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Original article

Predictive factors of scapular notching in patients with reverse shoulder arthroplasty



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ABSTRACT

Introduction: The main complication of reverse shoulder arthroplasty is the development of notches in the scapular pillar, which occurs in 44% to 100% of cases. Furthermore the functional score has been shown to be poorer in patients with high-grade notches. Many options have been proposed to reduce this risk. The purpose of this study was to evaluate the predictive factors of the development of scapular notches.

Materials and methods: We retrospectively evaluated 133 shoulders in 121 patients with reverse shoulder arthroplasty. We performed a radiographic assessment of the effect of positioning the glenoid component with inferior overhang of the glenosphere and the glenometaphyseal angle. All patients were reviewed after 2 years follow-up, including a clinical assessment based on the Constant score and X-rays to assess the presence of notches.

Results: Nineteen complications were reported, and 14 required revision surgery. We excluded patients in whom prosthetic components were changed. The quality of the X-rays was not satisfactory enough to be analyzed in over 15 patients so they were excluded. One hundred five patients were reviewed. At 2 years follow-up, 50.4% of shoulders presented with notches. The Constant score was 69.3 points (54–83) in shoulders without notches, and 66.4 points (38–82) in shoulders with notches. The average glenosphere overhang was 3.5 mm (–1 – 8 mm). Notches were present in 65.5% if it was less than 3 mm and 39.6% if it was more than 2 mm ($P < 0.05$). The average glenometaphyseal angle was 27.3° (4–59°), and notches developed in 72.2% if it was more than 28° and 26.5% if it was less than 28° ($P < 0.05$).

Conclusion: The position of the metaglene influences the development of notches. The risk decreases if the glenosphere overhangs the glenoid. The degree of adduction of the arm influences the development of notches and can be correlated with the patient's BMI.

Level of evidence: Level IV retrospective study.

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1. Introduction

Arthropathies from rotator cuff tears defined as “cuff tear arthropathies” by Neer [1] have long been a therapeutic challenge. Reverse shoulder arthroplasty developed by Grammont [2] is the only approach that has been validated and has paved the way for the development of existing prostheses for this type of arthropathy. The rate of complications in reverse arthroplasties is 24% [3] including infection, fracture, instability, loosening and neurological complications, which is higher than that in hemiarthroplasty or total shoulder arthroplasty. Moreover, the biomechanical modifications caused by these devices increase the risk of impingement

between the metaphysis of the component and the scapular pillar resulting in the development of notches, which was first reported by Sirveaux [4]. These notches are found in 44–100% of cases [4–8]. The development of notches can negatively influence functional results [4,6] and thus, long-term survival of the glenoid component although this has not been confirmed by all authors [7,9,10]. Nevertheless, long-term survival of reverse arthroplasties has only been evaluated in a few studies [11–13].

Numerous solutions have been proposed to reduce the risk of notching. Overhang of the glenosphere in relation to the inferior glenoid rim [6,14], downward tilt of the metaglene [15], lateralization of the center of rotation [16,17] or an increase in the size of the glenosphere [18] have all been proposed. Finally, Falaise [19] reported the relationship between the humerus and the glenosphere defined by the glenometaphyseal angle to explain the development of notching.

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The main goal of this study was to evaluate predictive factors of the development of scapular notching following reverse shoulder arthroplasty. The hypothesis was that lowering the glenoid baseplate and increasing the glenometaphyseal angle could decrease the incidence of scapular notching. The secondary goal was to analyze the influence of scapular notching on the clinical results to evaluate the hypothesis that notching has a negative influence on clinical results.

2. Materials and methods

We included patients who underwent reverse shoulder arthroplasty between December 1998 and November 2008 who were seen after a follow-up of 2 years and with a radiographic follow-up corresponding to our analytical criteria. We excluded prostheses that were performed for revision total shoulder arthroplasty.

