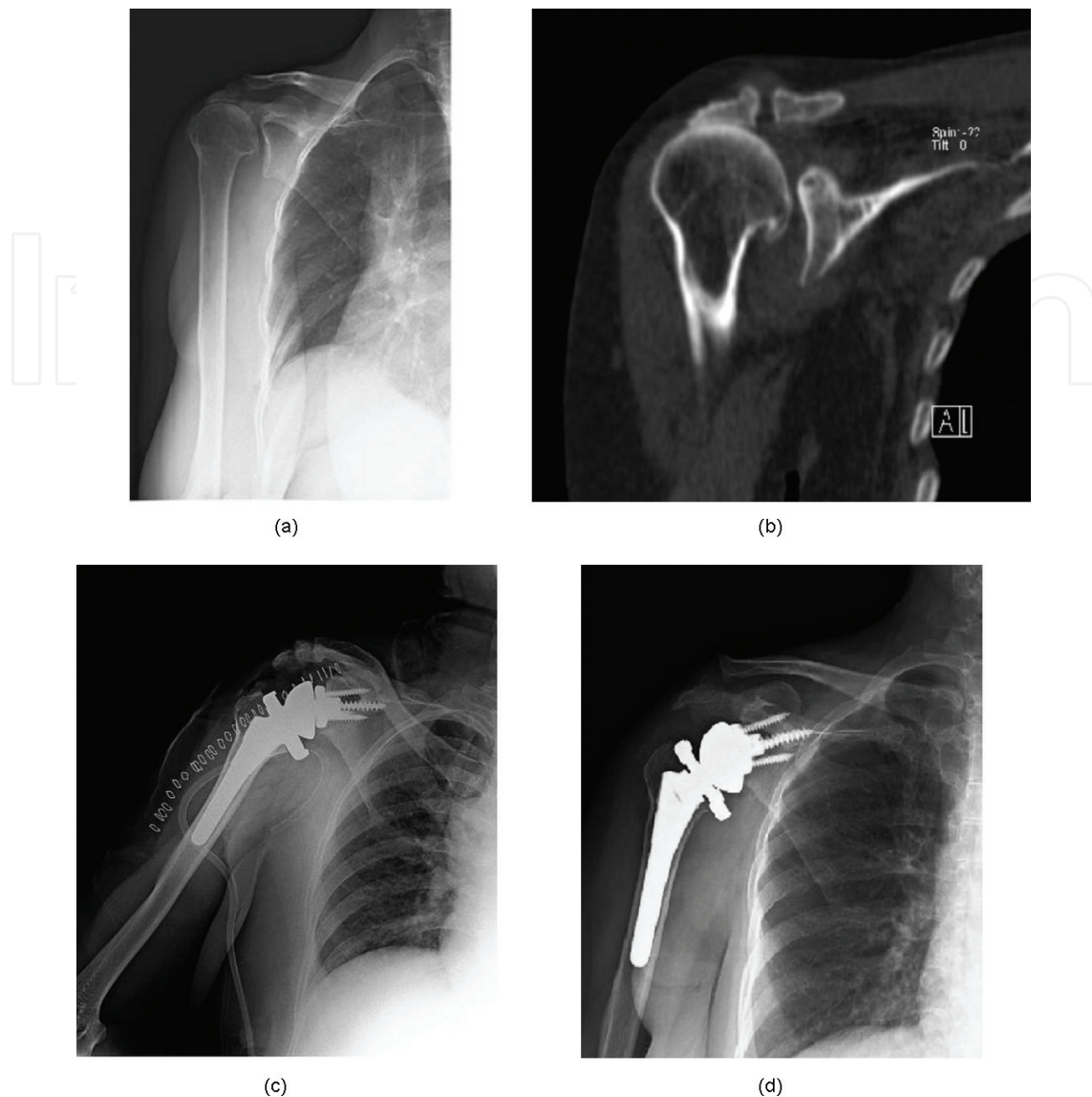
Holcomb et al. presented a larger case series (21 patients) with a mean 36 months follow-up. Included patients demonstrated heterogeneity for Larsen classification. For the Larsen Grade IV and V patients, glenoid structural autografts were used which were acquired from humeral head. The results revealed good functional outcomes and pain relief. Eight patient stated good or excellent outcome. Against the statement of Rittmeister, they found fewer complications

Publication	N	Age (mean)	Follow-up	PRE-op score	Post-op score	Improvement in FF	Improvement in ER	Satisfaction	Complication	Conclusion
Kelly et al. (1987) [105]	41	57 (range 21–59)	36 months (range 12–66)	Daily living activities: 16 (score value: min.9, max.36)	Daily living activities: 30 (score value: min.9, max.36)	20	29	%88	1 (postoperative pain due to rotator cuff tear)	Non-constraint total shoulder arthroplasty is a valuable surgical option with excellent pain relief and moderate functional outcome which is due to impaired rotator cuff
Friedman et al. [97]	24	59 (range 32–79)	54 months (range 24–120)	Pain score: 1.1 (score value: min:1, max:5) Daily living activity: 1 (score value: min: 0, max:5)	Pain score: 4.3 (score value: min:1, max:5) Daily living activity: 3 (score value: min: 0, max:5)	38	11	%92	None	With the restoration of mechanical integrity; pain relief, motion improvements can be achievable with total shoulder arthroplasty.
Sneppen et al. [107]	62	57 (range: 31–75)	92 months (range: 52–139)	ASES: 15.02	ASES: 28	44	6	%89	1 (glenoid loosening)	The presence of proximal migration does not effect the functional outcomes, but even pain relief and motion improvement can be achieved with total shoulder arthroplasty, glenoidal loosening is a major concern
Stewart et al. [106]	37	55 (range 22–71)	114 months (range 84–156)	N/A	N/A	22	33	%89	6 (3 glenoidal component loosening, 2 humeral component loosening, 1 deep infection)	Even the radiolucency rates are high in operated rheumatoid shoulders, not all patients had shown loosening and required revision.
Trail et al. [108]	40	59.1 ± 12.7	61 months (range 25–105.6)	Constant: 12.3 ASES: 22.3	Constant: 33.7 ASES: 56.9	17	20	N/A	N/A	Total shoulder arthroplasty relieves pain, improves strength and range of motion, and also use of cemented humeral stem and pegged glenoidal component result in good fixation
Betts et al. [104]	14	47.7 (range 21–67)	231.6 months (range 198–285.6)	N/A	N/A	15	20	N/A	5 (1 post-operative rotator cuff tear, 1 infection, 1 aseptic loosening of both components, 2 reasons unclear	Even though total shoulder arthroplasty enables the daily life activity, due to rotator cuff deficiency in rheumatoid shoulder, loosening rates are increased.

