Scapular notching in reverse shoulder arthroplasties: The influence of glenometaphyseal angle

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Summary Solutions described to limit the risk of scapular notching mainly concern the glenoid. Our hypothesis is that this risk also depends upon the glenoid-humeral relationship when the arm is resting along the body.

\textit{Patient and methods:} This is a retrospective study of a continuous series of 85 reverse shoulder arthroplasties; 62 of these fulfilled inclusion criteria. The following parameters were studied: body mass index (BMI), inferior overhang of the glenosphere, the angles showing the position of the glenoid (GH) and the humerus (MH) in the scapular plane as well as the glenometaphyseal angle (GM = MH−GH), during an initial postoperative follow-up, at 1 and 2 years, and at a final follow up of a mean 45 months (24−81). The parameters studied were compared in two groups with and without scapular notching.

\textit{Results:} There were 21 instances of notching at the final follow-up. This rate was significantly correlated to the BMI, which was a mean 27.2 in patients without a notch and 22.6 in patients with a notch, while the preoperative inclination of the glenoid in these groups was respectively 92.3° versus 85° respectively, the inferior overhang of the glenosphere was 4 mm versus 2.8 mm, the GM angle was 36° versus 47°, the MH angle at one year of follow-up was 135° versus 145° and the GH angle at the final follow-up was 103° versus 94° respectively. The BMI was significantly correlated to the GM angle, and a low BMI was associated with high values of this angle.

\textit{Discussion:} The relative position of the glenoid and humeral components, as shown by the GM angle, was an essential factor in the development of a scapular notching. The humeral component of the GM angle evolved in thin patients with progressive adduction of the arm, which is associated with a risk of notching. This should be taken into account when performing reverse shoulder arthroplasties.

\textit{Level of evidence:} Level IV retrospective study.

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Introduction

Glenohumeral arthropathies with rotator cuff deficiencies are very debilitating, painful and difficult to treat when medical treatment is unsuccessful. In these cases total shoulder arthroplasty is associated with a risk of rapid glenoid loosening due to the rocking horse effect [1]. These total arthroplasties, like hemiarthroplasties, barely improve function or range of motion [2,3]. On the other hand, the reverse shoulder arthroplasty developed by Grammont [4] is a treatment that improves pain, mobility and function [5]. This is due to the biomechanical changes caused by this implant, which associates lowering, and medialisation of the humerus [6]. Nevertheless, these changes favor the development of impingement of the medial metaphysis of the implant and the scapular pillar, which may result in notching, which was initially reported by Sirveaux et al. [7] and whose long term prognosis seems to be poor both for clinical results and viability of the glenoid component [8,9].

To reduce the risk of notching, Simovitch [10] recommended overhanging the glenosphere under the inferior margin of the glenoid and most other studies confirm this [11–13]. On the other hand, there is no consensus on the best inclination for this glenoid component. For Simovitch [10], a downward tilt favors the development of a notch. For Levigne [12], this inclination limits this risk. Moreover, Frankle, who uses a glenosphere that lateralizes the center of rotation, reports a rate of notches of (13.4%) [14] which is much lower than that of other studies, which range from 44% for Simovitch [10] to 96% for Werner [9]. Moreover Boileau, who lateralizes the center of rotation by interposing a bone graft between the glenoid baseplate and the glenoid called BIORSA (Bony Increase Offset Reverse Shoulder Arthroplasty), reported a low notch rate of 19% [15]. Nevertheless, all of these techniques to limit the risk of notching concern the position of the glenoid.

Our hypothesis is that the most important predisposing factor for the development of a scapular notch also depends upon the humerus in particular the relationship between the glenosphere and the humeral metaphysis when the arm is resting along the body.

The aim of this study was to evaluate the postoperative position of the glenoid in relation to the humerus with the arm at rest and the relationship with the development of a scapular notch.

