Scapular Notching in Reverse Shoulder Arthroplasty: Is It Important to Avoid It and How?

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Abstract

Background Scapular notching, erosion of the scapular neck related to impingement by the medial rim of the humeral cup during adduction, is a radiographic sign specific to reverse shoulder arthroplasty (RSA). Its clinical and radiological consequences remain unclear.

Questions/purposes Therefore, we: (1) determined the incidence of notching in a large series, (2) described the natural history of notching, (3) determined whether notching is related to functional scores or (4) radiographic signs of failure, and (5) identified factors related to notch development.

Patients and Methods We retrospectively reviewed 448 patients who underwent a Grammont-type RSA (461 shoulders) with a mean followup of 51 months (range,

24–206 months). RSA was implanted for cuff tear arthropathy or osteoarthritis with cuff deficiency. We assessed scapular notching using AP views standardized under fluoroscopy. Clinical assessment included Constant-Murley score and range of motion. Aside from notching, radiographic assessment included evaluation of humeral and glenoid radiolucent lines.

Results Notching occurred in 68% of cases. It appeared early, but its later evolution was variable. Notching was associated with followup, strength, passive and active elevation, humeral radiolucent lines, and glenoid lucent lines. It also correlated with a higher rate in patients with preoperative superior erosion.

Conclusions Scapular notching is frequent, generally progresses, and is associated with deterioration of some clinical parameters and radiolucent lines. We believe the preoperative pattern of glenoid erosion is of particular importance due to its influence on the surgeon's glenoid preparation and base-plate positioning. It is crucial to avoid cranial position and superior tilt.

Levels of Evidence Level IV, Therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Four authors (CL, PB, LF, GW) certify that they have commercial associations (royalties) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

This work was performed at the Clinique du parc Lyon France, the Hôpital de l'Archet Nice France, the Centre Hospitalier de Tours France, and the Centre Orthopédique Santy Lyon France.

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Introduction

Notching of the scapular pillar is a radiographic observation specific to reverse shoulder arthroplasty (Fig. 1). Grammont and Baulot [1, 9] initiated the concept and realization of semiconstrained reversed prosthesis, but did not report on notching. First described by Sirveaux in 1997 [17], and later by De Wilde et al. [6], this phenomenon is an osseous defect in the scapular neck caused by the impingement of the medial border of the humeral

Fig. 1 A radiograph shows a large scapular notch reaching the glenoid base plate's inferior screw.

prosthetic cup against the superior part of the scapular pillar when the arm is adducted. Nyffeler et al. [14] suggested an osteolytic reaction associated with polyethylene (PE) wear debris contributing to scapular notch progression. Moreover, it is reportedly related to eventual glenoid component loosening [4, 18–20]. However, the evolution of scapular notching is unclear, clinical and radiographic consequences are controversial, and causal factors are unknown.

The purposes of our study were to: (1) determine the incidence of notching in a large series; (2) describe the natural history of notching; (3) determine whether notching is related to functional scores and (4) radiographic signs of failure; (5) identify factors related to notch development; (6) deduce technical recommendations to avoid it.

Patients and Methods

This is a retrospective and multicenter study of 506 patients (527 shoulders) operated on between 1987 and 2003 at ten different centers for a Grammont-type reversed prosthesis with a minimum of 2 years of followup. We excluded 38 patients (43 shoulders): 10 patients (12 shoulders) died of causes unrelated to the surgery before the minimum followup, four (5 shoulders) were lost to followup, and 24 (26 shoulders) had prosthesis removal before 2 years of followup. We also excluded 20 additional patients (23 shoulders) due to inadequate radiographic views for an accurate evaluation of the scapular notch. These exclusions left 448 patients (461 shoulders). The patients' mean age was 73 years (range, 40–90 years) and gender ratio was 24% men and 76% women. Indications were cuff tear arthropathy in 92% of cases and osteoarthritis with cuff

Fig. 2 An image describes Favard et al.'s [7] classification of the different types of glenoid erosion – E0: superior humeral migration with no glenoid erosion; E1: concentric glenoid erosion; E2: glenoid erosion predominantly in the superior pole; E3: global glenoid erosion more severe in the superior pole; E4: glenoid erosion predominantly in the inferior pole.

deficiency in 8% of cases. The minimum followup was 24 months (mean, 51 months; range, 24–206 months).

