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Restoration of Internal Rotation After Reverse Shoulder Arthroplasty May Vary Depending on Etiology in Patients Younger Than 60 Years Old: A Multicenter Retrospective Study

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6 Chirurgie Orthopédique, Institut Universitaire Locomoteur et du Sport, CHU de Nice Hôpital Pasteur II, 30 Voie Romaine, 06000 Nice, France

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Authors contributions

Julien Berhouet: study design, data acquisition, statistical and data analysis, manuscript writing and editing.
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A. Jacquot: manuscript editing
Luc Favard: data acquisition, manuscript editing
P. Boileau: manuscript editing
MO. Gauci: manuscript editing

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Abstract

Background: Reverse shoulder arthroplasty (RSA) offers promising functional outcomes for young patients, yet challenges persist in restoring internal rotation (IR). This study aimed to assess the restoration of IR after RSA in patients younger than 60 years old and analyze the factors affecting IR recovery.

Methods: A retrospective multicenter study was conducted, examining the functional outcome of patients who underwent RSA, with a minimum follow-up period of 2 years. Two subgroups of patients who underwent primary RSA were analyzed separately with respect to active (AIR1): “difficult AIR1” and “easy AIR1.”

Results: The study included 136 patients (overall series) with a mean age of 51.6 years. The overall series showed statistically significant improvement in active range of motion (RoM), pain, and Constant scores, especially with active IR (p<0.01). According to etiology, statistically significant improvement (p<0.05) in active IR was observed for fracture sequelae, primary osteoarthritis, and rheumatoid arthritis, while no statistically significant improvement in internal rotation was observed for tumor, revision, and cuff tear arthropathy (p>0.05). In subgroup analysis, patients with easy AIR1 displayed a statistically significant lower body mass index and better Constant score mobility, as well as improved motion in forward elevation and active IR (p<0.05). No
statistically significant associations were found between improved IR and prosthetic design or subscapularis repair. Scapular notch, lysis of the graft, and teres minor atrophy were significantly associated with better active IR (p<0.05).

**Conclusion:** RSA improves active RoM, pain, and functional outcomes in patients under 60. However, the degree of improvement in IR may vary depending on several factors and the underlying etiologies. These insights are crucial for patient selection and counseling, guiding RSA optimization efforts.

**Keywords:** reverse shoulder arthroplasty, internal rotation, young arthritis shoulder, constant score, range of motion

**Level of evidence:** IV

**What are the new findings?**

1-Reverse shoulder arthroplasty offers promising functional outcomes for young patients under 60 years old.

2-The improvement of internal rotation may vary depending on several factors and the underlying etiologies.

3-Patients with a lower body mass index, scapular notch, graft lysis, and the status of teres minor atrophy are significantly associated with better active internal rotation.

**Introduction**

Since its inception, reverse total shoulder arthroplasty (RSA) has shown excellent functional outcomes and significantly improved the quality of life for patients, leading to its widespread acceptance as the preferred treatment for cuff tear arthropathy (CTA) [1]. In the last
decade, numerous studies have demonstrated that RSA is a reliable and safe treatment for patients younger than 65 years, showing substantial functional improvements in pain levels, range of motion (RoM), and strength. Furthermore, complication and revision rates were found to be similar to those in patients aged 70 years and older. Patient-reported outcome scores in younger patients were comparable to those in older patients, with younger patients experiencing better postoperative RoM [2–8].

Despite advances in surgical techniques and implant designs, the restoration of active internal rotation with the elbow at the side (AIR1) remains the main functional weak link of RSA [9,10]. One of the main reasons could be the medialization of the rotation center according to the Grammont prosthesis design, which leads to decreased recruitment of the remaining rotator cuff and the medial fibers of the deltoid. Although the literature has primarily focused on the recovery of external rotation, there has been comparatively less emphasis on exploring active internal rotation with the elbow at the side (AIR1), despite its importance in facilitating activities of daily living such as bathing, dressing, and maintaining perineal hygiene. To date, surgical factors such as a large diameter or eccentric design of the sphere, inferior and lateral offset for glenoid positioning, and anatomic retroversion for humeral implantation have been reported to improve results in active external and internal rotation [11,12]. The condition of the muscles, particularly the tensioning of the remaining cuff with the teres minor, as well as the 'motion room' available around the joint (especially in individuals with an obese morphotype), could affect the rotational RoM as well [13]. Therefore, these observations have mainly been provided by cadaveric studies, virtual simulations, or clinical studies enrolling patients older than 70 years [11,14–17].