Patient and methods

This is a retrospective study performed within the context of a prospective follow-up of all patients operated on by two senior surgeons (CL and LF) at the University Hospital (CHU) of Tours and the Clinique du Parc in Lyon, France between January 1, 2003 and December 31, 2006.

Inclusion criteria were the following:

- one type of implant: the Aequalis Reversed™ Prosthesis (Tornier, Inc, Edina, MN, USA) and one size of glenosphere (36 mm);
- a preoperative radiographic work-up including an AP view of the glenohumeral joint space and the subacromial space (Fig. 1);

Figure 1 Measurement of angles on preoperative AP view X-rays.

- a minimum follow-up of 2 years;
- postoperative radiographic evaluations more than 6 months apart (generally less than 3 months after surgery, at approximately 1 year, 2 years and at the final follow-up) performed according to the protocol described by Lévigne [16].

Exclusion criteria were the following:

- reverse shoulder arthroplasty for revision of total shoulder arthroplasty because the native glenoid could not be measured;
- reverse shoulder arthroplasty for recent fractures because reliable X-rays of the position of the humerus could not be obtained;
- patients whose X-rays were not of sufficiently good quality for radiographic analysis, in particular all images in which the medial overhang of the glenosphere was more than 3 mm larger than its vertical diameter (Fig. 2).

Fifteen of the 85 patients who underwent surgery between January 1, 2003 and December 31, 2006, were lost to follow-up with a radiographic follow-up of less than 2 years, and the quality of X-rays was insufficient in eight. Sixty-two patients, corresponding to 63 shoulders fulfilled inclusion criteria. There were 55 women and seven men. The mean age at surgery was 74.6 years old (56-82). Etiologies were the following: 37 glenohumeral arthritis with cuff tears (stages 4 and 5 on the Hamada classification [17]), 16 massive cuff tears without glenohumeral arthritis (stages 1, 2, and 3 of the Hamada classification), five fracture sequelae, two glenohumeral arthritis without elevation of the humeral head and with massive cuff tears, two revision hemiarthroplasties, one rheumatoid arthritis. Thirteen shoulders had undergone prior surgery: eight cuff tear repairs including one deltoid flap, three acromioplasties and two isolated tenotomies along the biceps.

Glenometaphyseal angle and the development of scapular notching

The surgical protocol was the same in both centers: the patient was installed in the beach chair position, surgery was performed by the deltopectoral approach with placement of the glenoid baseplate brushing up against the inferior glenoid margin.

The BMI was noted in the preoperative evaluation. The radiographic examination was performed on an AP view in neutral rotation with the patient standing, arms hanging by the sides, that is on the scapular plane. The following were evaluated: (Fig. 1)

- the glenoid angle Gh0: between the perpendicular line joining the inferior and superior poles of the glenoid and the horizontal;
- the humeral angle Hh0: between the axis of the humeral diaphysis and the horizontal.

All measurements were performed by an independent observer. Patients were seen for follow-up after a mean 45 months (24–81).

There were six complications: two partial disassemblies of the glenosphere, one fracture of the scapular spine and three fractures of the acromion. No surgical revisions were necessary.

At the first postoperative follow-up, the inferior border of the glenosphere was measured in mm between the inferior margin of the glenoid and the glenosphere.

During later follow-ups, criteria evaluated on AP view X-rays in neutral rotation were:

- the presence of a notch, classified according to Sirveaux et al. [7] (Fig. 3). The population was then divided into two groups: \( n^+ \) patients with a notch whatever the stage and \( n^- \) for all grades 0;
- the glenoid angle Gh1 (Fig. 4): between the glenosphere baseplate (or its vertical diameter if the radius was not strictly tangential to the glenosphere baseplate) and the horizontal;
- the angle of the humeral metaphysis Mh1 (Fig. 4): between the proximal humeral metaphysis and the horizontal. The angles Hh1 (between the axis of the humeral diaphysis and the horizontal) and Mh1 showing the position of humeral abduction, but Mh1, which also includes stem alignment (varus or valgus) and anteversion was used for the different studies;
- the glenometaphyseal angle (GM) (Fig. 4): between the large vertical diameter of the glenosphere and the proximal rim of the humeral metaphysis corresponding to the difference between the two preceding angles Gh1

Figure 2  Evaluation of the quality of postoperative AP view X-rays and exclusion criteria.