We classified glenoid erosion on the AP view using the method of Favard et al. [7] (Fig. 2): E0 for superior humeral head migration without erosion of the glenoid (53% of the series), E1 for concentric erosion of the glenoid (17%), E2 for erosion limited to the superior part of the glenoid (12%), E3 for erosion extending to the inferior part of the glenoid (15%), and E4 for erosion predominantly located at the inferior part of the glenoid (3%). We graded the severity of fatty infiltration on CT or MR images using the classification of Goutallier et al. [8]: Grade 1 for fat traces in muscle (8% of the series), Grade 2 for less fat than muscle (11%), Grade 3 for similar amount of fat and muscle (18%), Grade 4 for more fat than muscle (62%).

We implanted the prosthesis via a superolateral approach in 45% cases and through a deltopectoral approach in 55% cases. We used the Delta reverse prosthesis™ (DePuy International Ltd, Leeds, England) in 87% of cases and, after October 2002, the Aequalis Reverse Prosthesis™ (Tornier, Houston T, USA) in 13% of cases. Both models were designed according to Grammont recommendation with a 155° inclination angle. Two diameters of glenosphere and humeral cup were available in both models: we used 36 mm in 85% of cases and used 42 mm in 15% of cases.

Passive rehabilitation began the day after surgery in 98% of cases and was supervised by the physiotherapist, whereas ten shoulders (2%) were temporarily immobilized without rehabilitation. We used a regular sling with the arm adducted in 83% of cases and an abduction brace in 17%. The arm was free after an average of 6 weeks.

For purposes of the study, we contacted all patients for clinical and radiographic assessments to obtain maximal followup. Clinical evaluation included the absolute and age/gender-related weighted Constant-Murley scores [5] and active and passive range of motion. We recorded strength in external and internal rotation, as well as subjective ratings.

Fig. 3 A drawing shows classification of scapular notching according to Sirveaux et al. [18]. Grade 1 shows a notch limited to the scapular pillar, Grade 2 shows a notch reaching the inferior screw of the base plate, Grade 3 shows a notch extending beyond the inferior screw, and Grade 4 shows a notch reaching the base-plate's central peg.

Radiographic evaluation included true AP and axillary views. When available, we assessed radiographs at 6 weeks, 1 year, 2 years, and 3 years postoperatively to evaluate notch formation and early progression. According to standard protocol, we used fluoroscopic control to ensure that the flat side of the hemispheric glenoid implant appeared flat on the AP view. Inclination of the beam in the sagittal plane was not standardized. We analyzed the scapular notch on the AP view according to the classification of Sirveaux et al. [17]: Grade 1 for a notch limited to the scapular pillar, Grade 2 for a notch reaching the inferior screw of the base plate, Grade 3 for a notch extending beyond the inferior screw, and Grade 4 for a notch reaching the base-plate's central peg (Fig. 3). We also analyzed it using the axillary view and recorded pillar spurs and/or ossification in the scapulohumeral space. Regarding the glenoid component, we assessed radiolucencies under the baseplate and around the central peg and fixation screws and recorded humeral radiolucencies in seven different zones (Fig. 4).

Final radiographs beyond 2 year followup were available for 461 patients. Interval radiographs were available for 231 patients at 1 year followup, for 239 at 2 year followup, and for 254 at 3 year followup. Each center evaluated their radiographs for notching and one of us (CL) checked all radiographs. Radiographic followup averaged 51 months (range, 24–206 months). One-hundred-fifty-two shoulders (33%) had a followup greater than 60 months, 138 (30%) had a followup between 36 and 60 months, and 171 (37%) had a followup between 24 and 36 months.

Concerning statistical analysis, we tested all clinical and radiological variables in three different ways, according to the definition of the notch. For the first method, we compared cases with and without notching, regardless of grade, and determined differences in variables with the Mann-Whitney U test. For the second method, we compared cases without notching versus notching Grades 1 to 2 and versus

Fig. 4 A drawing depicts the zones of radiolucent lines around the humeral implant.

notching Grades 3 to 4 and used the Kruskal-Wallis test to determine differences in variables. As for the third method, we compared cases without notching and the four grades of notching independently. Software used was StatView (SAS Institute, Cary, NC, USA).