The aim of this study was to assess the restoration of AIR1 after RSA in a specific population of patients younger than 60 years old. The secondary goal was to analyze the factors affecting AIR1
recovery. Our hypothesis was that, at a minimum of two years of follow-up, there would be factors influencing AIR1 recovery after RSA.
Materials and Methods

1/ Materials (overall series):

The study was approved by our institutional review board (IRB: 13B-T-SHoulder-RM). This is a retrospective multicenter study that included RSAs implanted between December 1999 and March 2016, with a minimum follow-up of 2 years. These RSAs were extracted from a database of 1,679 operations for shoulder prostheses in patients younger than 60 years old. Due to the specificity associated with RSA in revision cases, and findings that RSA for revisions tends to have poorer outcomes compared to primary RSA, this group of patients was excluded [18–20].

Clinically, the active RoM, Constant score, and testing of the rotator cuff, particularly the subscapularis, were assessed preoperatively and at a minimum follow-up of 2 years. AIR1 measurement was defined as the highest midline vertebral segment of the back that could be reached. This was then converted into a 10-point scale according to the Constant score guidelines [21].

Radiographically, the glenoid morphology was recorded on preoperative CT scans in the axial and coronal planes according to the Walch and Favard classifications, respectively [22,23]. The status of the rotator cuff, particularly the subscapularis and teres minor, was also assessed to determine whether they presented with tears or atrophy. At the longest follow-up, a radiographic analysis using an AP view was performed to evaluate the position of the baseplate relative to the inferior aspect of the glenoid (high, flush, low, very low), the presence of scapular notching according to the Sirveaux classification, and the presence of a spur and/or ossifications in the joint space [24]. In cases with a glenoid graft for lateralization, lysis of the graft was assessed.

2/ Methods:
a/ AIR1 subgroups analysis

The two largest groups in the study population, corresponding to the main indications for RSA in patients younger than 60 years old—massive cuff tear Hamada Fukuda stages 1, 2, 3 (MCT) and cuff tear arthropathy Hamada Fukuda stages 4, 5 (CTA), as well as fracture sequelae—were studied separately to identify factors that influenced AIR1 [25]. We defined two sub-groups for analysis based on postoperative AIR1 evaluated on the Constant score: 'easy AIR1' in cases of internal rotation ≥ 6 points (at the level or above the third lumbar vertebra (L3)) and 'difficult AIR1' in cases of internal rotation ≤ 5 points (below L3).

b/ Statistical analysis

The Wilcoxon signed-rank test for paired samples was used to compare differences between the last follow-up and preoperative values, while the Fisher test or the Chi-square test were used to identify relationships between variables. To compare differences between two groups, the Student t-test for unpaired data was applied for normally distributed variables, or the Mann-Whitney test was used otherwise. Only bilateral tests were used, and the alpha risk was set at 0.05.
Results

1/ Overall series (n =136):

A total of 136 patients were included in the study (Figure 1). Among these patients, 60.7% were female and 39.3% were male, with a mean age at the time of surgery of 51.6 years. The mean follow-up period was 6.5 years (24-224 months). The surgical approach was delto-pectoral in 112 cases and antero-superior in 24 cases. The prosthesis design was inlay according to the Grammont concept in 100 cases, and onlay in 36 cases. A sphere with a diameter of 36mm was used in 76% of cases, while a 42mm diameter sphere was used in 24%. The sphere design was standard in 81% of cases, while an eccentric sphere with either an inferior offset or a 10° inclination was used in 17% and 2% of cases, respectively. A glenoid graft for lateralization according to the BIO-RSA technique was used in 38% of cases. However, no information was provided about the humeral version during the surgical procedure.

