J Shoulder Elbow Surg (2018) 27, 2183–2190

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Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

# Increased scapular spine fractures after reverse shoulder arthroplasty with a humeral onlay short stem: an analysis of 485 consecutive cases

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**Background:** Scapular stress fractures after reverse shoulder arthroplasty (RSA) are a potentially serious complication with modern lateralized and onlay implants. The aim of this study was to report the scapular spine stress fracture rate after RSA with an onlay, 145° humeral stem, analyzing potential fracture risk factors and clinical outcomes in a large cohort of patients.

**Methods:** A consecutive series of 485 RSAs were implanted with the Aequalis Ascend Flex stem. Data collection included preoperative and postoperative clinical and radiographic assessment findings (rotator cuff Goutallier grade; Hamada, Walch, and Favard classifications; range of motion; Constant score) and perioperative data. Patients with a scapular spine fracture following RSA were matched with nonfracture control patients, and preoperative variables were tested to determine whether they were predictive of a scapular spine fracture.

**Results:** A scapular spine fracture following RSA occurred in 21 patients (4.3%), with a mean time to diagnosis of 8.6 months (range, 1-34 months). No preoperative factor was found to be a significant predictor of scapular spine fracture. Both groups showed significant improvements in active mobility measurements and Constant scores from preoperatively to final follow-up ($P < .001$). The control group scored significantly better than the scapular spine fracture group regarding the Constant score and forward flexion.

**Conclusion:** Scapular spine fractures have shown an increased prevalence after onlay-design RSA. This series was not able to link any clear risk factors. Functional results are limited, regardless of the fracture management.

**Level of evidence:** Level IV; Case Series; Treatment Study



**Keywords:** Scapular fracture; acromion; spine; onlay design; lateralized stem; outcomes; postoperative complication; reverse shoulder arthroplasty

The ethical committees of the Hôpital Privé Jean Mermoz and the Centre Orthopédique Santy determined the project did not infringe upon the French ethical rules and/or the privacy of the patients and allowed us to perform the study.

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https://doi.org/10.1016/j.jse.2018.06.007

Reverse shoulder arthroplasty (RSA) is a commonly used treatment modality for an increasing number of etiologies and populations. As a result, an increased rate of complications and reoperations has followed.[1,3,9,11,26,32-34,36]

Scapular spine stress fractures have been previously studied by several authors, with a prevalence ranging from 0.8% to 10.2%.[1,2,5-9,11,15,17,19,20,22,24,25,28,31-33,36] Preoperative acromial insufficiency (os acromiale, acromion fragmentation, fractures of the anterior aspect of the acromion) and spine fracture nonunion are frequent preoperative findings in cases of cuff tear arthropathy and are a different entity than postoperative scapular fractures.[23,31] Inclusion of these entities and confounding factors (small sample sizes, various designs and/or surgical choices and different classifications in the same series) can generate an overestimation in the prevalence of postoperative scapular spine stress fracture.[2,6,9,15,17,20,22,33,34]

Over the past several years, the literature has proposed several changes to Grammont's original principles. These changes have resulted in decreased scapular notching and/or bony impingement, decreased humeral lucency, decreased resorption of the tuberosities, improved stability, and improved convertibility. Modern implant designs have been conceived with these goals in mind. However, perhaps as a result, postoperative scapular spine fracture rates are affected in those implants with a humeral onlay design and decreased neck-shaft angle, reaching 4%-5% in various targeted studies.[2,19,33] Potential factors producing stress on the scapular spine after RSA have been reported among several preoperative parameters, such as rotator cuff status, humeral head superior migration, superior glenoid wear, posterior glenoid wear, and poor range of motion.[2,12,15,16,18,21,25,26,28,35]

The purpose of this study was to report the scapular spine stress fracture rate after RSA with a short, curved, onlay stem with a 145° neck-shaft angle. In addition, we attempted to analyze potential fracture risk factors and relative clinical outcomes in a large cohort of patients in a retrospective multicenter study.

## Materials and methods

We conducted a retrospective analysis of patients who underwent RSA at the involved institutions. Between November 2012 and December 2015, a consecutive series of 485 RSAs were implanted by 4 senior experienced shoulder surgeons (G.W., T.B.E., A.G., and L.N.) in 2 different shoulder surgery centers. All arthroplasties were performed using the Aequalis Ascend Flex prosthesis (Tornier, Bloomington, MN, USA).