One hundred and thirty-three reverse shoulder arthroplasties were performed between December 1998 and November 2008 in 121 patients. This included 85 women and 36 men. The mean age at surgery was 73 years old (50–87). There were the following etiologies:

- one hundred and ten cuff tear arthropathies: 22 stage 2 shoulders according to the Hamada and Fukuda classification [20], 38 stage 3 shoulders, 34 stage 4 shoulders and 16 stage 5 shoulders;
- fourteen rheumatoid arthritis: 2 stage 3 shoulders according to the Larsen classification [21], 11 stage 4 shoulders and 1 stage 5 shoulder;
- nine fracture sequellae of the proximal humerus. There were 5 aseptic necrosis of the humeral head, 1 non-union of the surgical neck and 3 malunions of the tuberosities.

A deltopectoral approach was used in 103 cases and a transdeltoid in 30 cases. A Delta III prosthesis was used in all cases (Depuy international Ltd, Leeds, UK). A 36 mm glenosphere was used in all cases.

Clinical follow-up was prospective and radiographic predictive factors were obtained retrospectively. Patients underwent a pre-operative clinical and radiographic evaluation and the body mass index (BMI) was obtained for each patient.

There were 19 complications (2 postoperative neurological deficits, 2 perioperative glenoid fractures, 1 hematoma, 1 detached deltoid, 5 prosthetic dislocations, 7 periprosthetic infections and fracture of the scapular spine) requiring 14 surgical revisions with no need to change the implant in 13 cases. We therefore excluded the patient who underwent revision surgery of the implant for periprosthetic infection.

The X-ray used to analyze the predictive factors was an AP view in the neutral position so that the X-ray filmed the baseplate of the glenosphere. We analyzed X-rays performed in the first 6 postoperative months to select an image that corresponded to our criteria. After 2004, a fluoroscopic image of the baseplate of the glenosphere was performed by X-ray technicians before performing the X-ray. We therefore excluded 15 patients in which the X-rays did not identify the baseplate of the glenosphere and could not be exploited for analysis.

We analyzed the predictive radiological factors of notching:

- the overhang of the glenosphere in relation to the inferior glenoid rim (Fig. 1a);
- the glenometaphyseal angle [19] defined by the angle between the largest diameter of the glenosphere and the humeral metaphysis (Fig. 1b).

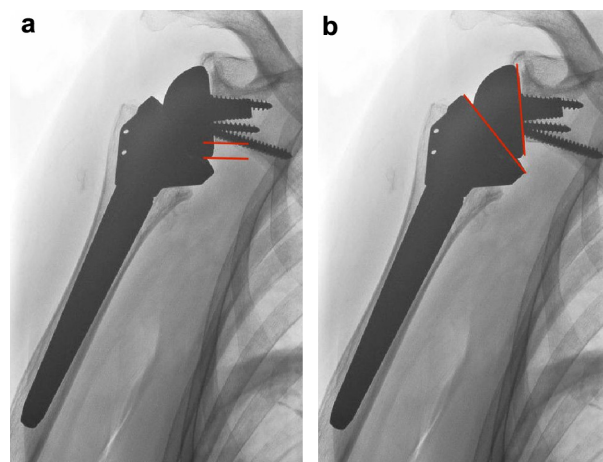


Fig. 1. Radiographic measurements on an AP X-ray with the glenoid base plate. a: overhang of the glenosphere in relation to the inferior rim of the glenoid component; b: glenometaphyseal angles.

All radiographic measurements were performed by an independent observer using Osirix®. Images were first scaled based on the known diameter of the glenosphere, then the measurement of distances and angles could be performed.

After 2 years follow-up we analyzed the clinical results of each patient based on the Constant score [22] and a radiographic evaluation was performed to identify the presence of notches according to the Sirveaux classification [4]. We chose a 2-year follow-up because Simovitch [6] showed that notches appeared within 14 months.

The statistical evaluation was performed with the Student *t* test, the Chi² test and the Spearman correlation. *P* < 0.05 was considered to be significant.

3. Results

There were no lost to follow-up patients at 2 years and we therefore evaluated 117 prostheses for predictive factors of notching.

There was a notch in 50.4% of cases after 2 years of follow-up. Fifty-eight shoulders (49.6%) did not have any notches, 48 shoulders (41%) had a stage 1 notch, 8 shoulders (6.8%) had a stage 2 notch and 3 shoulders (2.6%) had a stage 3 notch (Fig. 2).