There was a statistically significant improvement in the active RoM, pain levels, and Constant scores for the overall series of RSAs (p<0.01), particularly with an AIR1 reaching between the sacrum and L3. The AIR1 increased from 4.1 points to 4.8 points, an improvement of 0.7 points (p<0.01) (Table 1). According to each etiology, AIR1 showed a statistically significant improvement for fracture sequelae, primary osteoarthritis, and rheumatoid arthritis (p<0.05). Patients with fracture sequelae showed an improvement from 2 points preoperatively to 3.7 points postoperatively, an increase of 1.7 points (p<0.05). Rheumatoid arthritis patients improved from 3.1 points to 6 points, an increase of 2.9 points (p<0.05). Primary osteoarthritis patients demonstrated a statistically significant improvement from 3.3 points to 7.8 points, an increase of 4.5 points (p<0.05). However, this gain was not statistically significant for CTA, MCT, instability
arthropathy, tumors, and revisions (p>0.05). Postoperative AIR1 was poorest in cases of MCT and tumors (Table 2).

2/ RSA series according to subgroups for AIR1:

Two subgroups of patients who underwent primary RSA were analyzed separately regarding AIR1 at the mean follow-up: 'difficult AIR1' (n =63) and 'easy AIR1' (n =73) (Table 3). At inclusion, these subgroups were comparable in terms of age and sex ratio. Patients in the 'easy AIR1' subgroup exhibited a statistically significant difference with a lower body mass index (BMI) and better mobility in the Constant score, as well as improved active RoM for forward elevation and active internal rotation (p<0.05). Regarding surgical factors, the use of a graft for lateralization was statistically significantly higher in this group (p<0.05), and graft lysis was more frequently observed. Other factors previously reported to enhance active internal rotation, such as large diameter, eccentric design of the sphere, and subscapularis tear or repair, did not show any statistically significant difference (p>0.05). At the mean follow-up, all Constant score items and the range of active motion had statistically significant improvements in the 'easy AIR1' subgroup (p<0.05). The gain for AIR1 was greater than that in the 'difficult AIR1' subgroup, which showed a decrease. Scapular notching and graft lysis were associated with better AIR1 (p<0.05), while the height of the glenoid component had no effect. The atrophic status of the teres minor was associated with 'easy AIR1' (p<0.05). Other factors, such as the surgical approach, scapular spur, and ossification, did not statistically significantly affect AIR1 (p>0.05).

3/ MCT + CTA series according to subgroups for AIR1 (n =47):
Because of the lack of difference for AIR1 between MCT (5.4 points) and CTA (4.3 points), as well as because of the lack of patient numbers, those etiologies were gathered in a Hamada 1-5 group (Table 4). The mean follow-up duration was statistically significantly longer for the "easy AIR" subgroup (p<0.05). The main statistically significant factors improving AIR1 were low BMI and better pre-operative internal rotation. (p<0.05).

4/ Primary RSA for Fracture sequelae series according to subgroups for AIR1 (n =37): Analysis did not reveal any statistically significant difference for most of the preoperative, surgical, and postoperative factors that could affect AIR1 (p>0.05). The only exceptions were a high BMI and a high rate of notching, which were statistically significantly associated with 'easy AIR1' (p>0.05) (Table 5).
Discussion

The current study aimed to evaluate clinical outcomes, specifically AIR1, following RSA in patients younger than 60 years at the time of surgery. The results demonstrated a statistically significant improvement in clinical and functional outcomes, including active RoM, pain levels, and Constant scores (p<0.05), consistent with findings from previously published studies. However, these previous studies did not evaluate AIR1 (*Table 6*).

Although a statistically significant improvement in clinical and functional outcomes was observed in the overall RSA series (p<0.05), the restoration of AIR1 after RSA remains unsatisfactory (between sacrum and L3) in patients younger than 60 years old, similar to the older population. When analyzed based on etiology, the best outcomes were observed for primary osteoarthritis, rheumatoid arthritis, and fracture sequelae, while the worst outcomes were reported for tumors and MCT-CTA etiologies. Overall, preoperative RoM and functional scores, particularly the mobility item of the Constant score, were found to be predictive of restored AIR1, forward elevation, and external rotation after RSA. This finding is consistent with previously reported studies [16,26].