Results

At last followup, we observed scapular notching on the AP view of 312 of the 461 cases (68%). We recorded 22% as Grade 1 notches, 23% as Grade 2, 13% as Grade 3, and 10% as Grade 4.

Notching tended to appear early. We found notching in 48% of cases at 1 year postoperatively, 60% at 2 years, and 68% at 3 years. The incidence increased ($p < 0.001$) with followup (Fig. 5).

Notch evolution varied from case to case; some notches stabilized rapidly after their appearance, while others grew progressively over a long period of time. We observed three groups of patients: those who never developed scapular notches, those with notches that stabilized within 2 years, and those with notches that continue to progress beyond 3 years. We observed an increase ($p < 0.001$) in the number of Grade 3 and Grade 4 notches, with longer postoperative followup owing to the third group that progressed. At last followup, 22% of Grade 3 or Grade 4 notches were one grade less severe at 3 years postoperatively.

Fig. 5 A graph shows the notch incidence as a function of postoperative followup.

Activity level influenced the rate of notch development; more active patients had higher ($p = 0.03$) notch incidence (74% compared with 64% for inactive patients). Notch incidence varied ($p = 0.01$) with original diagnosis: 71% for cuff tear arthropathy and 47% for osteoarthritis with cuff deficiency. Notching also correlated with decreased preoperative acromiohumeral distance ($p < 0.0001$), severity of fatty infiltration of the infraspinatus muscle (68% for Grades 3 and 4, and 52% for Grades 0, 1, and 2, $p = 0.02$), and, interestingly, the type of glenoid erosion. The greatest ($p = 0.004$) difference appeared between Type E2 glenoid superior erosion, associated with a notch incidence of 83%, and Type E4 inferior glenoid erosion, associated with a 25% notch incidence. There was a lower ($p = 0.001$) notch incidence with a deltopectoral approach than with a superolateral approach (56% versus 86%, respectively). This may be debatable due to the different followup lengths of the two approaches (43 months versus 59 months, respectively).

We found no relationship between scapular notching and pain or Constant-Murley score. Strength was decreased by a mean of 0.5 kg in cases with notching compared to cases with no notch ($p = 0.04$). Also, we observed a decreased ($p = 0.01$) passive and active anterior elevation in the presence of a notch (141° and 128° , respectively), compared to cases with no notch (147° and 134° , respectively).

We found an association ($p < 0.001$) between notching and a “pillar spur” (63% spur incidence with notching versus 43% without). The incidence of humeral radiolucent lines was higher ($p = 0.001$) in the presence of notching (36% with notching versus 17% without), and greatest ($p < 0.0001$) in the proximal zones, particularly Zone 7, closest to the notch (Fig. 4). Glenoid radiolucent lines were more frequent ($p = 0.03$) in the presence of a notch than in the absence (9% and 3%, respectively). If the comparison concerns only notching of Grades 2, 3, and 4 versus no notch, the difference is stronger ($p < 0.001$): 13% and 3%, respectively.

Fig. 6 An imperfect anteroposterior radiograph shows how the glenoid hemisphere is not viewed in profile and obscures the zone of notching.

Discussion

Radiographically apparent scapular notching is specific to reverse shoulder arthroplasty (RSA). Despite numerous reports on the phenomenon, its clinical and radiological consequences remain unclear. The purposes of our study were therefore to: (1) determine the incidence of notching in a large series, (2) describe the natural history of notching, (3) determine whether notching is related to functional scores and (4) radiographic signs of failure, (5) identify factors related to notch development, and (6) deduce technical recommendations to avoid it.

