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Predictors of dislocations after reverse shoulder arthroplasty: a study by the ASES complications of RSA multicenter research group

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Background: Instability after reverse shoulder arthroplasty (RSA) is one of the most frequent complications and remains a clinical challenge. Current evidence is limited by small sample size, single-center, or single-implant methodologies that limit generalizability. We sought to determine the incidence and patient-related risk factors for dislocation after RSA, using a large, multicenter cohort with varying implants.
Methods: A retrospective, multicenter study was performed involving 15 institutions and 24 American Shoulder and Elbow Surgeons members across the United States. Inclusion criteria consisted of patients undergoing primary or revision RSA between January 2013 and June 2019 with minimum 3-month follow-up. All definitions, inclusion criteria, and collected variables were determined using the Delphi method, an iterative survey process involving all primary investigators requiring at least 75% consensus to be considered a final component of the methodology for each study element. Dislocations were defined as complete loss of articulation between the humeral component and the glenosphere and required radiographic confirmation. Binary logistic regression was performed to determine patient predictors of postoperative dislocation after RSA.
Results: We identified 6621 patients who met inclusion criteria with a mean follow-up of 19.4 months (range: 3-84 months). The study population was 40% male with an average age of 71.0 years (range: 23-101 years). The rate of dislocation was 2.1% (n = 138) for the whole cohort, 1.6% (n = 99) for primary RSAs, and 6.5% (n = 39) for revision RSAs ($P < .001$). Dislocations occurred at a median of 7.0 weeks (interquartile range: 3.0-36.0 weeks) after surgery with 23.0% (n = 32) after a trauma. Patients with a primary diagnosis of glenohumeral osteoarthritis with an intact rotator cuff had an overall lower rate of dislocation than patients with other diagnoses (0.8% vs. 2.5%; $P < .001$). Patient-related factors independently predictive of dislocation, in order of the magnitude of effect, were a history of postoperative subluxations before radiographically confirmed dislocation (odds ratio [OR]: 19.52, $P < .001$), primary diagnosis of fracture nonunion (OR: 6.53, $P < .001$), revision arthroplasty (OR: 5.61, $P < .001$), primary diagnosis of rotator cuff disease (OR: 2.64, $P < .001$), male sex (OR: 2.21, $P < .001$), and no subscapularis repair at surgery (OR: 1.95, $P = .001$).
Conclusion: The strongest patient-related factors associated with dislocation were a history of postoperative subluxations and having a primary diagnosis of fracture nonunion. Notably, RSAs for osteoarthritis showed lower rates of dislocations than RSAs for rotator cuff disease. These data can be used to optimize patient counseling before RSA, particularly in male patients undergoing revision RSA.
Level of evidence: Level III; Retrospective; Case-Control Design; Prognosis Study

Keywords: Glenohumeral dislocation; reverse shoulder arthroplasty; multicenter; risk factors; Delphi process; instability

Expanding indications and use of reverse shoulder arthroplasty (RSA) has shown multiple unique complications.[3,4,6,23,24] Prosthesis instability and dislocation is reported as one of the most common complications after RSA and a leading cause of reoperation.[5,15,24,27] Early reports show high rates of instability after primary RSA, with some reports as high as 31%.[8,9,11,14,26] However, recent evidence suggests that instability rates are much lower. Kang et al[13] reported a dislocation rate of less than 1%. A recent systematic review identified a cumulative rate of 3.3% (n = 308/9306), 2.5% for primary RSA (n = 168/6607), and 5.7% for revision RSA (n = 80/1404), with the majority (73.5%) of dislocations receiving component revision in the early, less than 90-day, period.[24]

Instability and dislocation after RSA are multifactorial and can be caused by a number of patient, implant, and surgical factors. Previously identified patient-specific risk factors include body mass index (BMI) > 30 kg/m^2, male sex, prior surgery, subscapularis integrity, bone deficiency of the proximal humerus, prior trauma, and deltoid deficiency.[1,12,19] Surgical factors identified in prior studies include inappropriate soft-tissue tensioning and implant sizing, malposition including humeral version and glenoid inclination, mechanical impingement, lack of subscapularis repair, and deltopectoral approach.[7,17,25] Implant-specific factors previously identified include implant design and asymmetric liner wear.[3,6,11] The cause of instability also varies over time, with early dislocations (<90 days) having greater association with patient and surgical factors, whereas late dislocations (>90 days) have greater association with liner wear, liner dissociation, or impingement.[3,6,11]