Publication	N	Age (mean)	Follow-up	PRE-op score	Post-op score	Improvement in FF	Improvement in ER	Satisfaction	Complication	Conclusion
Clement et al. [103]	29	55 (range 35–86)	132 months (range 96–168)	Constant: 20.6	Constant: 33.5	–4	10	N/A	5 (3 superior luxation of humeral head, 1 for infection, 1 for aseptic loosening)	Hydroxyapatite covered metal backed glenoid components key features for survival are the low profile metal back, hydroxyapatite cover and fixation of glenoid component with screws

*Abbreviations:* ER, external rotation; FF, forward flexion; ASES, American Shoulder and Elbow Surgeons Score.

**Table 5.** Summary of previous publications about total shoulder arthroplasty in RA patients.



**Figure 4.** Reverse shoulder arthroplasty surgery. (A) Preoperative AP plain radiography. (B) Preoperative coronal CT scan. (C) Early postoperative plain radiography. (D) Postoperative 6th month plain radiography.

and only three required revision surgery. Two of these three were evaluated as periprosthetic infection which occurred after 7 weeks and 6 years after surgery. They explained their low infection rates to routinely used tobramycin added methylmethacrylate. They supported that even though all rotator cuff muscles are affected by fatty infiltration, the choice of RSA is reasonable with improved functional outcomes, pain relief and low complication rates [121].

Guery et al. in 2006 published a survival analysis for RSA. They advocated that because of high infection rate and low quality of glenoid bone stock in RA, the use of RSA was contraindicated [122]. But after 5 years, Young et al. in the same institute published their experience of RSA in RA with an intermediate follow-up (3.8 years). No complications were seen that needs to be intervened by surgery. The structural bone graft acquired from resected humeral head is enough for restoring glenoidal bone stock and healing of the graft was satisfactory. As for the

Publication	N	Age (Mean)	Follow-up	Pre-op Score	Post-op Score	Improvement in FF	Improvement in ER	Satisfaction	Complications	Conclusion
Rittmeister et al. [116]	8	60.25 (range 34–86)	54.3 months (range 48–73)	Constant: 17	Constant: 63	N/A	N/A	100%	3 (reosteosynthesis of acromion required)	Reverse shoulder arthroplasty provides a stable and functional joint even though the deltoid is the functioning sole muscle when the rotator cuff is beyond restoration
Holcomb et al. [121]	21	70.3 (range 53–86)	36 months (range 24–73)	ASES: 28 SST: 1 VAS function score: 3	ASES: 82 SST: 7 VAS function score: 6	74	14	99.6%	3 (2 infection, 1 periprosthetic fracture)	Reverse shoulder arthroplasty is a reliable treatment option for rotator cuff deficient rheumatoid shoulders in contrary to previous reports, but long-term results are needed.
Young et al. [123]	16	70.1 (range 46.3–83.6)	45.6 months (range 25–84)	Constant: 22.5	Constant: 64.9	61.6	29.2	94%	None	Reverse shoulder arthroplasty results in rheumatoid shoulder are promising but care must be taken against intra and postoperative fractures in this population
Tiusanen et al. [120]	76	70.7 (range 49–90)	36 months	N/A	N/A	48.5	–5.5	90%	25 scapular notching (Grade I:19, Grade II: 3, Grade III: 3)	Even though external and internal rotations are limited, with no major complication, and improved FF, extension; high patient satisfaction can be achieved.

*Abbreviations:* ER, external rotation; FF, forward flexion; ASES, American Shoulder and Elbow Surgeons Score; SST, Simple Shoulder Test; VAS, Visual Analogue Scale.

**Table 6.** Summary of previous publications about reverse shoulder Arthroplasty in RA patients.

functional outcome, the forward flexion was increased to 138.6° which was a good functional outcome according to the total shoulder and hemiarthroplasty patients with the same radiographic properties. Eleven patients were stated as good or excellent result. But for the external rotation, the increase was not statistically significant. With an intact teres minor, external rotation was improved significantly when the arm was abducted 90° [123].

Even Holcomb et al. [121] stated their infection rate for 9.5% in 21 patients, Young et al. [123] stated 0% infection rate after RSA in rheumatoid shoulder. But a larger case series was published by Morris et al. with 42 rheumatoid shoulders contributing in 301 RSA. Only 5% of patients with RA were infected and required revision. They concluded that RA was not a bad prognostic factor for periprosthetic infection after RSA application [124].

In 2016, Liu et al. evaluated the osteoarthritic patients' return to sports after RSA or hemiarthroplasty surgeries. Even though minor population represents the RA patients, it may give some clue for the functionality of RSA. Inclusion criteria were the patients who had a contraindication for TSA and RSA or hemiarthroplasty was decided. A total of 102 RSA and 71 hemiarthroplasty patients were evaluated for 31.7 and 62.9 months, respectively. They concluded that RSA had a better return to sports activities than hemiarthroplasty, especially when the patient was female, younger than 70 of age and had a rotator cuff deficiency [125].

In conclusion, the choice for RSA is reserved for old aged, irreparable rotator cuff deficient patients. According to larger case series, the patients with morning stiffness, advanced radiological destruction of glenohumeral joint is considered to be the indication for RSA. The challenges for low glenoidal bone stock can be overwhelmed with the use of autografts acquired from humeral head to reinforce the glenoidal bone stock [50]. In the light of recent literature, we can assume that RSA will play role in young-aged patients due to return to sports rate and improved functional status. The functional status and complications of previous literature about RSA are summarized in **Table 6**.