Figure 3  Classification of notches according to Sirveaux et al. [17].


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and Mh1. This corresponds to the relationship between the position of the glenosphere and that of the humeral component.

The radiographic analysis was performed using Osirix® software. The X-rays were first scaled based on the known diameter of the sphere (36 mm) then measurement of distances and angles was performed.

The correlations between the different angles and the development of a notch were analyzed with StatView software (Abbacus Concepts Inc, Berkeley, CA, USA), using non-parametric Mann Whitney and Kruskall Wallis tests. Comparison between the two angles was performed with the non-parametric Wilcoxon rank test.

Results

Twenty-one scapular notches were visible at the final follow-up (33%). According to the Sirveaux [7] classification, there were seven stage 1 notches (11%), nine stage 2 (14%), one stage 3 (2%), and four stage 4 (6%).

The pre- and postoperative angles are shown in Table 1. The presence of a notch at the final follow-up was significantly correlated with the following preoperative factors:

- BMI whose mean value was 27.2 in patients without a scapular notch and 22.6 in those with a scapular notch ($P < 0.0001$);
- the $GH_0$ angle, whose mean value was 92.3° in patients without a scapular notch and 85° in those with a scapular notch ($P = 0.007$).

The presence of a scapular notch at the final follow-up was significantly correlated with the inferior overhang of the glenosphere whose mean value was 4 mm in patients without a scapular notch and 2.8 in those with a scapular notch ($P = 0.006$).

Angles measured 3 months after surgery were not significantly different between the two groups $n+$ and $n−$. At one

Table 1  Main pre- and postoperative values according to groups with and without scapular notching.

<table>
<thead>
<tr>
<th></th>
<th>$n−$</th>
<th>$n+$</th>
<th>All patients</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preop</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>27.2 ± 3.7</td>
<td>22.6 ± 3.7</td>
<td>25.4 ± 4.2</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>$GH_0$</td>
<td>92.3 ± 11</td>
<td>85 ± 6.4</td>
<td>88.7 ± 10.1</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>3 months</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inferior overhang (mm)</td>
<td>4</td>
<td>2.8</td>
<td>3.4</td>
<td>0.006</td>
</tr>
<tr>
<td>$GH_1$</td>
<td>103.6 ± 10.3</td>
<td>99.9 ± 9.9</td>
<td>102.5 ± 10</td>
<td>0.2</td>
</tr>
<tr>
<td>$MH_1$</td>
<td>135.7 ± 9.2</td>
<td>138.9 ± 8.6</td>
<td>136.7 ± 9</td>
<td>0.5</td>
</tr>
<tr>
<td>$GM$</td>
<td>32.1 ± 14.1</td>
<td>39.1 ± 11.3</td>
<td>34.3 ± 13.2</td>
<td>0.15</td>
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<tr>
<td><strong>1 year</strong></td>
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<td></td>
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<tr>
<td>$GH_1$</td>
<td>102.9 ± 7.3</td>
<td>98 ± 9.1</td>
<td>101.2 ± 8.2</td>
<td>0.09</td>
</tr>
<tr>
<td>$MH_1$</td>
<td>134.6 ± 8.1</td>
<td>144.8 ± 8</td>
<td>138.4 ± 9.1</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>$GM$</td>
<td>31.8 ± 11.1</td>
<td>46.9 ± 10.1</td>
<td>37.2 ± 12.3</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>2 years</strong></td>
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<tr>
<td>$GH_1$</td>
<td>102 ± 10.4</td>
<td>96.1 ± 8.6</td>
<td>99.3 ± 10.6</td>
<td>0.04</td>
</tr>
<tr>
<td>$MH_1$</td>
<td>137.5 ± 8.7</td>
<td>142.6 ± 7.9</td>
<td>139.8 ± 8.8</td>
<td>0.06</td>
</tr>
<tr>
<td>$GM$</td>
<td>35.5 ± 9.7</td>
<td>46.5 ± 9.6</td>
<td>39.7 ± 9.4</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Final follow-up</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$GH_1$</td>
<td>103.4 ± 11.5</td>
<td>94.2 ± 11.9</td>
<td>100 ± 12</td>
<td>0.006</td>
</tr>
<tr>
<td>$MH_1$</td>
<td>139.1 ± 7.8</td>
<td>141.1 ± 8.2</td>
<td>140 ± 7.9</td>
<td>0.25</td>
</tr>
<tr>
<td>$GM$</td>
<td>35.7 ± 11.6</td>
<td>46.9 ± 9.5</td>
<td>39.9 ± 11.6</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