The Ascend Flex is a short stem (66 to 94 mm long) and has proximal titanium plasma spray coating for metaphyseal press-fit fixation. Long and short stems with a polished surface finish were available for cementation if press-fit rotational stability could not be achieved. Three different neck-shaft angles were available: 127.5°, 132.5°, and 137.5°. The Ascend Flex stem has an onlay design and can accommodate a reversed tray with low or high offset. The 132.5° neck-shaft angle was used with a 12.5° polyethylene insert to reach a final 145° neck-shaft inclination for all cases.

The results were retrospectively analyzed from prospectively gathered databases. The implant and surgical technique were previously described in detail.[2]

Preoperative and postoperative patient assessment findings including forward flexion (FF), external rotation with the arm at the side, the Constant score, perioperative data (cemented or uncemented stems, implant sizes, intraoperative complications), and postoperative complications were collected. The postoperative clinical evaluation was performed by 2 independent examiners (F.A. and C.M.K.) not involved with the surgical procedure.

Standardized preoperative and postoperative radiographic films, including a true anteroposterior view with 3 different rotations of the arm (internal, external, and neutral) and the scapular Y view, and preoperative computed tomography scans were obtained. Images were analyzed for the cuff tear arthropathy stage according to Hamada et al[14] (modified by Walch et al[30]), glenoid assessment according to Walch and colleagues[4] and Favard et al,[10] and rotator cuff muscle fatty infiltration grade.[13]

### Fracture detection

Patients in whom a scapular fracture was diagnosed were further investigated with additional views (axillary views, focused views on the fracture site) or computed tomography according to the surgeon's preference. For the present study, each case was retrospectively analyzed. Patients with preoperative acromial insufficiency, scapular spine nonunion, or os acromiale were excluded.

The presence and location (acromion and/or spine) of the scapular fracture was confirmed by 2 senior surgeons (G.W. and T.B.E.), and 2 shoulder fellows (F.A. and C.M.K.) classified the fractures according to Levy et al.[20] The relationship between the baseplate screw location and the fracture line was also assessed. When there was disagreement between observers, a collegial discussion was held to obtain consensus.

### Subject matching

Patients with a scapular spine fracture following RSA were matched with nonfracture control patients by sex, hand dominance, and diagnosis; then, a nearest-neighbor technique was used to finalize the matching according to age and surgery date. For each scapular spine fracture patient, 4 control subjects were matched.

### Statistical analysis

Subject characteristics at baseline were tested for significant differences between the scapular spine fracture group and the control group. As appropriate, independent group $t$ tests, Fisher exact tests, or $\chi^2$ tests were performed to determine whether differences existed at baseline.

Preoperative variables were tested to determine whether they were predictive of a scapular spine fracture following RSA using logistic regression. For all preoperative variables, the odds ratio and the $R^2$ value were evaluated to determine whether the variable had a meaningful impact on the model. Linear mixed models were used to test for differences in preoperative to postoperative changes (improvement) in RSA patients grouped by scapular spine fracture status (fracture or matched control).

## Results

A scapular spine fracture was diagnosed following RSA surgery in 21 patients (Table I), resulting in a rate of 4.3% of 485 prostheses. The mean time to diagnosis was 8.6 months (range, 1-34 months) after surgery, and in 16 of 21 (76%), a scapular fracture occurred during the first 6 months following RSA.

Nonoperative treatment was used in 19 patients, with an abduction splint used for 6 weeks for pain relief. A bone stimulator was provided for interested patients. Two patients underwent open reduction–internal fixation and both underwent an additional procedure: the first following spine nonunion and persistence of pain and the second after a fall and consequent failure of the previous plate fixation. Both of these patients reported persistent pain and poor function at latest follow-up.

No preoperative factor was found to be a significant predictor of scapular spine fracture, including rotator cuff Goutallier grade, active mobility outcomes, or Constant score (Table II). Preoperative FF mean trended ($P = .08$) toward significance between control and scapular spine fracture patients, with less preoperative FF increasing the risk of a scapular spine fracture. In addition, the odds ratio and $R^2$ value for each preoperative factor were quite low, indicating that these factors have little impact on the risk of scapular spine fractures and that other unidentified factors may have a far more significant role.