### 3. Conclusion

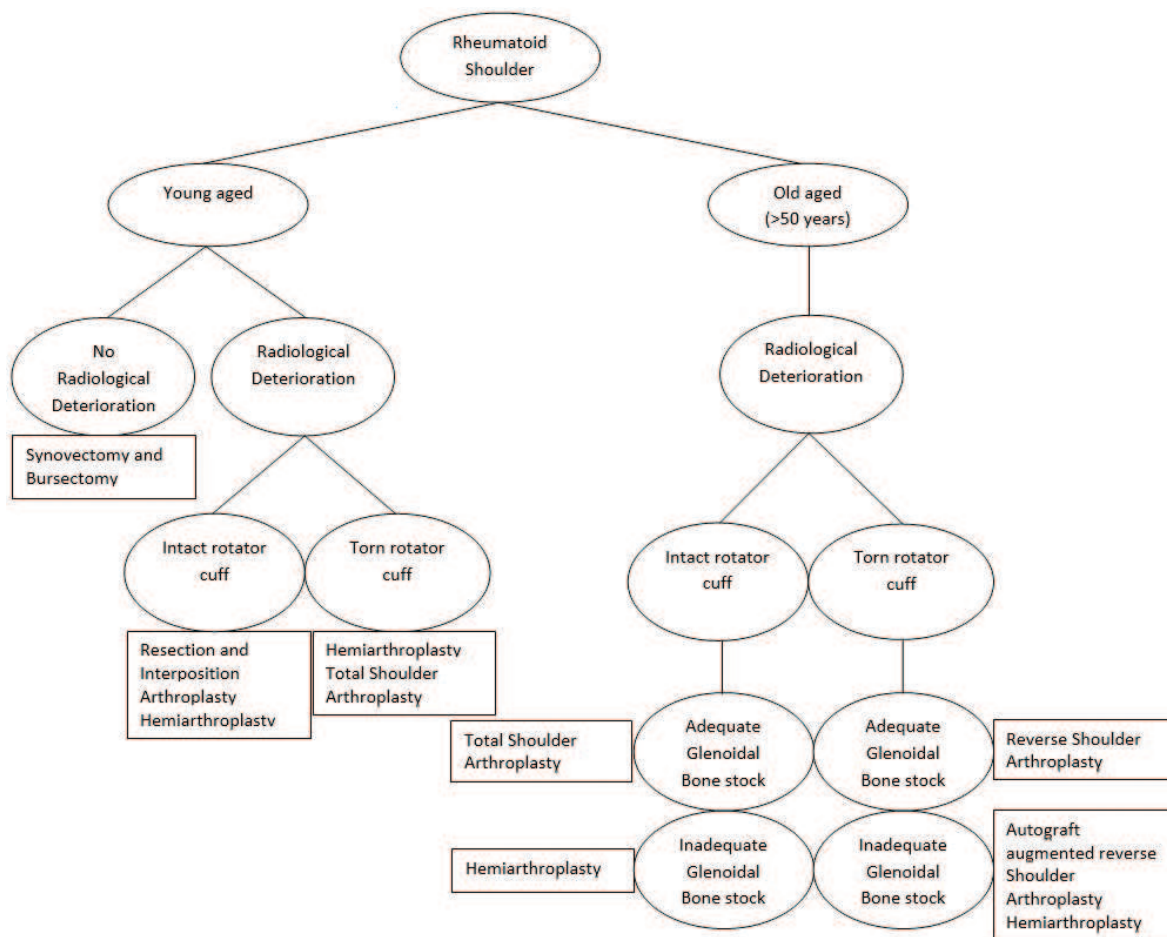
We tried to simplify the indications, advantages and disadvantages above-mentioned treatment options in **Table 7** and **Figure 5**. Main critical factors for decision making for optimal surgical treatment are patients' age, functional demand, rotator cuff status and remaining glenoid bone stock. Treatment for young-aged patients will require a long-term survival rated surgical treatments or a short-term treatment with preservation of bone stock to revise to prosthesis. If the patients' radiological evaluation is below Larsen class II, synovectomy or bursectomy may be preferred, but if it is moderately or severely deformed, rotator cuff status becomes the main identifier. If rotator cuff is intact, surgeon can prefer hemiarthroplasty or resurfacing arthroplasty which preserves glenoidal bone stock and with good survival rate. With torn rotator cuff, the situation becomes more dire, even though good functional outcomes can be achieved with anatomic TSA and rotator cuff repair, in long-term follow-up rotator cuff degeneration is inevitable which results in pain because of superior migration of prosthesis and loss of glenoidal bone stock, also tragically glenoidal component loosening due to rocking



Procedure	Pain relief	Advantages	Disadvantages	Purpose	Rotator cuff dependency	Glenoidal bone stock requirement
Synovectomy and bursectomy	Yes	<ul style="list-style-type: none"> <li>• Easy to Perform</li> </ul>	<ul style="list-style-type: none"> <li>• Unable to prevent disease progression in the joint</li> <li>• Only early stage patients can be candidates</li> </ul>	Symptomatic relief	No	No
Resection interposition arthroplasty	Controversial	<ul style="list-style-type: none"> <li>• Slows the progression of destruction</li> <li>• Protects bone stock</li> <li>• Delays arthroplasty requirement</li> </ul>	<ul style="list-style-type: none"> <li>• Limited range of motion</li> <li>• Humeral head resorption</li> </ul>	Convertible arthroplasty choice for the young aged	Yes	No
Resurfacing arthroplasty	Yes	<ul style="list-style-type: none"> <li>• Protects bone stock</li> <li>• High satisfaction rates</li> <li>• Lower glenoid erosion rate than HA</li> </ul>	<ul style="list-style-type: none"> <li>• Superior migration</li> <li>• High radiological loosening</li> </ul>	Protects bone stock with good functional results and enables future revision options	Yes (with intact RC, lower rate of complication)	No
Hemiarthroplasty	Yes	<ul style="list-style-type: none"> <li>• Stable glenohumeral joint</li> <li>• Convertible to TSA</li> <li>• Good functional outcome</li> <li>• Low loosening rates</li> </ul>	<ul style="list-style-type: none"> <li>• Painful glenoid erosion</li> <li>• Decreased satisfaction rates after 10 years</li> </ul>	Pain relief without losing glenoid bone stock	No (with intact RC, better functional outcomes)	No
Total shoulder arthroplasty	Yes	<ul style="list-style-type: none"> <li>• Stable glenohumeral joint</li> <li>• Better functional outcome than HA</li> <li>• Prevents the progression of destruction</li> </ul>	<ul style="list-style-type: none"> <li>• Decreased functional outcome after deterioration of RC</li> <li>• Concern of glenoidal loosening</li> </ul>	To achieve better glenohumeral joint alignment and functional outcome	Yes	Yes
Reverse shoulder arthroplasty	Yes	<ul style="list-style-type: none"> <li>• Good functional outcomes even after RC tear occurs</li> <li>• High satisfaction rates</li> </ul>	<ul style="list-style-type: none"> <li>• Complicated revision surgery</li> <li>• No alternative arthroplasty</li> </ul>	To achieve good functional outcomes even after RC tear occurs	No	Yes

*Abbreviations:* HA, hemiarthroplasty; TSA, anatomical total shoulder arthroplasty; RC, rotator cuff.

**Table 7.** Brief comparison of treatment modalities in rheumatoid arthritic shoulder.



**Figure 5.** A treatment strategy for the surgical treatment of rheumatoid shoulder [50].

horse phenomenon. RSA can be an option but literature lacks young-aged patients' outcomes. Recently, researches about RSA are focused on the daily functioning of patients and the results are promising. It can be foreseen that RSA age limit will be lowered in the future. In old-aged (>50 years) patients' radiological evaluation is mostly advanced to Larson class III. Main indicators are still rotator cuff and glenoidal bone stock for decision making. If the rotator cuff is intact and adequate glenoidal bone stock is present, TSA will be the optimal choice with long-term survival and good functional outcome. But if the glenoid bone stock is inadequate, hemiarthroplasty may be the optimal choice, also TSA with autograft use from humeral head would promise a better functional demand in these groups of patients. With the degeneration of the rotator cuff, surgical options narrow down to hemiarthroplasty and RSA. If glenoidal bone stock is adequate RSA would be optimal, but with inadequate glenoid bone stock, hemiarthroplasty still provides good functional demand but not better than autograft supported RSA. Even though these treatment indications are disputed, they will provide useful information for the surgeon dealing with RA.