Prior studies have identified numerous factors that can potentially improve AIR1 following RSA. These include, but are not limited to, reducing the neck-shaft angle, increasing the glenosphere diameter, lateralizing the glenoid, tilting and translating the baseplate inferiorly, repairing the subscapularis, and adjusting the versions of the humeral and baseplate components [11,14,15,27–33]. Despite existing studies exploring these factors, some remain controversial and continue to be topics of debate [27,34–36].
In our study, we identified specific prognostic factors for restoring AIR1 after RSA. These factors include a low BMI, the presence of a scapular notch, the use of a graft and its lysis, and the atrophic status of the teres minor. The results suggest that recovery of AIR1 may depend on the available space for prosthesis movement within the joint. A low BMI has been identified as a factor for better AIR1 after RSA, consistent with previously published studies [16,37]. Eichinger et al. conducted a study to examine the potential impact of BMI on AIR1 following RSA. Their findings demonstrated an inverse correlation between BMI and AIR1 in both preoperative and postoperative settings, concluding that BMI is an independent predictor of AIR1 and that increasing BMI adversely affects the shoulder's RoM, especially AIR1 [37]. Similar findings were reported in another study, where patients with a lower BMI experienced better AIR1 compared to those with a higher BMI [16].

The association between teres minor function and AIR1 has been examined in only one study to date. Rol et al. reported that patients with absent teres minor function exhibited greater AIR1, while those with good teres minor function showed worse AIR1. The authors suggested that the teres minor might act as a passive restraint during AIR1 [16]. Consistent with these findings, our study also revealed that patients with atrophic teres minor had a better AIR1. We believe that the increased joint space provided by an atrophic teres minor may allow for greater prosthetic motion within the joint, thereby promoting improved AIR1. This same mechanism may also explain why patients with scapular notching tended to exhibit better AIR1 in our study, as the bone osteolysis associated with notching can increase joint space and promote better AIR1. A similar hypothesis could be suggested regarding the effect of the lysis of the glenoid bone graft. However, it is important to note that these observations require further future studies in order to be confirmed.
In our study, subscapularis repair, inferior positioning of the glenoid, and an inferior eccentric design of the sphere did not significantly affect AIR1 recovery, although previous studies have suggested otherwise [11,14,27–29]. This lack of significance could be attributed to the study's limited statistical power. Furthermore, the presence of a scapular spur was not significantly associated with better AIR1, contrary to previous reports [16].

Our study is subject to several limitations, including its retrospective multicenter design, which enrolled patients with varying pathologies, and the absence of a comparative group of older patients. Additionally, important criteria such as the design of the humeral component (inlay/onlay, neck shaft angle value), its retroversion positioning, and the radiographic measurement of the glenoid component's inclination are missing. Moreover, we did not analyze the frontal orientation of the scapula or its pillar morphology, which could affect the available motion room. However, the study also has several strengths. To our knowledge, it is the largest study that evaluates overall outcomes following RSA in patients younger than 60 years of age. Although the mean follow-up of 6.5 years is considered a reasonable long-term follow-up compared to previously published studies, our study was specifically aimed at evaluating AIR1. Nonetheless, further prospective studies should be conducted to assess the functional outcomes of RSA in this younger patient population.
Conclusion

RSA can provide significant improvements in active RoM, pain levels, and functional outcomes. However, the degree of improvement in AIR1 may vary depending on several factors and the underlying etiologies. These findings can be useful in guiding patient selection and counseling for RSA, as well as informing ongoing research efforts to optimize outcomes for different patient populations.
References


Figure legends and Table

Figure 1: Flowchart illustrating the process of participant selection for the study of patients who underwent reverse shoulder arthroplasty and the primary diagnosis of the series
(RSA= Reverse shoulder arthroplasty; MCT = massive cuff tear; CTA= cuff tear arthropathy)

Table 1: Comparison of active range of motion and scores for the overall series of patients who underwent reverse shoulder arthroplasty at preoperative and postoperative follow-up
(AFE= active forward elevation; AER1= active external rotation elbow at side; AIR1= active internal rotation elbow at side)

Table 2: Comparison between preoperative and postoperative range of motion of active internal rotation elbow at side (AIR1) in points according to primary diagnosis after reverse shoulder arthroplasty
(MCT HF= massive cuff tear Hamada Fukuda; CTA HF= cuff tear arthropathy Hamada Fukuda)