It is important to understand both risk factors and etiology of instability after RSA as this can dictate appropriate and effective treatments. Furthermore, understanding patient risk factors for dislocation after RSA is important in perioperative patient counseling and longitudinal monitoring. Although risk factors have been previously identified, most current evidence is limited by studies with small or inadequate sample sizes and single-surgeon and single-center evaluations with questionable generalizability. The purpose of this study by the American Shoulder and Elbow Surgeons (ASES) Complications After RSA study group was to determine the incidence of dislocation after RSA and describe patient-related risk factors contributing to this instability through a large, multicenter patient cohort.

Methods

Study design

This is a retrospective cohort study using data on primary and revision RSA performed between January 2013 and June 2019 at 15 institutions across the United States. Study definitions, inclusion criteria, and variables for study were determined using the Delphi method. A total of 24 surgeon members of the ASES contributed cases and contributed to the Delphi process. Inclusion criteria of our study cohort included patients receiving primary or revision RSA with minimum 3-month follow-up. Patients with clinical and radiographic evidence of dislocation, defined as complete loss of articulation between the humeral component and glenosphere, were included for further analysis. Suspected dislocations required radiographic confirmation to be classified as such and included in the study cohort.

Delphi method

The Delphi method was an iterative survey distributed amongst the 24 participating ASES surgeons. The Delphi process was used to reach group consensus regarding all key term definitions, data collection factors (demographic factors, comorbidities, etc), and study design components (study period, minimum follow-up required, etc), as previously published.[16] Consensus was defined as a minimum of 75% agreement among the 24 participating surgeons on each item of the methodology. Anonymity was maintained throughout the iterative process to minimize bias.

The definition for dislocation after RSA was determined through iterative surveys to be the complete loss of articulation between the humeral component and glenosphere, confirmed radiographically with X-ray or computed tomography. An example of normal and dislocated shoulders after RSA is shown in Fig. 1.

Responses were recorded for both closed and open-ended questions in each round, and written responses from participants were further included in iterative rounds. Results were presented to the entire group after iterative rounds. There was no contributory attrition between rounds from participants.

The patient factors determined to contribute to risk of dislocation after RSA through the Delphi process included age, sex, BMI, smoking status, follow-up duration, presence of osteoporosis, presence of inflammatory arthritis, history of prior shoulder ipsilateral surgery, revision shoulder arthroplasty, presence of an os acromiale, subjective history of subluxation as determined through history and patient questioning, lack of subscapularis repair at the time of last surgery, and primary diagnosis/surgical indication (acute fracture, rotator cuff insufficiency, chronic dislocation, malunion, nonunion, and other). Subluxation was further defined as patients' subjective sensation of instability occurring at any follow-up period after RSA, initiated by either patient complaint or surgeon questioning, without demonstrable dissociation of the implant on plain radiographs. Subjective instability and subluxation have been previously described after RSA.[25]

Statistical analysis

Data were analyzed for normality, and parametric or nonparametric testing was performed as appropriate. Data were presented as mean and standard deviation for continuous variables, or number of patients and percentages for categorical variables. Average time after surgery when dislocation occurred was presented as a median and interquartile range to avoid any misleading effects due to outliers. Variables determined as important by the Delphi process were compared for patients with and without confirmed dislocation. Categorical variables were analyzed using Pearson χ^2 tests and continuous variables were assessed by Wilcoxon tests. A binary logistic regression analysis was performed on patient factors to determine variables predictive of dislocation after RSA. Interaction effects were analyzed to determine if the effect of subscapularis repair on dislocation was different based on the surgery being primary vs. revision. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Partial effects plots were produced for significant variables predicting dislocation after RSA. Statistical analysis was performed using R (R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 6621 patients were included for analysis. There were 138 patients who met Delphi process definitions of dislocation for a cumulative incidence of 2.1%. The average follow-up was 19.4 months (range: 3-84 months) and did not differ significantly between dislocation and no dislocation groups. Patients with a dislocation were younger (68.6 ± 8.2 vs. 70.9 ± 8.6; $P < .001$) and were more likely to be male (57% [n = 79/138] vs. 39% [n = 2547/6483]; $P < .001$). A total of 6019 patients received a primary RSA, of whom 99 (1.6%) developed a dislocation. Revision arthroplasty surgery accounted for 601 patients, of whom 59 (6.5%) developed a dislocation, and was significantly different when compared with primary RSA ($P < .001$). Prior, ipsilateral shoulder surgery of