The decision making of a RA patient with shoulder pain is still a challenging concept. Not because of the mentioned criteria but also for the disease nature, lower extremity concerns which might have led the patient to use upper extremity for mobilization by an apparatus.

Thus the shoulder surgery might cause an immobilization and further decrease the quality of life for the patient. Consultation and working together with a rheumatologist for following-up is essential for the patient's health status because of cessation of RA drugs preoperatively and following-up postoperatively. Decision making process must be made according to other concerns and needs of the patient and discussed thoroughly with the patient and also his/her rheumatologist.

## Author details

Nuri Aydin<sup>1</sup>, Lercan Aslan<sup>2\*</sup>, Janne Lehtinen<sup>3</sup> and Vedat Hamuryudan<sup>4</sup>

\*Address all correspondence to: lercan.aslan86@gmail.com

1 University of Istanbul, Cerrahpasa Medical School, Department of Orthopedics and Traumatology, Turkey

2 Bitlis State Hospital, Department of Orthopaedics and Traumatology, Turkey

3 Hatanpää Hospital, Department Chief of Orthopaedics and Traumatology, Tampere, Finland

4 University of Istanbul, Cerrahpasa Medical School, Department of Rheumatology, Turkey

## References

- [1] Cuomo F, Greller MJ, Zuckerman JD. The rheumatoid shoulder. *Rheumatic Diseases Clinics of North America*. 1998;**24**(1):67-82
- [2] Heldt C, Listing J, Sozeri O, Blasing F, Frischbutter S, Muller B. Differential expression of HLA class II genes associated with disease susceptibility and progression in rheumatoid arthritis. *Arthritis and Rheumatism*. 2003;**48**(10):2779-2787
- [3] Arnett FC, Edworthy SM, Bloch DA, et al. Differentiation from rheumatoid arthritis, causes of pain, treatment. *Postgraduate Medicine*. 1990;**87**:66-78
- [4] Rose HM, Ragan C, et al. Differential agglutination of normal and sensitized sheep erythrocytes by sera of patients with rheumatoid arthritis. *Proceedings of the Society for Experimental Biology and Medicine*. 1948;**68**:1-6
- [5] van der Helm-van Mil AH, Huizinga TW. Advances in the genetics of rheumatoid arthritis point to subclassification into distinct disease subsets. *Arthritis Research & Therapy*. 2008;**10**:205
- [6] Stahl EA, Raychaudhuri S, Remmers ER, et al. Genome-wide association study meta-analysis identifies seven new rheumatoid arthritis risk loci. *Nature Genetics*. 2010;**42**:508-514

- [7] Pincus T, Gibson KA, Shmerling RH. An evidence based approach to laboratory tests in usual care of patients with rheumatoid arthritis. *Clinical and Experimental Rheumatology*. 2014;**32**(85):23-28
- [8] Okada Y, Wu D, Trynka G, et al. Genetics of rheumatoid arthritis contributes to biology and drug discovery. *Nature*. 2014;**506**:376-381
- [9] Zheng X, Suzuki M, Zhang M, et al. RNAi, mediated CD-40-CD154 interruption promotes tolerance in autoimmune arthritis. *Arthritis Research & Therapy*. 2010;**12**:R13
- [10] Garber K. Pfizer's first in class JAK inhibitor pricey for rheumatoid arthritis market. *Nature Biotechnology*. 2013;**31**:3-4
- [11] Jones SA, Scheller J, Rose-John S. Therapeutic strategies for the clinical blockade of IL-6/gp130 signalling. *The Journal of Clinical Investigation*. 2011;**121**:3375-3383
- [12] Bos WH, Ursum J, deVries N, et al. The role of the shared epitope in arthralgia with anticyclic citrullinated peptide antibodies (anti-CCP), and its effect on anti-CCP levels. *Annals of the Rheumatic Diseases*. 2008;**67**:1347-1350
- [13] Hensvold AH, Magnusson PK, Joshua V, et al. Environmental and genetic factors in the development of anticitrullinated protein antibodies (ACPAs) and ACPA-positive rheumatoid arthritis: An epidemiological investigation in twins. *Annals of the Rheumatic Diseases*. 2013;**74**:375-380
- [14] Jutley G, Karim R, Buckley CD. New pathogenic insights into rheumatoid arthritis. *Current Opinion in Rheumatology*. 2015;**27**(3):249-255
- [15] Demoruelle MK, Weisman MH, Simonian PL, et al. Brief report: Airways abnormalities and rheumatoid arthritis related autoantibodies in subjects without arthritis: Early injury or initiating site of autoimmunity? *Arthritis and Rheumatism*. 2012;**64**:1756-1761
- [16] Machold KP, Stamm TA, Eberl GJ, Nell VK, Dunky A, et al. Very recent onset arthritis: Clinical, laboratory, and radiological findings during the first year of the disease. *The Journal of Rheumatology*. 2002;**29**:2278-2287
- [17] Alehata D, Neogi T, Silman AJ, et al. Rheumatoid arthritis classification criteria. *Arthritis and Rheumatism*. 2010, 2010;**62**(9):2569-2581
- [18] Gibofsky A, Cannon GW, Harrison DJ, et al. Discontinuation of disease-modifying antirheumatic drugs and clinical outcomes in the Rheumatoid Arthritis DMARD Intervention and Utilization Study 2 (RADIUS 2). *Clinical and Experimental Rheumatology*. 2015 Feb 18 ( Epub ahead of print)
- [19] Dongen V, Van Aken J, Lard LR, et al. Efficacy of methotrexate treatment in patients with probable rheumatoid arthritis: A double-blind, randomized, placebo-controlled trial. *Arthritis and Rheumatism*. 2007;**56**:1424-1432
- [20] Arnett FC, Edworthy SM, Bloch DA, et al. The American Rheumatism Association 1987 revised criteria for classification of rheumatoid arthritis. *Arthritis and Rheumatism*. 1988;**31**:315-324