Table 3: The primary Reverse shoulder arthroplasty series was analyzed according to subgroups for AIR1 (difficult AIR1 vs. easy AIR1), comparing preoperative, surgical, and postoperative factors.
(RSA= Reverse shoulder arthroplasty; BMI= body mass index; AFE= active forward elevation; AER1= active external rotation elbow at side)

Table 4: Reverse shoulder arthroplasty in patients with MCT+CTA HF 1-5 was analyzed according to subgroups for AIR1 (difficult AIR1 vs. easy AIR1), comparing preoperative, surgical, and postoperative factors.
(MCT = massive cuff tear; CTA= cuff tear arthropathy; HF= Hamada Fukuda; BMI= body mass index; AFE= active forward elevation; AER1= active external rotation elbow at side; AIR1= active internal rotation elbow at side)

Table 5: Analysis of reverse shoulder arthroplasty in patients with fracture sequelae, comparing subgroups for AIR1 (difficult AIR1 vs. easy AIR1) in terms of preoperative, surgical, and postoperative factors.
(BMI= body mass index; AFE= active forward elevation; AER1= active external rotation elbow at side; AIR1= active internal rotation elbow at side)

Table 6: Published results of Reverse shoulder arthroplasty outcomes in patients younger than 65 years old.

AER= Active External rotation; AFE= Active forward elevation; Constant = Constant score; ASES = American Shoulder and Elbow Surgeons score; SSV= Subjective Shoulder Value; SST= Simple Shoulder Test; SANE= Single Assessment Numeric Evaluation; VAS= visual analog scale; pain= pain score; Strength = strength score
Table 1: Comparison of active range of motion and scores for the overall series of patients who underwent reverse shoulder arthroplasty at preoperative and postoperative follow-up

(AFEl= active forward elevation; AER1= active external rotation elbow at side; AIR1 = active internal rotation elbow at side)
<table>
<thead>
<tr>
<th>Overall series (n = 136)</th>
<th>AIR1 Pre-operative</th>
<th>AIR1 Follow-up</th>
<th>Improvement</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture sequelae ((n = 37))</td>
<td>2</td>
<td>3.7</td>
<td>1.7</td>
<td>(&lt;0.05)</td>
</tr>
<tr>
<td>MCT HF 1, 2, 3 ((n = 30))</td>
<td>5.5</td>
<td>5.2</td>
<td>-0.3</td>
<td>(&gt;0.05)</td>
</tr>
<tr>
<td>Tumor ((n = 18))</td>
<td>6.9</td>
<td>5.3</td>
<td>-1.6</td>
<td>(&gt;0.05)</td>
</tr>
<tr>
<td>CTA HF 4, 5 ((n = 17))</td>
<td>4.3</td>
<td>4.8</td>
<td>0.5</td>
<td>(&gt;0.05)</td>
</tr>
<tr>
<td>Rheumatoid arthritis ((n = 15))</td>
<td>3.1</td>
<td>6</td>
<td>2.9</td>
<td>(&lt;0.05)</td>
</tr>
<tr>
<td>Instability arthropathy ((n = 11))</td>
<td>3.5</td>
<td>5.8</td>
<td>2.3</td>
<td>(&gt;0.05)</td>
</tr>
<tr>
<td>Primary osteo-arthritis ((n = 8))</td>
<td>3.3</td>
<td>7.8</td>
<td>4.5</td>
<td>(&lt;0.05)</td>
</tr>
</tbody>
</table>

Table 2: Comparison between preoperative and postoperative range of motion of active internal rotation elbow at side (AIR1) in points according to primary diagnosis after reverse shoulder arthroplasty

\((MCT HF = \text{massive cuff tear Hamada Fukuda}; CTA HF = \text{cuff tear arthropathy Hamada Fukuda})\)
<table>
<thead>
<tr>
<th>Primary RSA series n =136</th>
<th>Difficult AIR1 n =63</th>
<th>Easy AIR1 n =73</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR1 (points) at the follow-up</td>
<td>2.2</td>
<td>7.3</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>

**Preoperative factors**

- **Sex ratio (Male/Female)**
  - Difficult AIR1: 49/51%
  - Easy AIR1: 40/60%
  - p>0.05