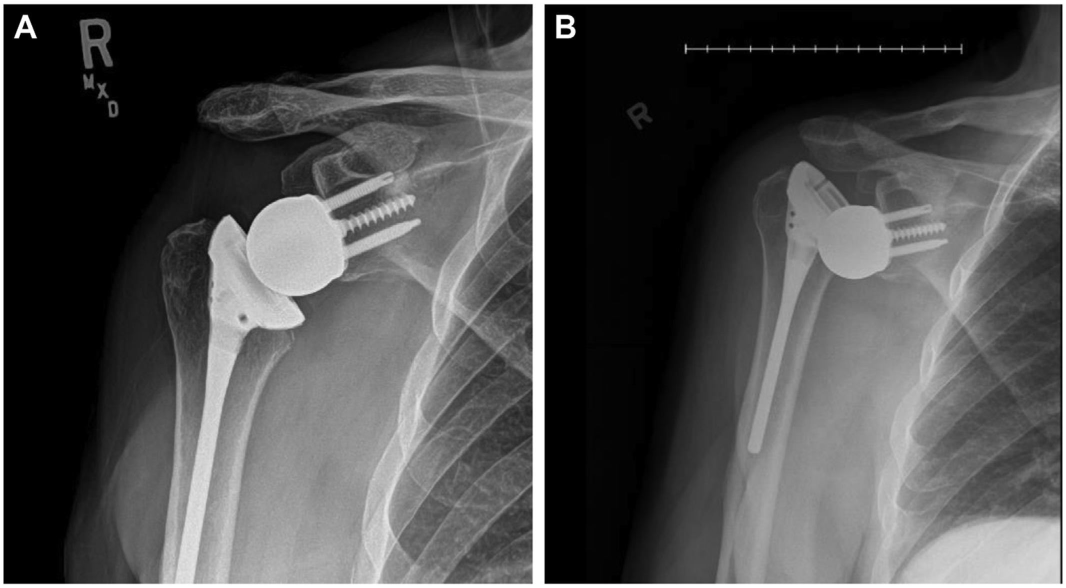

Figure 1 (**A**) Postoperative radiograph of a reverse shoulder arthroplasty. (**B**) Radiographically confirmed postoperative dislocation showing a dissociation of the humeral and glenoid components.

any kind occurred in 2169 and differed significantly between the dislocation (n = 59/138; 42.8%) and no dislocation (n = 2110/6483; 32.5%) (P = .012) groups. By diagnosis, rotator cuff disease, including rotator cuff arthropathy and massive rotator cuff tears without arthritis, was associated with the most dislocations (51%; n = 70/138) followed by glenohumeral osteoarthritis (GHOA) with intact rotator cuff (10%; n = 14/138), nonunion (9%; n = 12/138), acute fracture (3%; n = 4/138), and malunion (1%; n = 2/138). The rate of dislocation in patients with a primary diagnosis of GHOA (0.8%, n = 14/1685) was significantly lower than those with a primary diagnosis other than GHOA (2.5%; n = 124/4936) (P < .001) (Table I).

Dislocations occurred at a median of 7.0 weeks (interquartile range [IQR]: 3.0-36.0 weeks) after surgery. Traumatic dislocations accounted for 23% (n = 32/138) of the total dislocations in any period. Eighteen (n = 18/54; 33%) traumatic dislocations occurred in the late dislocation group (>90 days postoperatively), and 14 (n = 14/84; 17%) occurred traumatically in the early dislocation group (<90 days postoperatively). Ninety-eight (n = 98/138; 71%) dislocations were considered atraumatic in nature, accounting for 57.4% (n = 31/54) of the cases in the late dislocation group and 79.8% (n = 67/84) in the early dislocation group.