- [21] Fukae J, Isobe M, Kitano A, Henmi M, Sakamoto F, Narita A, et al. Radiographic prognosis of finger joint damage predicted by early alteration in synovial vascularity in patients with rheumatoid arthritis: Potential utility of power Doppler sonography in clinical practice. *Arthritis Care & Research (Hoboken)*. 2011;**63**:1247-1253
- [22] Yoshimi R, Hama M, Takase K, Ihata A, Kishimoto D, Terauchi K, et al. Ultrasonography is a potent tool for the prediction of progressive joint destruction during clinical remission of rheumatoid arthritis. *Modern Rheumatology*. 2013;**23**:456-465
- [23] Suzuki T, Horikoshi M, Sugihara M, Hirota T, Ogishima H, Umeda N, et al. Therapeutic efficacy of tocilizumab in patients with rheumatoid arthritis refractory to anti-tumor-necrosis-factor inhibitors: 1 year follow-up with low-field extremity MRI. *Modern Rheumatology*. 2013;**23**:782-787
- [24] Yonemoto Y, Okamura K, Kobayashi T, Kaneko T, Okura C, Suto T, Tachibana M, Tsushima Y, Takagishi K. Predictive factors related to shoulder joint destruction in rheumatoid arthritis patients treated with biologics: A prospective study. *Modern Rheumatology*. 2017;**27**(4):587-592
- [25] Schill S, Thabe H, Grifka J. Differentialtherapie der rheumatischen Schulter. *Orthopade*. 2002;**31**:1132-1144
- [26] Mont MA, Payman RK, Laporte DM, Petri M, et al. Atraumatic osteonecrosis of the humeral head. *The Journal of Rheumatology*. 2000;**27**:1766-1773
- [27] Subramaniam R, Tan JW, Chau CY, Lee KT. Subacromial bursitis with giant rice bodies as initial presentation of rheumatoid arthritis. *Journal of Clinical Rheumatology*. 2012;**18**(7):352-355. DOI: 10.1097/RHU.0b013e3182677023
- [28] Schiavon F, Ragazzi R. Bilateral scapulothoracic bursitis. *Arthritis and Rheumatism*. 2008;**58**(2):585. DOI: 10.1002/art.23197
- [29] Lehtinen JT, Kaarela K, Belt EA, Kautiainen HJ, Kauppi MJ, Lehto MUK. Relation of glenohumeral and acromioclavicular joint destruction in rheumatoid shoulder. A 15 year follow up study. *Annals of the Rheumatic Diseases*. 2000;**59**:158-160
- [30] Kanazawa T, Nishino J, Tohma S, Tanaka S. Analysis of the affected joints in rheumatoid arthritis patients in a large Japanese cohort. *Modern Rheumatology*. 2013;**23**(1):44-49. DOI: 10.1007/s10165-012-0636-7
- [31] Hambright D, Henderson R, Cook C, Worrel T, Moorman CT, Bolognesi MP. A comparison of perioperative outcomes in patients with and without rheumatoid arthritis after receiving a total shoulder replacement arthroplasty. *Journal of Shoulder and Elbow Surgery*. 2011;**20**:77-85
- [32] Olofsson Y, Book C, Jacobson LT. Shoulder joint involvement in patients with newly diagnosed rheumatoid arthritis. Prevalance and associations. *Scandinavian Journal of Rheumatology*. 2003;**32**:25-32
- [33] Van der Zwaal P, Pijls BG, Thomassen BJW, Lindenburg R, Nelissen RGHH, Van de Sande MAJ. The natural history of the rheumatoid shoulder a prospective long-term



- follow-up study. *Journal of Bone and Joint Surgery (British)*. 2014;**96-B**:1520-1524. DOI: 10.1302/0301-620X.96B11
- [34] Kojima T, Ishikawa H, Tanaka S, Haga N, Nishida K, Yukioka M, Hashimoto J, Miyahara H, Niki Y, Kimura T, Oda H, Asai S, Funahashi K, Kojima M, Ishiguro N. Characteristics of functional impairment in patients with long-standing rheumatoid arthritis based on range of motion of joints: Baseline data from a multicentre prospective observational cohort study to evaluate the effectiveness of joint surgery in the treat-to-target era. *Modern Rheumatology*. 2017;**25**:1-8. DOI: 10.1080/14397595.2017.1349593
- [35] Lehtinen JT, Lehto MU, Kaarela K, et al. Radiographic joint space in rheumatoid glenohumeral joints. A 15-year prospective follow-up study in 74 patients. *Rheumatology (Oxford)*. 2000;**39**:288-292
- [36] Larsen A, Dale K, Eek M. Radiographic evaluation of rheumatoid arthritis and related conditions by standard reference films. *Acta Radiologica: Diagnosis*. 1977;**18**(4):481-491
- [37] Amin MF, Ismail FM, Shereef RR. The role of ultrasonography in early detection and monitoring of shoulder erosions, and disease activity in rheumatoid arthritis patients; comparisons with MRI examination. *Academic Radiology*. 2012;**19**(6):693-700. DOI: 10.1016/j.acra.2012.02.010
- [38] Lapner PL, Jiang L, Zhang T, Athwal GS. Rotator cuff fatty infiltration and atrophy are associated with functional outcomes in anatomic shoulder arthroplasty. *Clinical Orthopaedics and Related Research*. 2015;**473**(2):674-682. DOI: 10.1007/s11999-014-3963-5
- [39] Lehtinen JT, Kaarela K, Belt EA, et al. Incidence of glenohumeral joint involvement in seropositive rheumatoid arthritis. A 15-year endpoint study. *The Journal of Rheumatology*. 2000;**27**:347-350
- [40] Amundsen A, Rasmussen JV, Olsen BS, Brorson S. Mortality after shoulder arthroplasty: 30-day, 90-day, and 1-year mortality after shoulder replacement-5853 primart operations reported to the Danish Shoulder Arthroplasty registry. *Journal of Shoulder and Elbow Surgery* 2016;**25**:756-762. DOI: <http://dx.doi.org/10.1016/j.jse.2015.09.020>
- [41] Kanbe K, Inoue K. Efficacy of arthroscopic synovectomy for the effect attenuation cases of infliximab in rheumatoid arthritis. *Clinical Rheumatology*. 2006;**25**(6):877-881
- [42] Kanbe K, Chiba J, Inoue Y, Taguchi M, Iwamatsu A. Analysis of clinical factors related to the efficacy of shoulder arthroscopic synovectomy plus capsular release in patients with rheumatoid arthritis. *European Journal of Orthopaedic Surgery and Traumatology*. 2014 Dec 24 [Epub ahead of print]
- [43] Pahle JA. Synovektomie des Schulterge- lenks. *Orthopiide*. 1973;**2**:70-72
- [44] Schmidt K, Miehle RK. Mittelfristige Ergebnisse nach arthroskopischer Synovektomie des Schultergelenkes von Rheumatikern. *Aktuel Rheumatol*. 1994;**19**:148-154
- [45] Petersson CJ. Shoulder surgery in rheumatoid arthritis. *Acta Orthopaedica Scandinavica*. 1986;**57**(3):222-226