Among the Hamada, Favard, and Walch classifications, none significantly predicted scapular spine fracture (Table III). However, Hamada stage 4A trended toward being protective from a scapular spine fracture. In addition, bony glenoid baseplate lateralization with the use of the Bony Increased Offset RSA (BIO-RSA) technique (Tornier) was applied in 12 of 21 fracture patients (57%) compared with 37 patients (44%) in the matched control group. The indications for the BIO-RSA technique were both correction of severe glenoid defects and glenoid lateralization. The use of this procedure was not a significant predictor of scapular spine fracture ($P = .31$).

The impact of a scapular spine fracture on outcome measures was investigated using preoperative and final follow-up measurements (Fig. 1). Both groups showed significant improvements in active mobility measurements and Constant scores from preoperatively to final follow-up ($P < .001$). The control group scored significantly better than the scapular spine fracture group regarding the Constant score and FF (Fig. 1). Although the screw tip–fracture relationship is difficult to determine on plain radiographs, we found that 57.1% of the scapular spine fractures (12 of 21) occurred at the distal tip of the superior screw (Fig. 2).

**Table I** Subject characteristics

| | Scapular spine fracture (%) | Matched control (%) | *P* value |
|---|---|---|---|
| n | 21 | 84 | |
| Sex | 6 male; 15 female | 24 male; 60 female | >.999 |
| Age at surgery, mean ± SD, yr | 72.6 ± 7.1 | 72.3 ± 7.6 | .861 |
| Follow-up, mean ± SD, mo | 16.3 ± 6.5 | 16.5 ± 9.1 | .938 |
| Dominant shoulder | 18 (85.7) | 69 (82.1) | .698 |
| Treatment | | | |
| ORIF | 2 (9.5) | | |
| Conservative | 19 (90.5) | | |
| Fracture | | | |
| Acromion (type I) | 3 (14.3) | | |
| Spine (type II-III) | 18 (85.7) | | |

*ORIF*, open reduction–internal fixation.

**Table II** Prediction of scapular spine fracture following RSA by preoperative measures

| | Scapular spine fracture | Matched control | *P* value |
|---|---|---|---|
| Preoperative SS status (Goutallier grade) | 3.2 ± 1.0 | 3.0 ± 1.1 | .41 |
| Preoperative ISP status | 2.5 ± 1.5 | 2.6 ± 1.4 | .73 |
| Preoperative SSC status | 1.6 ± 1.6 | 1.9 ± 1.5 | .36 |
| Preoperative TM status | 0.8 ± 1.5 | 0.3 ± 1.0 | .21 |
| Preoperative Constant score | 21.1 ± 11.3 | 21.3 ± 10.8 | .92 |
| Preoperative forward flexion, ° | 58 ± 36 | 68 ± 40 | .14 |
| Preoperative external rotation, ° | 6 ± 12 | 8 ± 18 | .71 |

*RSA*, reverse shoulder arthroplasty; *SS*, supraspinatus; *ISP*, infraspinatus; *SSC*, subscapularis; *TM*, teres minor.