Dislocation risk factors

Patient-related factors independently predictive of dislocation, in order of the magnitude of significance, were a history of subluxations (OR: 19.5, 95% CI: 12.00-31.75), primary diagnosis of fracture nonunion (OR: 6.5, 95% CI: 2.83-15.03), revision arthroplasty (OR: 5.6, 95% CI: 2.93-10.74), primary diagnosis of rotator cuff disease (OR: 2.64, 95% CI: 1.57-4.43), male sex (OR: 2.2, 95% CI: 1.48-3.30), and no subscapularis repair at surgery (OR: 1.95, 95% CI: 1.30-2.94). The interaction effect of case type (primary vs. revision) on subscapularis repair as a predictor of dislocation was found not significant (P = .360) and therefore was excluded from the final regression. Other variables of age, BMI, follow-up period, acute fracture, chronic dislocation, malunion, and previous ipsilateral shoulder surgery did not contribute significantly to the model (Table II).

Discussion

Through a large, multicenter study comprising 24 ASES surgeon members, the incidence of dislocation after RSA was shown to be 2.1%, with nonmodifiable patient factors and surgical indications providing the greatest contributions to the predictive model. Patient-provided history of postoperative subluxation was most predictive of dislocation, with an almost 20 times risk compared with patients not describing this phenomenon. Surgical indications including nonunion, revision arthroplasty, and computed tomography angiography (CTA) were also significantly predictive. Combinations of these patient factors are frequently encountered in clinical practice, and surgeons should be aware of these individual and combined risk factors for preoperative risk discussions and longitudinal monitoring.

Our incidence of 2.1% is in agreement with prior published systematic reviews and incorporates the largest to-date pooled patient cohort across 15 surgical sites using a

Table I Baseline characteristics of cohort

Parameter	No dislocation (n = 6483)	Dislocation (n = 138)	*P* value
BMI	30.2 ± 6.7	31.3 ± 6.6	.012*
Age, yr	70.9 ± 8.6	68.6 ± 8.2	<.001*
Male sex	2547 (39)	79 (57)	<.001*
Smoking status			
Never	3418 (55)	69 (54)	.830
Former	2365 (38)	51 (40)	
Current	463 (7)	8 (6)	
Follow-up (mths)	19 ± 16	21 ± 18	.380
Presence of osteoporosis	823 (13)	18 (13)	.900
Presence of inflammatory arthritis	694 (11)	18 (13)	.360
History of prior ipsilateral shoulder surgery	2108 (33)	59 (43)	.012*
Revision arthroplasty	562 (9)	39 (28)	<.001*
Presence of os acromiale	200 (3)	7 (5)	.250
History of postoperative subluxation	94 (1)	37 (27)	<.001*
No subscapularis repair at surgery	1768 (28)	62 (50)	<.001*
Primary diagnosis			
Other	2599 (40)	50 (36)	<.001*
Acute fracture	305 (5)	4 (3)	
Cuff disease	3209 (49)	70 (51)	
Chronic dislocation	59 (1)	0	
Malunion	158 (2)	2 (1)	
Nonunion	153 (2)	12 (9)	

BMI, body mass index.
Data are presented as mean ± standard deviation and n (%), which represents frequencies and proportions; subluxation defined as instability without radiographic evidence of dislocation.
* Denotes statistical significance with α-risk set at .05.

variety of implants. Dislocations occurred at a median of 7.0 weeks (IQR: 3.0-36.0 weeks) after surgery. Eighty-four patients (60%) had dislocations in the early (<90-day) period (median: 4, IQR: 2.0-6.0 weeks), whereas 54 (40%) had dislocations in the late (>90-day) period (median: 73.2, IQR: 24.0-155.5 weeks). The time of dislocation was comparable to previously published values (mean: 9.6 weeks, range: 3.4-24 weeks), with the majority occurring in the early postoperative period.[7,9,11,18]