- **BMI (kg/m²)**
  - Difficult AIR1: 29.4
  - Easy AIR1: 24.5
  - p<0.05

- **Positive Belly-press test**
  - Difficult AIR1: 40%
  - Easy AIR1: 25%
  - p>0.05

- **Positive Lift-off test (Gerber)**
  - Difficult AIR1: 29%
  - Easy AIR1: 21%
  - p>0.05

- **AIR1 (points)**
  - Difficult AIR1: 3.1
  - Easy AIR1: 4.5
  - p<0.05

- **AFE (degrees)**
  - Difficult AIR1: 68.5
  - Easy AIR1: 86.1
  - p<0.05

- **AER1 (degrees)**
  - Difficult AIR1: 11.4
  - Easy AIR1: 14.7
  - p>0.05

- **Constant pain (points)**
  - Difficult AIR1: 5.4
  - Easy AIR1: 6.3
  - p>0.05

- **Constant activity (points)**
  - Difficult AIR1: 7
  - Easy AIR1: 7.8
  - p>0.05

- **Constant mobility (points)**
  - Difficult AIR1: 12.4
  - Easy AIR1: 16.2
  - p<0.05

- **Constant strength (points)**
  - Difficult AIR1: 2.7
  - Easy AIR1: 3.5
  - p>0.05

- **Constant total (points)**
  - Difficult AIR1: 26.9
  - Easy AIR1: 34.6
  - p>0.05

- **Subscapularis tear**
  - Difficult AIR1: 46%
  - Easy AIR1: 49%
  - p>0.05

- **Teres minor status (atrophic/normal)**
  - Difficult AIR1: 8/92%
  - Easy AIR1: 31/69%
  - p<0.05

**Surgical factors**

- **Approach (Deltopectoral/Anterolateral)**
  - Difficult AIR1: 87/13%
  - Easy AIR1: 89/11%
  - p>0.05

- **Sphere diameter (36/42)**
  - Difficult AIR1: 69/31%
  - Easy AIR1: 72/28%
  - p>0.05

- **Type of sphere (Standard/Eccentric)**
  - Difficult AIR1: 81/19%
  - Easy AIR1: 86/14%
  - p>0.05

- **Glenoid graft (yes)**
  - Difficult AIR1: 39%
  - Easy AIR1: 65%
  - p<0.05

- **Subscapularis repair (yes)**
  - Difficult AIR1: 45%
  - Easy AIR1: 51%
  - p>0.05

**Post operative factors**

- **Reoperation**
  - Difficult AIR1: 13%
  - Easy AIR1: 7%
  - p>0.05

- **AFE (degrees)**
  - Difficult AIR1: 112.8
  - Easy AIR1: 137.4
  - p<0.05

- **AER1 (degrees)**
  - Difficult AIR1: 10.6
  - Easy AIR1: 26.6
  - p<0.05

- **Gain in AIR1 (points)**
  - Difficult AIR1: -0.9
  - Easy AIR1: 2.8
  - p<0.05

- **Constant pain (points)**
  - Difficult AIR1: 9.8
  - Easy AIR1: 13
  - p<0.05

- **Constant activity (points)**
  - Difficult AIR1: 11.4
  - Easy AIR1: 15.5
  - p<0.05

- **Constant mobility (points)**
  - Difficult AIR1: 20
  - Easy AIR1: 29.8
  - p<0.05

- **Constant strength (points)**
  - Difficult AIR1: 5.4
  - Easy AIR1: 7.8
  - p<0.05

- **Constant total (points)**
  - Difficult AIR1: 46.7
  - Easy AIR1: 66
  - p<0.05

- **Glenoid height Flush/Low**
  - Difficult AIR1: 35/65%
  - Easy AIR1: 40/60%
  - p>0.05

- **Glenoid height Flush/High**
  - Difficult AIR1: 90/10%
  - Easy AIR1: 85/15%
  - p>0.05

- **Glenoid height High/Low**
  - Difficult AIR1: 6/94%
  - Easy AIR1: 10/90%
  - p>0.05