- [46] Smith AM, Sperling JW, Cofield RH. Rotator cuff repair in patients with rheumatoid arthritis. *The Journal of Bone and Joint Surgery. American Volume*. 2005;**87**(8):1782-1787
- [47] Ossyssek B, Anders S, Grifka J. Surgical synovectomy decreases density of sensory nerve fibers in synovial tissue of non-inflamed controls and rheumatoid arthritis patients. *Journal of Orthopaedic Research*. 2011;**29**(2):297-302
- [48] Pahle JA. The shoulder joint in rheumatoid arthritis: Synovectomy. *Reconstruction Surgery and Traumatology*. 1981;**18**:33-47
- [49] Wakitani S, Imoto K, Saito M, Murata N, Hirooka A, Yoneda M, Ochi T. Evaluation of surgeries for rheumatoid shoulder based on the destruction pattern. *The Journal of Rheumatology*. 1999;**26**(1):41-46
- [50] Aydin N, Aslan L, Lehtinen J, Hamuryudan V. Shoulder in rheumatoid arthritis and its surgical options. *Current Rheumatology Reviews*. 2016 [Epub ahead of print]
- [51] Fink B, Sallen V, Guderian H, Tillmann K, Rütther W. Resection interposition arthroplasty of the shoulder affected by inflammatory arthritis. *Journal of Shoulder and Elbow Surgery*. 2001;**10**(4):365-371
- [52] Milbrink J, Wigren A. Resection arthroplasty of the shoulder. *Scandinavian Journal of Rheumatology*. 1990;**19**(6):432-436
- [53] Baer WS. Arthroplasty with the aid of animal membrane. *The Journal of Bone & Joint Surgery*. 1918;**16**
- [54] Jones L. The shoulder joint: Observations on the anatomy and physiology with an analysis of a reconstructive operation following extensive injury. *Surgery, Gynecology & Obstetrics*. 1942;**75**:433
- [55] Brown BN, Chung WL, Almarza AJ, Pavlick M, Reppas S, Ochs MW, et al. An inductive, scaffold-based, regenerative medicine approach to reconstruction of the temporomandibular joint disk. *Journal of Oral and Maxillofacial Surgery*. 2012;**70**(11):2656-2668. DOI: 10.1016/j.joms.2011.12.030. Doi: 10.1016/j.joms.2011.12.030
- [56] Valentini V, Vetrano S, Agrillo A, Torroni A, Fabiani F, Iannetti G. Surgical treatment of TMJ ankyloses: Our experience (60 cases). *The Journal of Craniofacial Surgery*. 2002 Jan;**13**(1):59-67
- [57] Pignatti G, Ferrari D, Tigani D, Scardovi M, Trentanti P, Trentani F, Giunti A. The treatment of post-traumatic stiffness of the elbow. *Chirurgia Degli Organi di Movimento*. 2000;**85**(4):381-387
- [58] Strauss JM, Rütther W, Fink B, Tillmann K. Biomechanical aspects of resection-interposition-arthroplasty (RIAP). *Aktuelle Rheumatologie*. 1996;**21**:149-153
- [59] Matsen FA, Clinton J, Rockwood CA, Wirth MA, Lippitt SB. Glenohumeral arthritis and its management. In: Rockwood CA, Matsen FA, Wirth MA, Lippitt SB, Editors. *The Shoulder*. 4th ed. Philadelphia, PA. 2009. p: 1089-1246. ISBN: 978-1-4160-3427-8

- [60] Bateman JE. Arthritis of the glenohumeral joint. In: Bateman JE, editor. *The Shoulder and Neck*. Philadelphia: Saunders; 1978. p. 343-362
- [61] Copeland S, Funk L, Levy O. Surface-replacement arthroplasty of the shoulder. *Current Orthopaedics*. 2002;**16**:21-31. DOI: 10.1054/ycuor.239
- [62] Levy O, Funk L, Sforza G, Copeland SA. Copeland surface replacement arthroplasty of the shoulder in rheumatoid arthritis. *Journal of Bone and Joint Surgery*. 2004;**86**:512-518
- [63] Voorde PCT, Rasmussen JV, Olsen BS, Brorson S. Outcome in 167 patients from the Danish Shoulder Registry. *Acta Orthopaedica*. 2015;**86**(3) (Epub ahead of publishing). DOI: 10.3109/17453674.2015.10187761
- [64] Rydholm U, Sjögren J. Surface replacement of the humeral head in the rheumatoid shoulder. *Journal of Shoulder and Elbow Surgery*. 1993;**2**:286-295
- [65] Ålund M, Hoe-Hansen C, Tillander B, Hedé BÅ, Norlin R. Outcome after cup hemiarthroplasty in the rheumatoid shoulder. A retrospective evaluation of 39 patients followed for 2-6 years. *Acta Orthopaedica Scandinavica*. 2000;**71**(2):180-184
- [66] Levy O, Copeland SA. Cementless surface replacement arthroplasty of the shoulder. 5- to 10- year results with the Copeland Mark-2 prosthesis. *Journal of Bone and Joint Surgery (British)*. 2001;**83**(2):213-221
- [67] Fink B, Singer J, Lamla U, Rütther W. Surface replacement of the humeral head in rheumatoid arthritis. *Archives of Orthopaedic and Trauma Surgery*. 2004;**124**:366-373
- [68] Thomas SR, Wilson AJ, Chambler A, Harding I, Thomas M. Outcome of Copeland surface replacement shoulder arthroplasty. *Journal of Shoulder and Elbow Surgery*. 2005;**14**(5):485-491. DOI: 10.1016/j.jse.2005.02.011
- [69] Fuerst M, Fink B, Rütther W. The DUROM cup humeral surface replacement in patients with rheumatoid arthritis. *Journal of Bone and Joint Surgery*. 2007;**89**:1756-1762. DOI: 10.2106/JBJS.F.01290
- [70] Mansat P, Coutié AS, Bonneville N, Rongièrès M, Mansat M, Bonneville P. Resurfacing humeral prosthesis: Do we really reconstruct the anatomy? *Journal of Shoulder and Elbow Surgery*. 2013;**22**:612-619. DOI: 10.1016/j.jse.2012.07.014
- [71] Levy O, Tsvieli O, Merchant J, Young L, Trimarchi A, Dattani R, Abraham R, Copeland SA, Narvani A. Atoun Ehad. Surface replacement arthroplasty in patients aged younger than fifty years: Results after a minimum ten-year follow-up. *Journal of Shoulder and Elbow Surgery*. 2015;**16**. DOI: 10.1016/j.jse.2014.11.035. (Epub Ahead of Print)
- [72] Neer CS. Displaced proximal humeral fractures. Treatment of three-part and four-part displacement. *The Journal of Bone and Joint Surgery. American Volume*. 1970;**52**:1090-1103
- [73] Gadea F, Alami G, Pape G, Boileau P, Favard L. Shoulder hemiarthroplasty: Outcomes and long-term survival analysis according to etiology. *Orthopaedics & Traumatology, Surgery & Research*. 2012;**98**(6):659-665. DOI: 10.1016/j.otsr.2012.03.020