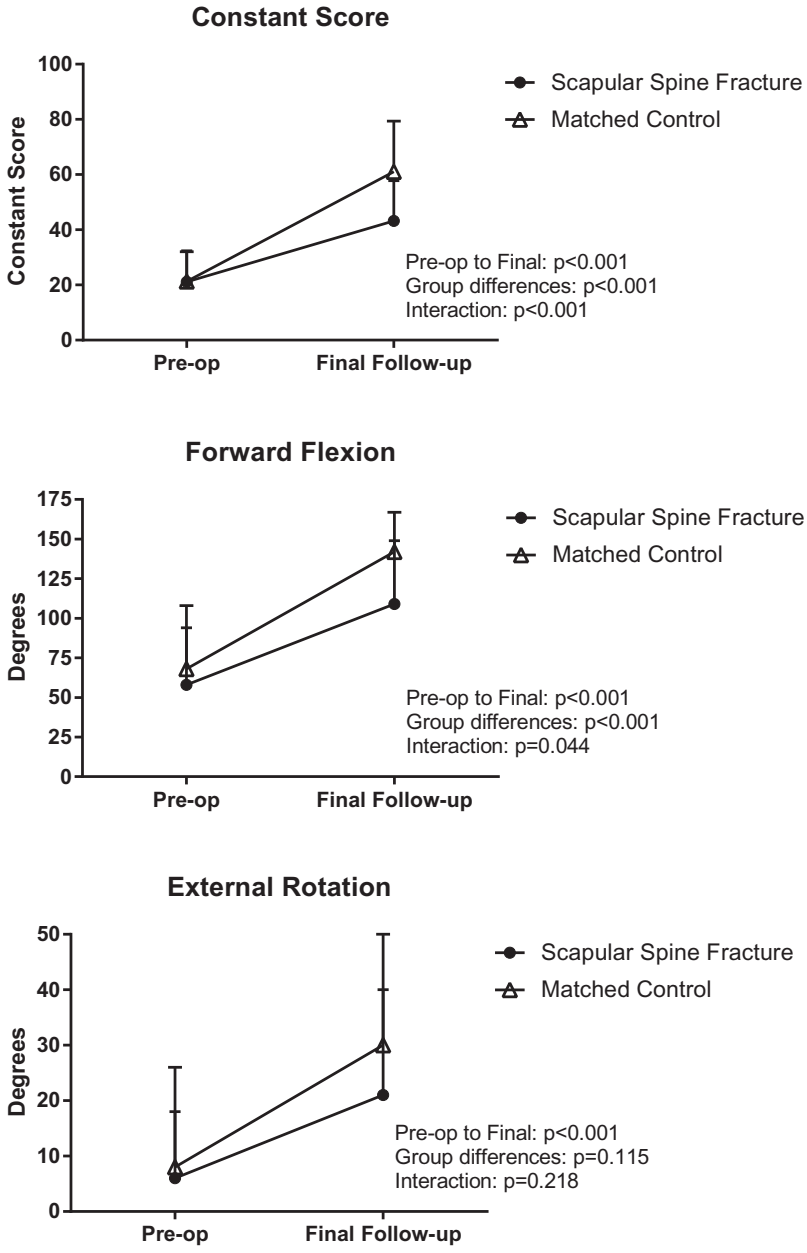


**Figure 1** Outcome scores and linear mixed-model results. *Pre-op*, preoperative.

## Discussion

Scapular fractures after Grammont-design RSA have been described by several authors.[1,5-9,11,15,17,19,20,22,24,28,31-33,36] Neyton et al[24] described the largest series with a Grammont-design 155° neck-shaft angle implant in the literature, reporting on 1953 RSAs. They reported a 1.3% fracture rate, almost 4-fold lower than that in our study. These fractures occurred in the first 6 months after surgery, and the patients averaged FF of 109° and a Constant score of 47 points at minimum 5-year follow-up.

Another large series using a single implant (Reverse Shoulder Prosthesis; DJO Surgical, Austin, TX, USA) was described by Teusink et al,[29] with a prevalence of scapular fracture of 3.1% among 1018 RSAs. It is interesting to note that Levy et al[20] reported a prevalence of 10% using the same implant but in a smaller series of 157 RSAs and with a different classification system. Progressive modifications of this prosthesis may have had an influence.

Perhaps the most interesting finding of our study is that an RSA implanted with a modern lateralized onlay stem resulted in an increased incidence of postoperative scapular spine stress fractures compared with Grammont's original design.[1,5-9,11,15,17,19,20,24,31-33,36] Our prevalence in 485 implants was 4.3%. Scapular fracture rates with a similar humeral onlay stem vary from 4.4% with the Equinoxe Reverse Total