Our binary model identified patient-specific risk factors including male sex (OR: 2.21, 95% CI: 1.48-3.30), revision arthroplasty (OR: 5.61, 95% CI: 2.93-10.74), and proximal humerus nonunion (OR: 6.53, 95% CI: 2.83-15.03) similar to those previously published.[7,12,18] A recent meta-analysis provided pooled ORs for these variables (male sex OR: 3.78, 95% CI: 1.73-8.28; revision arthroplasty OR: 4.01, 95% CI: 2.14-7.58; proximal humerus nonunion OR: 8.83, 95% CI: 3.62-21.55) similar in magnitude when considering 3810 patients across 12 studies.[7] In contrast to other studies, both patient age and BMI were not significant in our binary model.[9,19] Prior studies using smaller patient cohorts have rationalized that these factors were significant due to both expected patient activity level and lever arm, respectively. Cuff tear arthropathy was seen as an independent risk factor for dislocation when compared with other diagnoses with intact rotator cuff (OR: 2.64, 95% CI: 1.57-4.43) in our binary regression. This is in contrast to Padegimas et al,[19] who described CTA as protective against dislocation (OR: 0.025; $P = .008$) in their single institutional series of 15 dislocations across 487 included RSAs (primary and revision). Patients with CTA exhibit significantly worse patient-reported outcome measures including ASES score and overall range of motion when compared with patients with primary GHOA and intact rotator cuff.[22] Biomechanically, humeral socket and glenosphere compression through arc of motion is dependent on appropriate soft-tissue tensioning. Regardless of implant type, the presence of a rotator cuff and capsular tissues add additional soft-tissue stability and constraint. Counseling patients presenting with CTA should include expectation management and added discussion of risk of dislocation and possible revision surgeries.

Subscapularis repair at the time of surgery has been variably implicated in RSA instability. Our binary model indicated that subscapularis repair significantly reduced the risk of dislocation (OR: 1.95, 95% CI: 1.30-2.94), though had a more moderate effect than other reports. Borbas et al[7] showed in a meta-analysis a pooled odds of over 18 times risk when compared with patients not receiving subscapularis repair. The added anterior soft-tissue constraint from subscapularis repair likely adds stability in preventing anterior dislocation, the most common type of RSA

Table II Predictors of dislocation after RSA

Parameter	OR (95% CI)	*P* value
Male vs. female	2.21 (1.48-3.30)	<.001*
Revision vs. primary	5.61 (2.93-10.74)	<.001*
No subscapularis repair	1.95 (1.30-2.94)	.001*
History of postoperative subluxation	19.52 (12.00-31.75)	<.001*
Acute fracture vs. other diagnosis	2.77 (0.92-8.33)	.069
Cuff disease vs. other diagnosis	2.64 (1.57-4.43)	<.001*
Chronic dislocation vs. other diagnosis	0.01 (0.00-1.37 $\times$ 10^{16})	.815
Malunion vs. other diagnosis	1.66 (0.37-7.44)	.510
Nonunion vs. other diagnosis	6.53 (2.83-15.03)	<.001*

RSA, reverse shoulder arthroplasty; *subluxation*, instability without radiographic evidence of dislocation; *OR*, odds ratio; *CI*, confidence interval.
* Denotes statistical significance with α-risk set to .05.

dislocation. In contrast to our findings, Roberson et al[21] described no significant difference in patient-reported outcome measures or dislocation rates in a case-control, retrospective series of 58 patients receiving subscapularis repair and 41 without repair. Frequently, the subscapularis may become nonfunctional and irreparable in revision surgeries. Our series demonstrated a higher overall dislocation rate in revision RSA procedures, potentially indicating the absence of an anterior soft-tissue constraint provided by the subscapularis, though in these settings, there are additional surgical factors that may contribute to overall instability including the overall rotator cuff integrity, associated tuberosity and/or proximal humeral bone loss, soft tissue tensioning provided by implant offset, overall implant orientation, and anterior deltoid function. Revision RSA procedures have been previously reported to yield a greater incidence of neurologic injury compared with primary RSA. Through a systematic review of 4135 shoulders, Shah et al[23] found neurologic injury incidence levels of 1.1% and 0.4% for revision and primary RSA procedures, respectively ($P = .03$). Although we did not see any overt axillary nerve palsies or anterior deltoid deficiencies after revision as a cause of instability, these are important factors for surgeons to consider as they can result in loss of compression to the implant.

Proximal humeral bone loss, resorption, or nonunion after fracture has been shown as an independent risk factor for dislocation in other studies as well as ours.[11,12,20] A systematic review by Borbas et al[7] demonstrated that 75% of patients with RSA instability had resorbed or nonunion of the greater tuberosity. Our results reflect this, with a large and significant effect of tuberosity nonunion on the incidence of dislocation (OR: 6.53, 95% CI: 2.83-15.03). Edwards et al[10] reported that subscapularis insufficiency occurred more in proximal humeral nonunions or other failed prior arthroplasties, adding overlap to these risk factors. Previous studies have also implicated a deltopectoral approach as an independent risk factor for dislocation; however, this is likely attributable to the management of the subscapularis, and this was not included in our model.[2] Revision of a nonunion may result in erroneous implant size or location during reconstruction by inadequately lengthening the arm, thus producing instability by soft tissue laxity.