Our study has a number of limitations. First, our mean followup is relatively short (51 months), but 33% of cases had a followup between 5 and 17 years. Second, it is a retrospective and multicentre study, which implies a relative lack of standardized method of radiographic technique and analysis. We attempted to reduce variability of radiographic interpretations with systematic review of all the radiographs by one of authors (CL). This eliminates interobserver variability, but introduces the possibility of systematic bias in interpretations. Third, evaluation of notching requires precise patient positioning (Fig. 6) and fluoroscopy for alignment of the X-ray beam with the flat side of the baseplate (Fig. 7). In the sagittal plane, orientation of the beam must be horizontal (not craniocaudal) to accurately show notching, which is at the inferior pole of the glenoid and, in some cases, posteroinferior, where the scapular pillar arises (Fig. 8). This anatomic fact may explain why, in some cases, the notch is better visualized in the axillary view than the AP view (Fig. 9). A postmortem analysis illustrates the variability of notching appearance according to the orientation of the beam, the same case being possibly graded notching 1 to 4 depending of the position of the scapula (Fig. 10). The presence of a bony spur medial to the notch may make the notch appear larger (Fig. 11). Fourth, it is difficult to evaluate the size of the notch. Several radiographic classifications have been

Fig. 7A–B (A) Photo shows patient undergoing anteroposterior radiograph of the shoulder. (B) The patient's radiographs show the procedure to attain the correct anteroposterior view. (1) The patient stands naturally and turns toward the involved side until the glenoid base plate appears perfectly flat (tangential) on the fluoroscopic monitor, (2) the X-ray beam is oriented horizontally, and (3) the image is taken during the expiration phase to minimize overlap between the ribcage and the prosthesis.

Fig. 8 Photo of the profile view of a scapula shows the scapular pillar's posterior origin (arrow) in reference to the glenoid.

Fig. 9A–B Radiograph indicating notching. (A) The notch is difficult to see in the anteroposterior view due to the downward orientation of the X-ray beam. (B) It is seen more easily on an axillary view (arrow).

proposed [2, 17, 19]. We used a four-grade classification presented by Sirveaux [17] (Fig. 3). However, in light of the above-mentioned difficulties, we now use a more practical and realistic two-grade classification that regroups Sirveaux Grades 1 and 2 into a single group and Grades 3 and 4 into another [12] (Fig. 12).

We found an incidence of notching in 68% of cases with a mean followup of 51 months which is consistent with the literature [3, 4, 7, 16, 18–21], which reported ranges of 50% to 96% at 31 to 84 months followup.

The frequency of scapular notching increased with followup: we observed notching in 48% of shoulders at 1 year postoperatively, 60% at 2 years, and it continued to increase over time. We observed three groups of patients: those who never developed scapular notches, those with notches that stabilized within 2 years, and those with notches that continued to progress beyond 3 years. This explains the increase of the proportion of Sirveaux Grade 3 and 4 notches with longer postoperative followup. Variability of evolution is possibly related to the mechanism of notch formation, depending on the respective participation of the two major presumed causes: mechanical contact and/or osteolytic reaction secondary to PE debris [2, 6, 10, 14].

We found no relationship between notching and pain or the Constant-Murley score. However, our mean followup was only 51 months and it is possible clinical symptoms will appear with longer followup. Strength, as measured in

Fig. 10A–B Postmortem radiographs explain RSA. The anatomic specimen (A) shows a notch (arrow) exposing partially the inferior screw (definition of Grade 2), whereas a radiograph of that specimen can give the false impression that the notch does not reach the screw (defined as Grade 1) (B), or extends all the way to the base plate's central peg (definition of Grade 4) (C). (Illustration courtesy of L. Favard.)

Fig. 11 This radiograph shows a bony spur adjacent to the zone of notching.

Constant-Murley score, showed a mean diminution of 0.5 kg in the presence of notching. Glenoid radiolucent lines were more frequent in the presence of a notch than in its absence (9% and 3%, respectively). However, our data provides no support for the suggestion of progressively failing glenoid fixation due to notch progression, proposed by several authors [15, 20]. The correlation between notching and radiolucencies around the implants is certainly worrying for the future and a sufficient reason to avoid it, even if there is no current clinical consequence.