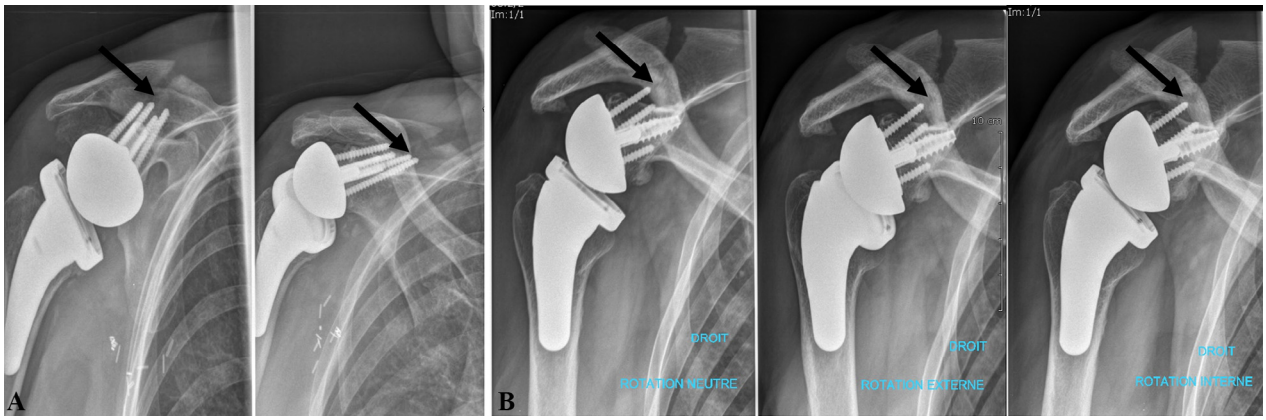


**Figure 2** (**A**, **B**) Evidence of baseplate screw tip relationship with fracture line (*black arrows*) on plain radiographs.

**Table III** Prediction of scapular spine fracture following RSA by glenoid classification and surgical technique

| | Scapular spine fracture (%) | Matched control (%) | *P* |
|---|---|---|---|
| Hamada | | | |
| 1 | 1 (5) | 8 (10) | .29 |
| 2 | 3 (14) | 13 (16) | |
| 3 | 3 (14) | 11 (13) | |
| 4A | 2 (10) | 26 (31) | |
| 4B | 10 (48) | 25 (30) | |
| 5 | 2 (10) | 1 (1) | |
| Favard | | | |
| E0 | 9 (43) | 53 (63) | .34 |
| E1 | 6 (29) | 10 (12) | |
| E2 | 3 (14) | 10 (12) | |
| E3 | 2 (10) | 8 (10) | |
| E4 | 1 (5) | 3 (4) | |
| Walch | | | |
| A1 | 12 (57) | 52 (62) | .93 |
| A2 | 5 (24) | 15 (18) | |
| B1 | 2 (10) | 6 (7) | |
| B2 | 1 (5) | 9 (11) | |
| B3 | 1 (5) | 2 (2) | |
| BIO-RSA | | | |
| Yes | 12 (57) | 37 (44) | .31 |
| No | 9 (43) | 47 (56) | |

*RSA*, reverse shoulder arthroplasty; *BIO*, Bony Increased Offset.

Shoulder Arthroplasty (Exactech, Gainesville, FL, USA)[19] to 5% with the Aequalis Ascend Flex prosthesis,[2,33] which are consistent with our results.

Several changes to Grammont's original design have been employed in the system used in our study. These include changes on the humeral side (short, onlay, lateralized 145° stem) and on the glenoid side (BIO-RSA, glenosphere inferior offset). While these design changes have been thought to improve many issues related to convertibility and scapular notching, their coexistence may increase deltoid stresses on the acromion and scapular spine, thus producing more stress across bone that is frequently osteopenic.

Wong et al[35] concluded that both glenosphere lateralization and stem lateralization produce a substantial increase in acromial stress in activities of daily living, repeatedly subjecting bone to microdamage propagating faster than repair thresholds, causing Levy type II stress.[20] Glenoid lateralization (produced by the BIO-RSA technique in our series), previously identified as producing the largest effect on acromial stress, was not demonstrated to be a risk factor.

No preoperative factor was found to be a significant predictor of scapular spine fracture. Giles et al[12] demonstrated that an intact rotator cuff resulted in an increased demand on the deltoid during abduction, by acting as an antagonist to the deltoid. However, our study did not identify rotator cuff integrity as a factor that increases the occurrence of fractures.

The only preoperative parameter that trended toward significance was lower FF. A potential reason for this observation may be the relatively large increase in motion that occurs after RSA, and thus after a challenging rehabilitation program and deltoid strength recovery,[26] placing a sudden increase in stress along the scapular spine.