BMI: body mass index; $GH$: glenoid angle; $MH$: metaphyseal humeral angle; $GM$: glenometaphyseal angle; $n−$: patients without notching; $n+$: patients presenting notching.

year of follow-up MH1 was significantly different between the two groups. After 1 year, GM was significantly different between the two groups. At the final follow-up GH1 was significantly different between the two groups (Table 1).

There was no significant variation in angle GH1 over time in the two groups although it tended to gradually decrease in the n+ group. There was no significant variation in angle MH1 in the first postoperative year in patients without a scapular notch. There was a significant increase in angle MH1 in patients with a scapular notch from a mean 138.9° less than 3 months after surgery to 144.8° at 1 year (P=0.04). MH1 then tended to decrease until the final follow-up. There was no significant variation in angle GM over time in patients without a scapular notch. There was a significant increase in angle GM in the first postoperative year in patients with a scapular notch, with a mean value of 39.1° less than 3 months after surgery to 46.9° at 1 year (P=0.007) after which it stabilized (Fig. 5).

The BMI was significantly correlated with the preoperative HH0 (P=0.002) angle, and the MH1 (P=0.003) and GM (P=0.02) angles at the final follow-up and a low BMI was associated with high values of these angles.

**Discussion**

The development of a notch on the pillar of the scapula following reverse shoulder arthroplasty is a frequent complication associated with a risk of poorer functional results [10,7]. Numerous changes have been made to glenoid components including their shape, size, alignment or position. The analysis of the relationship between the glenoid...
component and the humerus is also important. In our study the rate of notching was 33% at a mean follow-up of 45 months. The preoperative parameters, which were signifi-
cantly correlated with notching, were low BMI and small GH0 angle. The postoperative parameters, which were sig-
nificantly correlated with notching, were a small inferior overhang of the glenoid implant, large glenometaphyseal and MH1 angles and a small GH1 angle.

There are several limitations to this study. First, it is a retrospective study, although the follow-up of these patients was prospective within the framework of an evaluation of functional results. Despite this, there were 15 lost to follow-up patients and despite the care taken performing the X-rays, eight patients were excluded due to poor quality X-rays. The etiologies were heterogenous but only etiolo-
gies in which preoperative measurements of the glenoid and humerus could be obtained were included. Nevertheless it is possible that progression of these angles could differ accord-
ing to etiology but this could not be evaluated because of the small sample size of certain etiologies. Finally, there was the problem of reproducibility of X-rays to obtain reli-
able measurements. Measurements were all obtained by an independent observer but the intraobserver reliability was not studied. Nevertheless, in each X-ray the glenoid base-
plate is well implanted which is a criteria of quality and values did not change over time in patients without notches, suggesting that the measurements are reproducible.