Superior glenoid erosion (Type E2) is associated with a high rate of notching, and we think it leads to superior positioning of the base plate, which increases contact between the medial edge of the humeral cup and the inferior edge of the glenoid or the scapular pillar (Fig. 13). We did not quantitatively demonstrate the importance of this factor in this series, but we now measure the cranio-caudal position of the glenoid component (Fig. 14). As recommended by Nyffeler et al. [13], we strive to place the inferior border of the base plate at the inferior edge of the glenoid so the glenoid hemisphere overhangs it by 4 mm. However, we think an inferiorly positioned base plate does

not always prevent impingement with the inferior screw, especially if the base plate is in valgus (superior tilt) (Fig. 15). We suggest coronal inclination of the baseplate is also a factor of notching that may be influenced by the type of preoperative glenoid erosion. The surgeon's natural tendency is to prepare the glenoid in its native orientation. When the glenoid is eroded superiorly the inclination is in valgus (superior tilt), and the tendency is to position the base plate with a similar orientation, allowing the humeral cup to override the inferior glenoid hemisphere and contact the scapular pillar (Fig. 16). Conversely, with inferior glenoid erosion, the inclination is in varus (inferior tilt), with a tendency to position the base plate likewise. There is little or no overriding by the humeral cup medial to the glenoid hemisphere, resulting in a lower risk of impingement and subsequent notching (Fig. 17). In order to quantitatively demonstrate the incidence of baseplate inclination in notching, we have tested, unsuccessfully, different radiographic methods, including referring to the scapular neck, proposed by Simovitch et al. [16]. We now calculate baseplate inclination in reference to the horizontal line in a standardized AP view, with patients standing naturally with their arm at their side (Fig. 18) [11]. This method is independent of any anatomic landmarks on the scapula and integrates the tilt of the scapula itself in the coronal plane (which varies greatly among patients). An inclination angle that is greater than 90° implies a varus position (inferior tilt), while an inclination angle less than 90° implies a valgus position (superior tilt). We adapted our glenoid reaming to the preoperative glenoid inclination, evaluated in the same manner described above on a preoperative standardized AP view. If the preoperative inclination is neutral (vertical), we ream uniformly without attempting to alter glenoid orientation. If the preoperative inclination is in valgus, we ream the inferior portion of the glenoid to reestablish neutral

Fig. 12 This image shows the two-grade SOFCOT classification [12]: Grade 1 representing a notch falling short of the inferior screw, and Grade 2 representing a notch reaching or extending beyond the inferior screw. Grade 0 signifies the absence of notching.

Fig. 13A–B These radiographs depict a scapular notch associated with a glenoid component implanted too superiorly (**B**), which may have been favored by predominantly superior preoperative glenoid erosion (**A**).

Fig. 14 A radiograph shows the method of measuring glenoid component height in reference to the inferior glenoid rim.

inclination. In so doing, it is essential to combine inferior translation to avoid leaving an inferior bony ridge. We agree with Werner et al. [21] that this method slightly

Fig. 15 A radiograph shows a glenoid component implanted in an inferior position but with superior tilt; the inferior screw is beneath the scapular pillar and the superior screw is beneath the base of the coracoid. Note the erosion of the inferior screw and the “kissing lesion” on the medial edge of the metallic humeral implant.

Fig. 16A–B These radiographs show that when the glenoid erosion is superior, its overall coronal inclination is in valgus (**A**), and the surgeon's tendency is to position the base plate also in valgus (**B**), increasing the humeral cup's overriding of the inferior glenoid hemisphere during adduction and, perhaps, increasing the risk of notching.

Fig. 17A–B Radiographs show that when the glenoid erosion is inferior, its overall coronal inclination is in varus (A), and the surgeon's tendency is to position the base plate also in varus (B), reducing the extent the humeral cup can override the inferior glenoid hemisphere and, perhaps, decreasing the risk of notching.

Fig. 18 A radiograph shows the method of measuring glenoid-implant inclination using the angle formed by the line parallel to the glenoid base plate and the horizontal. An angle greater than 90° indicates a glenoid in varus (inferior tilt) while an angle less than 90° indicates a glenoid in valgus (superior tilt).

affects the inferior bone stock of the glenoid, but believe this is an acceptable trade-off to help avoid scapular notching in the future.

In summary, at a mean followup of 4 years, we found scapular notching increased in incidence and severity and was accompanied by decreases in strength and anterior elevation. It was also associated with an increased incidence in humeral and glenoid radiolucent lines. Therefore, it is essential to do everything possible to prevent this phenomenon. Of all the associated factors discussed above, the type of preoperative glenoid erosion seems to be

especially influential, likely through its effect on the base plate's final position. Nyffeler et al. [13] demonstrated the preventive effect of positioning the baseplate flush with the inferior glenoid edge, and we advocate the avoidance of a superiorly tilted base plate.

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