The mean Constant score was 67.8 points (38–83). The Constant score was 69.3 points (54–83) in the group without notches. It was 66.9 points (49–82) in the group with stage 1 notches (*P* = 0.16), 64.2 points (38–78) in the group with stage 2 notches (*P* = 0.19) and 67.7 points (61–75) in the group with stage 3 notches (*P* = 0.17) (Table 1).

We used ROC curves to determine the discriminant value of mean glenosphere overhang and the glenometaphyseal angle. Mean overhang of ≥ 3 mm was discriminant and the discriminant value for the glenometaphyseal angle was $\leq 28^\circ$.

The mean overhang was 3.5 mm (–1–8 mm). When the overhang was less than 3 mm, the rate of notching was 65.5% and when the overhang was ≥ 3 mm, the rate of notching was 39.6% (*P* = 0.027). The mean glenometaphyseal angle was 27.3°. When the angle was

Table 1
Constant score according to the stage of notches.

| Notch | Number | Constant score |
|---------|------------|---------------------|
| None | 58 (49.6%) | 69.3 points (54–83) |
| Stage 1 | 48 (41%) | 66.9 points (49–82) |
| Stage 2 | 8 (6.8%) | 64.2 points (38–78) |
| Stage 3 | 3 (2.6%) | 67.7 points (61–75) |



Fig. 2. Development of a stage 2 notch in a patient with 0 mm overhang and a glenometaphyseal angle of 31°.

above 28° the rate of notching was 72.2%, when it was ≤28° the rate of notching was 26.5% ($P=2.7 \cdot 10^{-5}$).

Thirty-seven shoulders had an overhang of more than 3 mm and a glenometaphyseal angle of less than 28°. The rate of notching in this population was 21.6%.

The glenometaphyseal angle was analyzed in relation to the patient's BMI; the mean BMI was 28 kg/cm² (19.4–41.0). The BMI was significantly correlated to the GM angle ($P=2.5 \cdot 10^{-7}$) with a correlation coefficient (r^2) of 23.7% (Fig. 3).

4. Discussion

This study shows that the development of notches is influenced by the overhang of the glenosphere and the glenometaphyseal angle. Nevertheless, this study did not show that the development of notches has a negative influence on short-term functional results.

The development of notches in the scapular pillar following reverse shoulder arthroplasty remains a problem in this therapeutic option. Furthermore, the clinical influence of notches has been evaluated in various ways by different authors and for certain [7,9,10] there is no difference between patients with and without notches. On the other hand, other authors [4–6] report deterioration in function mainly with grade 3 and 4 notches, while we did

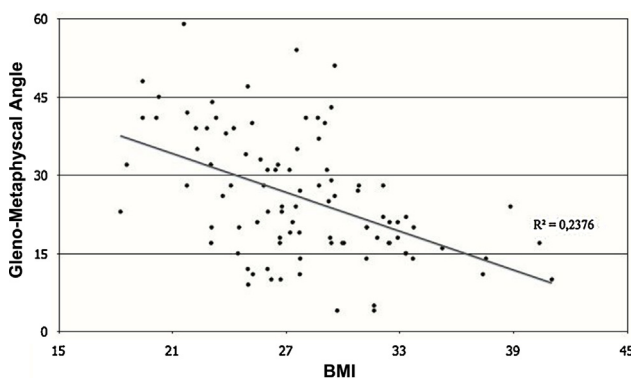


Fig. 3. Variation of the glenometaphyseal angle in relation to the patient's BMI.

not find any statistical difference in our series, although the follow-up was short and the population with stage 3 and 4 notches was too small. The mechanical hypothesis of impingement between the scapular pillar and the humeral metaphysis [8,9,14] is the most widely accepted explanation for the development of notches. Certain authors [7,23] have explained the progression of scapular pillar notches by a mechanism of bone loss due to reactionary osteolysis of polyethylene wear [6,9,23]. This could explain the significant decrease in the Constant score in certain series [4,6].