- [74] Sperling JW, Cofield RH, Schleck CD, Harmsen WS. Total shoulder arthroplasty versus hemiarthroplasty for rheumatoid arthritis of the shoulder: Results of 303 consecutive cases. *Journal of Shoulder and Elbow Surgery*. 2007;**16**(6):683-690. Epub 2007 Oct 29
- [75] Rozing PM, Brand R. Rotator cuff repair during shoulder arthroplasty in rheumatoid arthritis. *The Journal of Arthroplasty*. 1998;**13**(3):311-319
- [76] Smith KL, Matsen FA 3rd. Total shoulder arthroplasty versus hemiarthroplasty. Current trends. *Orthopedic Clinics of North America*. 1998 Jul;**29**(3):491-506
- [77] Sneppen O, Fruensgaard S, Johannsen HV, et al. Total shoulder replacement in rheumatoid arthritis: Proximal migration and loosening. *Journal of Shoulder and Elbow Surgery*. 1992;**5**:47-52
- [78] Cofield RH, Frankle MA, Zuckerman JD. Humeral head replacement for glenohumeral arthritis. *Seminars in Arthroplasty*. 1995;**6**(4):214-221
- [79] Watson M. Bipolar salvage shoulder arthroplasty. Follow-up in 14 patients. *Journal of Bone and Joint Surgery. British Volume (London)*. 1996;**78**(1):124-127
- [80] Sperling JW, Cofield RH, Rowland CM. Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. *The Journal of Bone and Joint Surgery. American Volume*. 1998 Apr;**80**(4):464-473
- [81] Collins N, Harryman DT, Wirth MA. Shoulder arthroplasty for the treatment of inflammatory arthritis. *Journal of Bone and Joint Surgery*. 2004;**86-A**(11):2489-2496
- [82] Rees JL, Dawson J, Hand GC, Cooper C, Judge A, Price AJ, Beard DJ, Carr AJ. The use of patient-reported outcome measures and patient satisfaction ratings to assess outcome in hemiarthroplasty of the shoulder. *Journal of Bone and Joint Surgery. British Volume (London)*. 2010 Aug;**92**(8):1107-1111. DOI: 10.1302/0301-620X.92B8.22860
- [83] Rozing PM, Nagels J, Rozing MP. Prognostic factors in arthroplasty in the rheumatoid shoulder. *HSS Journal*. 2011 Feb;**7**(1):29-36. DOI: 10.1007/s11420-010-9172-1. Epub 2010 Jul 14
- [84] Wirth MA, Agrawal CM, Mabrey JD, et al. Isolation and characterization of polyethylene wear debris associated with osteolysis following total shoulder arthroplasty. *The Journal of Bone and Joint Surgery. American Volume*. 1999;**81**:29-37
- [85] Weldon EJ III, Boorman RS, Smith KL, Matsen FA III. Optimizing the glenoid contribution to the stability of a humeral hemiarthroplasty without a prosthetic glenoid. *The Journal of Bone and Joint Surgery. American Volume*. 2004;**86**(9):2022
- [86] Matsen FA III, Clark JM, Titelman RM, et al. Healing of reamed glenoid bone articulating with a metal humeral hemiarthroplasty: A canine model. *Journal of Orthopaedic Research*. 2005;**23**:18-26
- [87] Clinton J, Franta AK, Lenters TR, Mounche D, Matsen FA III. Nonprosthetic glenoid arthroplasty with humeral Hemiarthroplasty and total shoulder arthroplasty yield similar



- self-assessed outcomes in the management of comparable patients with glenohumeral arthritis. *Journal of Shoulder and Elbow Surgery*. 2007;**16**:534-538
- [88] Lynch JR, Franta AK, Montgomery Jr WH, Lenters TR, Matsen FA III. Self-assessed outcome at two to four years after shoulder hemiarthroplasty with concentric glenoid reaming. *The Journal of Bone and Joint Surgery. American Volume*. 2007;**89**:1284-1292. DOI: 10.2106/JBJS.E.00942
- [89] Gilmer BB, Comstock BA, Jette JL, Warme WJ, Jackins SE, Matsen FA III. The prognosis of improvement in comfort and function after the Ream-and-Run arthroplasty for glenohumeral arthritis. *Journal of bone and joint surgery. American volume*. 2012;**94**: e102 (1-9) d <http://dx.doi.org/10.2106/JBJS.K.00486>
- [90] Somerson JS, Wirth MA. Self-assessed and radiographic outcomes of humeral head replacement with nonprosthetic glenoid arthroplasty. *Journal of Shoulder and Elbow Surgery*. 2014:1-8
- [91] Matsen FA III. The ream and run: Not for every patient, every surgeon or every problem. *International Orthopaedics*. 2015 Feb;**39**(2):255-261. DOI: 10.1007/s00264-014-2641-2
- [92] Chen AL, Joseph TN, Zuckerman JD. Rheumatoid arthritis of the shoulder. *The Journal of the American Academy of Orthopaedic Surgeons*. 2003;**11**:12-24
- [93] Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. *The Journal of Arthroplasty*. 1999;**14**(6):756-780
- [94] Kany J, Katz D. How to deal with glenoid type B2 or C? How to prevent mistakes in implantation of glenoid component? *European Journal of Orthopaedic Surgery and Traumatology*. 2013;**23**:379-385
- [95] Barrett W, Franklin JL, Jackins SE, Wyss CR, Matsen FA. Total shoulder arthroplasty. *The Journal of Bone and Joint Surgery. American Volume*. 1987;**69A**:865-872
- [96] Barrett WP, Thornhill TS, Thomas WH, Gebhart EM, Sledge CB. Nonconstrained total shoulder arthroplasty in patients with polyarticular rheumatoid arthritis. *The Journal of Arthroplasty*. 1989;**4**:91-96
- [97] Friedmann R, Thornhill TS, Thomas WH, Sledge CB. Nonconstrained total shoulder replacement in patients who have rheumatoid arthritis and class IV function. *The Journal of Bone and Joint Surgery. American Volume*. 1989;**49A**(8):71A
- [98] Franklin JL, Barrett W, Jackins SE, Matsen FA. Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. *Journal of Arthroplasty*. 1988;**3**:39-46
- [99] Jain A, Stein BE, Skolasky RL, Jones LC, Hungerford MW. Total joint arthroplasty in patients with rheumatoid arthritis: A United States experience from 1992 through 2005. *The Journal of Arthroplasty*. 2012;**27**(6):881-888
- [100] Brems J. The glenoid component in total shoulder arthroplasty. *Journal of Shoulder and Elbow Surgery*. 1993;**2**:47-54