Our study identified the subjectively reported account of instability and subluxation as the greatest factor predictive of dislocation after RSA (OR: 19.52, 95% CI: 12.00-31.75). Patients with frank, nonreducible, and radiographically confirmed dislocation had prior subjective postoperative sensations of subluxation (27%) more than those who did not (1%) ($P < .001$). Several patients described a low-energy, nontraumatic cause of their subluxation such as reaching and grabbing objects requiring repositioning of the arm to neutral to alleviate the sensation. Similar rates of subluxation occurred for patients in the early (24.7%) and late (35.1%) dislocation periods ($P = .190$). Tashjian et al[25] evaluated 99 patients receiving a medialized RSA at minimum 2-year follow-up and described a 4-point scale of instability after RSA including (1) none, (2) feelings of instability, (3) subluxation and probable dislocation self-reduced, and (4) dislocation requiring intervention. Four patients (4.0%) had overt dislocation; however, 13 (13%) described some form of instability after their RSA. The authors relate inferior impingement to this sensation and recommend a more inferior inclination of the glenoid baseplate.[25] Subjective instability is an important and identifiable risk factor for dislocation that should be recognized by the surgeon and asked about during follow-up. Patients with subjective sensations of subluxation may proceed to frank dislocation either by atraumatic or traumatic mechanisms. Atraumatic events accounted for 71% of all reported dislocations, followed by trauma (23%) and 6% showing dislocation after other events such as secondary to hematoma, after an acromial spine fracture, or unclear mechanisms after hospital stays in the intensive care unit.

The strengths of this study include the large, multicenter patient cohort. The inclusion of 6621 patients is, to our knowledge, the largest analysis of its type, providing many more patients than comparable systematic reviews. Our included risk factors were determined through a robust, iterative Delphi format, providing clinically relevant patient variables as determined by 24 ASES members. Our Delphi method also produced clinically relevant definitions of dislocation, requiring radiographic confirmation of uncoupling of the humeral prosthesis from the glenosphere, and subluxation in the postoperative period. Our statistical analysis was robust, with a binary model appropriately fit to the dataset and based on available degrees of freedom relative to the number of dislocations and variables included by the Delphi process. Our results are clearly interpretable that nonmodifiable patient factors, including preoperative diagnoses, contribute to RSA dislocation and that subjective patient subluxation may indicate impending dislocation.

The limitations of the study include the retrospective nature of data collection, lack of radiographic analyses, and lack of implant factors included in the analysis. The retrospective analysis limits the level of evidence despite the large patient cohort. Our Delphi process relies on consensus thresholds, and thus, a small group of participating surgeons may ultimately disagree with consensus statements and inclusion criteria for variable analysis, though there was no attrition and all surgeons contributed to the process. We did not analyze humeral shortening or other radiographic parameters such as acromiohumeral distance, lateralization shoulder angle, or distalization shoulder angle as contributing to dislocation. We did not evaluate implant designs or component sizing or contributing surgeon volume. We did not analyze or provide treatment and subsequent outcomes for patients with dislocation, such as shoulder range of motion, visual analog scale pain scores, or other patient-reported outcome scores, as this was not the focus of the study. Patient subluxation, though significantly predictive of further frank dislocation, is inherently subjective and obtained retrospectively, and thus presents both quantifiable and standardization difficulties and recall bias. Patient follow-up period was not significantly predictive of dislocation and did not differ between dislocation and no dislocation groups ($P = .377$). The follow-up period included patients at minimum of 3 months who may have missed dislocations occurring later and thus may misrepresent the overall incidence in the cohort.

Conclusion

The overall incidence of dislocation after RSA in this large, multicenter cohort study was 2.1%. Patient factors including a history of subluxation, nonunion, revision arthroplasty, lack of subscapularis repair, cuff tear arthropathy, and male sex are strongly predictive of dislocation. These data suggest that patient history of subluxation may predict subsequent dislocation episodes. Dislocation after RSA appears to be multifactorial, and perioperative patient counseling and symptom monitoring are important considerations for surgeons.

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