Based on these observations, many authors have worked on the position of the glenosphere to reduce the risk of developing notches and we have shown that good positioning of the glenosphere reduces the risk of notching. At present, there are 3 avenues of research: inferior overhang of the glenosphere, the tilt of the metaglene and lateralization of the center of rotation. The first option is to move the metaglene off center to obtain inferior overhang of the glenosphere in relation to the scapular neck, a hypothesis which is supported by several authors. In a study of 77 shoulders, Simovitch [6] showed that high implantation of the glenosphere was correlated with an increased risk of notching. In a cadaveric study, Nyffeler [24] showed that adduction increased by 24° if the glenosphere hung over the inferior rim of the glenoid, thus reducing the risk of contact between the polyethylene and the scapular pillar. This angle was also identified by De Wilde [14] in a study using computerized 2D models. He showed that 5 mm overhang increased possible adduction by 39°. Our study confirms this hypothesis because we found a reduced risk of notching when the glenosphere hung over the inferior glenoid rim. To obtain this overhang Kelly [25] showed that the baseplate should be placed 12 mm from the inferior glenoid rim to obtain an overhang of between 1 and 4 mm.

The second option proposed by several authors is tilting the metaglene by 15 to 20°. Nyffeler [24] also showed that possible adduction in the resting position is increased by 16° in case of 15° tilt, and this tilt has also been proposed Boileau [9] based on the prior study. Levigne [5] found notches in 81% of patients in case of superior tilt while in the presence of erosion of the inferior glenoid which is equivalent to inferior tilt, notching was only found in 30%. However, Simovitch [6] does not agree with this theory of metaglene tilt. Indeed, in a group of patients without notching, the tilt was 9° while in patients with notching the tilt was 31°. The author states that this was due to overdrilling of the distal glenoid which places the glenosphere closer to the scapular pillar. Edward [26] confirmed this hypothesis in a prospective study comparing two groups of patients with or without 10° tilt and did not find any significant difference in the development of notches. In a study based on a computerized model, Gutierrez [27] also indicated that inferior tilt did not reduce the risk of impingement between the humeral metaphysis and the scapular pillar in relation to the position of the glenoid component with the inferior rim. We did not measure tilt of the glenosphere in our study because the reproducibility of this measurement did not seem satisfactory.

The third option is lateralization of the center of rotation. Franke [16] performed lateralization of the glenoid component in a series of 60 patients and there were no notches after 33 months of follow-up, although 12% of the patients had loosening of the glenoid component. Boileau [17] proposed lateralization of the center of rotation with the help of a spongy graft harvested from the humeral head. This BIO-RSA (Bony increased offset reverse shoulder arthroplasty), prevents the development of notches with minimal stress on the glenoid component because the center of rotation is located in the scapula once graft incorporation is obtained. He reported the results of this technique in a series of 42 patients in whom the graft was found to be incorporated in 98% with notches in only 19%. However, our series did not include the use of this technique in any of our cases.

Falaise [19] introduced the notion of the glenometaphyseal angle in 2011, and explained the development of notches by a combination of the glenoid and humeral components and not simply the glenoid component. In that study this angle was correlated with the development of notches and the angle was 35.7° in the group without notches and 46.9° in the group with notches. The BMI was also significantly higher in the group without notches (27.2), while it was 22.6 in the group with notches. We had similar results in our study.

This study has certain limitations. It is retrospective, the evaluation of notches was not always easy on standard X-ray, notches were only analyzed on AP X-rays in the resting position and CT scan was not performed. Moreover, we used the Sirveaux classification for notches although the intra- or interobserver reproducibility of this classification has not been determined. Nevertheless, this is still a large single surgeon series of reverse shoulder arthroplasty analyzing the predictive factors of notches.

5. Conclusion

This study confirms the influence of the position of the metaglene on the development of notches of the scapular pillar. The risk of notches decreases if the glenosphere overhangs the glenoid component. The degree of adduction of the arm in the resting position also plays a role and this adduction depends on the patient's BMI. However, even under the most optimal conditions described in this series, notches still occurred. The position of the metaglene must therefore be adapted to each patient's morphology and morphology of the glenoid to reduce the risk of the development of notches. In our practice we create overhang of the glenosphere in all cases, and adapt the tilt to the patient's BMI to preserve the inferior glenoid. This tilt is nearly inexistent in patients with a high BMI and we increase the tilt as the BMI decreases.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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