- [101] Boileau P, Avidor C, Krishnan SG, Walch G, Kempf JF, Mole D. Cemented polyethylene versus uncemented metal-backed glenoid components in total shoulder arthroplasty: A prospective, double-blind, randomized study. *Journal of Shoulder and Elbow Surgery*. 2002;**11**:351-359
- [102] Martin SD, Zurakowski D, Thornhill TS. Uncemented glenoid component in total shoulder arthroplasty. Survivorship and outcomes. *The Journal of Bone and Joint Surgery. American Volume*. 2005;**87**:1284-1292
- [103] Clement ND, Mathur K, Colling R, Stirrat AN. The metal-backed glenoid component in rheumatoid disease: Eight- to fourteen-year follow-up. *Journal of Shoulder and Elbow Surgery*. 2010;**19**:749-756
- [104] Betts HM, Abu-Rajab R, Nunn T, Brooksbank AJ. Total shoulder replacement in rheumatoid disease: A 16- to 23-year follow up. *Journal of Bone and Joint Surgery. British Volume*. 2009;**91-B**(9):1197-1200
- [105] Kelly IG, Foster RS, Fisher WD. Neer total shoulder replacement in rheumatoid arthritis. *Journal of Bone and Joint Surgery (British)*. 1987;**69-B**:723-726
- [106] Stewart MPM, Kelly IG. Total shoulder replacement in rheumatoid disease: 7- to 13- year follow-up of 37 joints. *Journal of Bone and Joint Surgery (British)*. 1997;**79-B**:68-72
- [107] Sneppen O, Fruensgaard S, Johannsen HV, Olsen BS, Sojbjerg JO, Andersen NH. Total shoulder replacement in rheumatoid arthritis: Proximal migration and loosening. *Journal of Shoulder and Elbow Surgery*. 1996 Jan-Feb;**5**(1):47-52
- [108] Trail IA, Nuttall D. The results of shoulder arthroplasty in patients with rheumatoid arthritis. *Journal of Bone and Joint Surgery (British)*. 2002;**84-B**:1121-1125
- [109] Barlow JD, Yuan BJ, Schleck CD, Harmsen WS, Cofield RH, Sperling JW. Shoulder arthroplasty for rheumatoid arthritis: 303 consecutive cases with minimum 5-year follow-up. *Journal of Shoulder and Elbow Surgery*. 2014;**23**(6):791-799. DOI: 10.1016/j.jse.2013.09.016
- [110] Denard PJ, Walch G. Current concepts in the surgical management of primary glenohumeral arthritis with a biconcave glenoid. *Journal of Shoulder and Elbow Surgery*. 2013;**22**:1589-1598
- [111] Kersten AD, Flores-Hernandez C, Hoenecke HR, D'Lima DD. Posterior augmented glenoid designs preserve more bone in biconcave glenoids. *Journal of Shoulder and Elbow Surgery*. 2015;**23**:1-7
- [112] Greiner S, Berth A, Kaab M, Irlenbusch U. Glenoid morphology affects the incidence of radiolucent lines around cemented pegged polyethylene glenoid components. *Archives of Orthopaedic and Trauma Surgery*. 2013;**133**:1331-1339
- [113] Boyd AD, Thomas WH, Scott RD, Sledge CB, Thornhill TS. Total shoulder arthroplasty versus hemiarthroplasty: Indications for glenoid resurfacing. *Journal of Arthroplasty*. 1990;**5**:329-336

- [114] Figgie HE, Inglis AE, Goldberg VM, Ranawat CS, Figgie MP, Wile JM. An analysis of factors affecting the long term results of total shoulder arthroplasty in inflammatory arthritis. *The Journal of Arthroplasty*. 1988;**3**:123-130
- [115] McCoy SR, Warren RF, Bade HA, Ranawat CS, Inglis AE. Total shoulder arthroplasty in rheumatoid arthritis. *The Journal of Arthroplasty*. 1989;**4**:105-113
- [116] Rittmeister M, Kerschbaumer F. Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. *Journal of Shoulder and Elbow Surgery*. 2001;**10**:17-22
- [117] van de Sande MA, de Groot JH, Rozing PM. Clinical implications of rotator cuff degeneration in the rheumatic shoulder. *Arthritis and Rheumatism*. 2008;**59**:317-324
- [118] Grammont PM, Baulot E. Delta shoulder prosthesis for rotator cuff rupture. *Orthopedics*. 1993;**16**:65-68
- [119] John M, Pap G, Angst F, Flury MP, Lieske S, Schwyzer HK, Simmen BR. Short-term results after reversed shoulder arthroplasty (Delta III) in patients with rheumatoid arthritis and irreparable rotator cuff tear. *International Orthopaedics*. 2010;**34**:71-77
- [120] Tiusanen H, Sarantsin P, Stenholm M, Mattie R, Saltychev M. Ranges of motion after reverse shoulder arthroplasty improve significantly the first year after surgery in patients with rheumatoid arthritis. *European Journal of Orthopaedic Surgery and Traumatology*. 2016;**26**:447-452
- [121] Holcomb JO, Hebert DJ, Mighell MA, Dunning PE, Pupello DR, Pliner MD, Frankle MA. Reverse shoulder arthroplasty in patients with rheumatoid arthritis. *Journal of Shoulder and Elbow Surgery*. 2010;**19**:1076-1984
- [122] Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G. Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. *Journal of Bone and Joint Surgery. American Volume*. 2006;**88**:1742-1747
- [123] Young AA, Smith MM, Bacle G, Moraga C, Walch G. Early results of reverse shoulder arthroplasty in patients with rheumatoid arthritis. *The Journal of Bone and Joint Surgery. American Volume*. 2011;**93**:1915-1923
- [124] Morris BJ, O'Connor DP, Torres D, Elkousy HA, Gartsman GM, Edwards TB. Risk factors for periprosthetic infection after reverse shoulder arthroplasty. *Journal of Shoulder and Elbow Surgery*. 2015;**24**:161-166
- [125] Liu JN, Garcia GH, Mahony G, HH W, Dines DM, Warren RF, Gulotta LV. Sports after shoulder arthroplasty: A comparative analysis of hemiarthroplasty and reverse total shoulder replacement. *Journal of Shoulder and Elbow Surgery*. 2016;**25**:920-926