Moreover, adding lateral offset to the humerus may increase the deltoid force necessary for motion, potentially lengthening the recovery time and leading to a higher risk of deltoid-related pain, stress fractures, and glenoid component loosening.[18,21] This may be amplified by an onlay design, resulting in increased humeral lengthening and consequent stresses on the deltoid insertions.[33]

Preoperatively, shoulders classified as Hamada stage 4A (acromiohumeral interval < 7 mm with glenohumeral arthritis without acetabulization)[14,30] trended toward being protective against stress fractures in our series. An acceptable acromiohumeral space in an osteoarthritic shoulder could preserve scapular kinematics in contrast to acromial insufficiency and/or acetabulization (Hamada stage 4B), in which a scapulothoracic biomechanical alteration is produced consequent to the rotator cuff injury.[5] There is likely an increase in the activity of the muscles with the origin and insertion in the scapular spine or base of the acromion while elevating

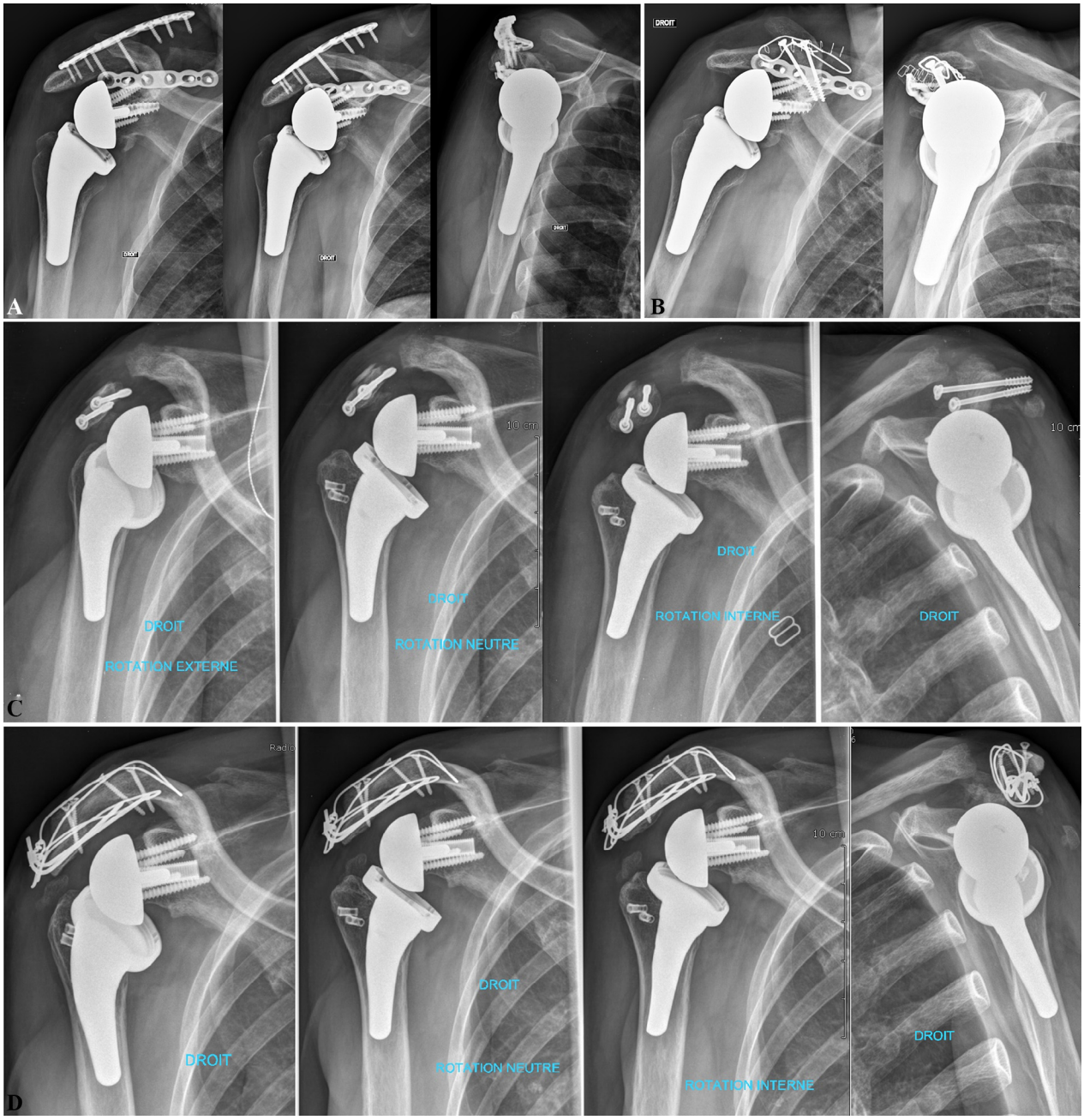


**Figure 3** (**A-D**) Failure of surgical fracture fixation in 2 patients.

the arm, combined with the presence of reduced bone mineral density and micro-architectural changes, such as in osteoporosis (found to be significantly associated with a fracture[25]).

The length and orientation of baseplate screws have been proposed as a potential stress riser when the tip of the screw reaches or crosses through the scapular spine.[6,19,25] Kennon et al[19] compared 2 different baseplate fixation techniques in an onlay humeral design, with and without the superior screw. They decreased the incidence of scapular fractures from 4.4% to 0% in the construct with only inferior screws. These results may indicate increased fracture propensity with a superior screw, given the screw's proximity to the spine. Nevertheless, the relationship between screw tip and spine fracture remains uncertain and does not indicate why the vast majority of the patients do not experience any scapular fracture despite the use of the same implant with superior screw fixation. In our series, just over half of the scapular fractures occurred at the distal tip of the superior screw (Fig. 2).

Scapular spine fractures lead to inferior clinical results compared with controls. In addition, the nonunion rate is high with nonoperative treatment.[2,6,11,15,17,24,29,31] Our study further confirms the inferior functional outcomes and active mobility outcomes in this patient population. Fractures of the scapular spine (Levy type II-III) constitute a different issue than

fractures of the anterior process of the acromion, involving a greater part of the deltoid insertion (entire middle and posterior origin). Consequently, RSA function and stability are affected. Meanwhile, with lateral acromion fractures (Levy type I), the scapulothoracic movement remains unaltered.[5]