- **Notch (yes)**
  - Difficult AIR1: 26%
  - Easy AIR1: 55%
  - p<0.05

- **Scapular spur (yes)**
  - Difficult AIR1: 38%
  - Easy AIR1: 40%
  - p>0.05

- **Ossifications (yes)**
  - Difficult AIR1: 22%
  - Easy AIR1: 18%
  - p>0.05

- **Graft lysis (yes)**
  - Difficult AIR1: 29%
  - Easy AIR1: 61%
  - p<0.05

Table 3: The primary reverse shoulder arthroplasty series was analyzed according to subgroups for AIR1 (difficult AIR1 vs. easy AIR1), comparing preoperative, surgical, and postoperative factors.
(RSA = Reverse shoulder arthroplasty; BMI = body mass index; AFE = active forward elevation; AER1 = active external rotation elbow at side)
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<tr>
<th>Fracture sequelae series n =37</th>
<th>Difficult AIR1 n =25</th>
<th>Easy AIR1 n =12</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR1 (points) at the follow-up</td>
<td>2.2</td>
<td>6.8</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Mean follow-up (months)</td>
<td>75.9</td>
<td>86.2</td>
<td>p&gt;0.05</td>
</tr>
</tbody>
</table>

**Preoperative factors**

<table>
<thead>
<tr>
<th></th>
<th>Difficult AIR1</th>
<th>Easy AIR1</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex ratio (Male/Female)</td>
<td>56/44%</td>
<td>58/42%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>29.1</td>
<td>23.9</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>AIR1 (points)</td>
<td>1.7</td>
<td>2.5</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>AFE (degrees)</td>
<td>49.6</td>
<td>58.3</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>AER1 (degrees)</td>
<td>-1.82</td>
<td>-6.82</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Constant total (points)</td>
<td>22</td>
<td>19.6</td>
<td>p&gt;0.05</td>
</tr>
</tbody>
</table>

**Surgical factors**

<table>
<thead>
<tr>
<th></th>
<th>Difficult AIR1</th>
<th>Easy AIR1</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphere diameter (36/42)</td>
<td>67/33%</td>
<td>83/17%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Type of sphere (Standard/Eccentric)</td>
<td>77/23%</td>
<td>92/8%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Glenoid graft (yes)</td>
<td>44%</td>
<td>58%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Subscapularis repair (yes)</td>
<td>48%</td>
<td>27%</td>
<td>p&gt;0.05</td>
</tr>
</tbody>
</table>

**Post operative factors**

<table>
<thead>
<tr>
<th></th>
<th>Difficult AIR1</th>
<th>Easy AIR1</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFE (degrees)</td>
<td>107.6</td>
<td>131.3</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>AER1 (degrees)</td>
<td>0.8</td>
<td>12.5</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Gain in AIR1 (points)</td>
<td>-0.6</td>
<td>4.3</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Constant total (points)</td>
<td>42.6</td>
<td>58.9</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Glenoid height Flush/Low</td>
<td>29/63%</td>
<td>30/60%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Glenoid height Flush/High</td>
<td>29/4%</td>
<td>30/0%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Glenoid height High/Low</td>
<td>4/63%</td>
<td>0/10%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Notch (yes)</td>
<td>27%</td>
<td>80%</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Scapular spur (yes)</td>
<td>46%</td>
<td>46%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Ossifications (yes)</td>
<td>32%</td>
<td>36%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Graft lysis (yes)</td>
<td>20%</td>
<td>50%</td>
<td>p&gt;0.05</td>
</tr>
</tbody>
</table>

Table 5: reverse shoulder arthroplasty in patients with fracture sequelae series was analyzed according to subgroups for AIR1 (difficult AIR1 vs. easy AIR1), comparing preoperative, surgical, and postoperative factors.

(BMI= body mass index; AFE= active forward elevation; AER1= active external rotation elbow at side; AIR1= active internal rotation elbow at side)
Table 6: Published results of Reverse shoulder arthroplasty outcomes in patients younger than 65 years old.