This study confirms the influence of superior positioning of the glenoid component on the development of notch-
ing, and the decrease in this risk the more the glenosphere overhangs the lower margin of the glenoid. Although the two surgeons positioned the glenoid baseplate tangentially to the lower margin of the glenoid, the differences in the lower overhang of the glenosphere show the perioperative difficulty in evaluating this reference. Like Simovitch [10], we think that the inferior overhang of the glenosphere in relation to lower margin of the glenoid is important and should be approximately 4 mm, which was the mean value in patients without notching in our study.

The preoperative frontal inclination of the glenoid, shown by the GH0 angle was significantly correlated with the development of a notch. This is probably linked to the fact that it determines the frontal inclination of the glenoid component, even if this also depends upon the inclination of the component by the surgeon during the operation, and of the postoperative rotation of the scapula. This well-known notion was reported by Lévine [12], who showed the risk of developing a notch was greater in glenoids with superior wear. This suggests that superior wear favors a positioning of the baseplate in the same position, and thus the develop-
ment of a notch.

The relative postoperative positions of the glenoid and humeral components shown by the glenometaphyseal angle, does seem to be one of the major factors influencing notch development, which confirms our hypothesis. This angle depends upon two elements:

- the frontal inclination of the glenoid component, repre-
sented by the angle GH1;
- the degree of humeral adduction, represented by angle
MH1.

A frontal inclination of the glenoid component down-
wards, or the inferior tilt, reduces the glenometaphyseal angle, limits overhang of the humeral cup under the gleno-
sphere reducing the risk of impingement with the scapular pillar. This inferior tilt thus seems to reduce the risk of a notch. Besides the preoperative orientation of the glenoid, two elements determine the GH1 angle: first, the inclina-
tion the surgeon gives to the components, and the other, a rock- ing movement of the scapula during surgery, which may be because deltoid tension limits spontaneous adduction of the arm because the latter can only drop along the body by scapulothoracic movement.

When the degree of adduction of the arm, represented by the angle MH1, is low, corresponding to spontaneous abduc-
tion of the arm at rest, this reduces the glenometaphyseal angle, limiting the overhang of the humeral cup under the glenosphere and thus the risk of notching.

Several elements seem to influence the value of this angle:

- the corpulence of the patient; a low BMI is associated
with a large MH1 angle. This suggests that the thinner the
person is, the greater the adduction of the arm which is
easily explained by the limited interference of soft tissue
in these cases;
- progression of arm adduction over time: we found a sig-
nificant tendency towards a loss of spontaneous abduction
of the arm the first year after surgery in patients with a
notch, while the MH1 angle did not change in those with-
out a notch.

Thus in the glenometaphyseal angle, the humeral compo-
ment usually changes in the first postoperative year. Although it seems to play an important role, this element has not
been evaluated in series published thus far. Lévine is the
only author who hypothesized that the degree of arm adduc-
tion and the glenometaphyseal angle could influence the
development of a notch [12].

Schematically it would seem that in the first year after
surgery in patients with a notch, arm adduction, which is
possible because of progressive loss of deltoid tension and
lack of body mass, draws the metaphyseal humeral compo-
ment closer to the pillar of the scapula creating the condi-
tion for the development of a notch.

This is the first study to report a relationship between the
patient's body mass and the development of a notch. Our
results seem to show that thanks to spontaneous abduction
of the arm and a smaller glenometaphyseal angle, heavier
patients have a lower risk of scapular notching.

Thus the risk of notching could be limited:

- in case of a preoperative glenoid with an upward tilt
(angle GH0 < 89°): the risk could be reduced by surgical
correction of glenoid inclination which should be tilted
downwards. Scapulothoracic mobilization can also help
tilt the glenoid downwards but for the moment this is
difficult to control;
- in thin patients (BMI < 25):
  o an inferior overhang of the glenoid sphere must be
    obtained, by using a sphere that is aligned downwards,
  o an implant with a lower or no risk of notching can also
    be considered [18,19] or additional components such

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as BIORSA [15], these techniques lateralize the glenoid implant and increase the distance between the humeral metaphysis and the scapular pillar.

Disclosure of interest

Some authors have a financial relation with Tornier Company.

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