Several authors have established that good outcomes may be achieved with nonsurgical management of these fractures.[6,20,27,31] Conversely, many concerns have been expressed in the literature with surgical fracture fixation. These include difficulty in achieving fracture stability with osteoporotic bone under deltoid tension, poor functional results, high rates of reoperation, and fracture nonunion. Although we had only 2 patients who underwent surgical fixation of a spine fracture, our results agree with the literature, as fracture fixation failed in both patients and they ultimately had a poor outcome (Fig. 3). However, evidence guiding treatment is poor, and further studies are required to determine the optimal treatment regimen.

We acknowledge this study is not free of limitations. This is a retrospective multicenter series with a relatively small sample size of scapular fractures. As a result, the ability to detect significant differences between subgroups or prognostic factors may be compromised. Moreover, the short follow-up did not allow us to analyze clinical results and the rate of fractures occurring after 2 years postoperatively.

Despite these limitations, this is the largest RSA cohort with a single prosthetic lateralized design, providing further insight into potential issues with this design. In addition, we highlighted and eliminated the methodologic flaws present in the literature on scapular fractures that preclude comparison between the series. These flaws may result in underestimation or overestimation of postoperative fracture occurrence.

## Conclusion

Scapular spine fractures remain a significant issue after RSA, with an increased prevalence in onlay designs (4.3%). We were unable to determine any clear risk factors for their occurrence, thus illustrating the likely multifactorial nature of this relatively common problem.

Functional results are modest, regardless of the treatment modality, and fracture management guidelines are not clearly identified. Selection of various RSA designs (glenoid lateralization and/or inferiorization, humeral lateralization and/or neck-shaft angle, onlay platforms) could be guided toward specific patient populations to optimize functional outcomes and stability, thereby reducing fracture risk.

## Disclaimer

Lionel Neyton receives royalties and fees for consulting from Wright-Tornier and fees for consulting from Arthrex. Arnaud Godeneche receives royalties and fees for consulting from Wright-Tornier and FH societies and fees for consulting from Arthrex and ConMed societies. T. Bradley Edwards receives royalties and fees for consulting from Wright Medical and DJO. Gilles Walch receives royalties from Wright-Tornier and equity from Imascap.

The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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