AER= Active External rotation; AFE= Active forward elevation; Constant = Constant score; ASES = American Shoulder and Elbow Surgeons score; SSV= Subjective Shoulder Value; SST= Simple Shoulder Test; SANE= Single Assessment Numeric Evaluation; VAS= visual analog scale; pain= pain score; Strength = strength score

<table>
<thead>
<tr>
<th>Authors</th>
<th>No. of RSA</th>
<th>Av. age (yrs)</th>
<th>Av. FU (m)</th>
<th>Pre op &gt; post op AFE (°)</th>
<th>Pre op &gt; post op AER (°)</th>
<th>Pre op &gt; post op Abduction (°)</th>
<th>Functional score</th>
<th>Pre op &gt; post op</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muh et.al (2013) [4]</td>
<td>67</td>
<td>52.2</td>
<td>36.5</td>
<td>54 &gt; 134</td>
<td>10 &gt; 19</td>
<td>-</td>
<td>40 &gt; 72.4</td>
<td>7.5 &gt; 3.0</td>
<td>15%</td>
</tr>
<tr>
<td>EK et.al (2013)[5]</td>
<td>46</td>
<td>60</td>
<td>93</td>
<td>72 &gt; 119</td>
<td>27 &gt; 26</td>
<td>67 &gt; 112</td>
<td>34 &gt; 74 (Constant)</td>
<td>23 &gt; 66 (SSV)</td>
<td>37%</td>
</tr>
<tr>
<td>Sershon et.al (2014) [6]</td>
<td>36</td>
<td>54</td>
<td>33.6</td>
<td>57 &gt; 121</td>
<td>23 &gt; 30</td>
<td>-</td>
<td>24.4 &gt; 72.0</td>
<td>6.0 &gt; 2.1</td>
<td>13.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32.4 &gt; 65.8 (ASES)</td>
<td>1.4 &gt; 6.2 (SST)</td>
<td></td>
</tr>
<tr>
<td>Black et.al (2014) [18]</td>
<td>33</td>
<td>59.3</td>
<td>54.7</td>
<td>- &gt; 112</td>
<td>- &gt; 35</td>
<td>-</td>
<td>7.0 &gt; 2.1</td>
<td>19 &gt; 76 (SSV)</td>
<td>18.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- &gt; 74 (ASES)</td>
<td>- &gt; 67.3 (SST)</td>
<td></td>
</tr>
<tr>
<td>Ernstbrunner et.al (2017) [8]</td>
<td>23</td>
<td>57</td>
<td>140.4</td>
<td>64 &gt; 117</td>
<td>28 &gt; 26</td>
<td>58 &gt; 111</td>
<td>24 &gt; 59 (Constant)</td>
<td>20 &gt; 71 (SSV)</td>
<td>39%</td>
</tr>
<tr>
<td>Samuelsen et.al (2017) [2]</td>
<td>67</td>
<td>60</td>
<td>36</td>
<td>58 &gt; 132</td>
<td>20 &gt; 39</td>
<td>57 &gt; 132</td>
<td>- &gt; 62 (ASES)</td>
<td>- &gt; 5.9 (SST)</td>
<td>9%</td>
</tr>
<tr>
<td>Leathers et.al (2017) [7]</td>
<td>34</td>
<td>57</td>
<td>40.8</td>
<td>67 &gt; 133</td>
<td>24 &gt; 40</td>
<td>69 &gt; 127</td>
<td>36 &gt; 72 (ASES)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current study</td>
<td>214</td>
<td>51.6</td>
<td>78</td>
<td>75 &gt; 119</td>
<td>11.8 &gt; 15.9</td>
<td>-</td>
<td>4.7 &gt; 11.3 (pain)</td>
<td>29.1 &gt; 53.7 (Constant)</td>
<td>27%</td>
</tr>
</tbody>
</table>
1679 Operations

Age < 60 years old
Minimum follow-up > 2 years

214 RSA

n=214

<table>
<thead>
<tr>
<th>Condition</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revision</td>
<td>78</td>
</tr>
<tr>
<td>Fracture sequelae</td>
<td>37</td>
</tr>
<tr>
<td>MCT Hamada 1,2,3</td>
<td>30</td>
</tr>
<tr>
<td>Tumor</td>
<td>18</td>
</tr>
<tr>
<td>CTA Hamada 4,5</td>
<td>17</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>15</td>
</tr>
<tr>
<td>Instability arthropathy</td>
<td>11</td>
</tr>
<tr>
<td>Primary Osteoarthritis</td>
<td>8</td>
</tr>
</tbody>
</table>

Excluded: Revisions

n = 78

136 RSA

1st indication