Orthopaedics & Traumatology: Surgery & Research 100 (2014) 495–502

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Original article

Effect of scapular pillar anatomy on scapular impingement in adduction and rotation after reverse shoulder arthroplasty

J. Berhouet[a,*,b], P. Garaud[a], M. Slimane[b], J. Nicot[b], J. Banah[b], E. Waynberger[c], L. Favard[a]

[a] *Service d'orthopédie traumatologie 2A, CHRU Trousseau, faculté de médecine de Tours, université François-Rabelais de Tours, 1C, avenue de la République, 37170 Chambray-les-Tours, France*
[b] *Laboratoire d'informatique, école d'ingénieurs polytechnique universitaire de Tours, université François-Rabelais de Tours, 64, avenue Portalis, 37200 Tours, France*
[c] *Service de radiologie, clinique Saint-Gatien, 8, place de la Cathédrale, 37000 Tours, France*

ARTICLE INFO

Article history:
Accepted 11 March 2014

Keywords:
Shoulder
Total reverse shoulder arthroplasty
Scapular pillar
Notching
Glenosphere offset

ABSTRACT

Background: Notching of the scapular pillar is the main radiographic complication seen during follow-up of reverse shoulder arthroplasties. Several recommendations pertaining to the implantation technique and glenoid component design have been suggested. No studies have investigated potential anatomic risk factors for inferior scapular impingement.
Hypothesis: A specific anatomic shape of the scapular pillar promotes the development of notching.
Materials and methods: The Aequalis Reversed® (Tornier Inc., Edina, MN, USA) prosthesis was implanted into 40 cadaver scapulae. We measured maximal range-of-motion (ROM) in internal rotation, external rotation, and adduction. The anatomic specimens were then imaged using two-dimensional computed tomography (CT) and the scapular neck angle, surface area under the scapular pillar, and distance from the central glenosphere peg to the inferior glenoid rim were measured. Associations between these CT parameters and ROM values were assessed using statistical independence tests.
Results: ROM values were greatest when the surface area under the scapular pillar was above 0.8 cm^2 ($P < 0.5$). This feature combined with a scapular neck angle less than 105° produced the largest ROM values ($P < 0.5$).
Discussion: The scapular neck angle alone is not sufficient to identify a scapular morphology that increases the risk of notching. The surface area under the scapular pillar, in contrast, discriminates between scapulae with and without a high risk of notching. The surface area under the scapular pillar is influenced by the inferior glenoid offset.
Conclusion: We were unable to define a specific scapular shape at high risk for notching. The prevention of notching should rely chiefly on a rigorous glenoid component implantation technique, with particular attention to the inferior offset.
Level of evidence: III, experimental study.

1. Introduction

Reverse shoulder arthroplasty was developed by Grammont et al. [1] in 1985 and has since then been proven effective in older patients with eccentric gleno-humeral osteoarthritis. Boileau et al. [2] reported significant improvements in pain scores and forward arm elevation in the plane of the scapula, which had increased by 70° after the mean follow-up of 40 months. The two main adverse outcomes after reverse shoulder arthroplasty are decreased range-of-motion (ROM) with the elbow by the side [3–5] and notching of the scapular pillar [6].

Recommendations regarding the surgical technique have been made to prevent these adverse outcomes. The first criterion identified to ensure optimal implantation of the glenoid component is inferior positioning of the glenoid baseplate as described by Nyffeler et al. [7] and Kelly et al. [8], according to the 12-mm rule. If the drill guide used to prepare the glenoid cavity is placed 12 mm away from the inferior glenoid rim, the supero-inferior position of the glenoid implant will be appropriate to prevent the development of notching, regardless of the shape of the scapula. The second technical criterion is lateralisation of the centre of rotation achieved either by using lateralising implants as suggested by Frankle et al. [9], Kalouche et al. [10], and Valenti et al. [11]; or by

* Corresponding author. Tel.: +33 247 474 747; fax: +33 247 475 912.
E-mail address: julien.berhouet@gmail.com (J. Berhouet).

http://dx.doi.org/10.1016/j.otsr.2014.03.021
1877-0568/

implanting a lateralised bone graft according to the BIO-RSA (Bony Increased Offset-Reverse Shoulder Arthroplasty) concept developed by Boileau et al. [12]. Nevertheless, lateralisation would be expected, in theory, to increase the loads on the bone-glenoid baseplate interface [13], thereby potentially increasing the risk of glenoid component loosening in the event of prosthetic lateralisation or of non-union in the event of bony lateralisation.

A number of improvements in the material have been introduced, and glenospheres are now available in various diameters and designs. Gutiérrez et al. [14–16] obtained better elevation in the plane of the scapula with glenospheres that had a lateralising effect, whereas notching prevention was most effective with glenospheres that were positioned off-centre. In previous works [17,18], our group showed that a large-diameter glenosphere with BIO-RSA lateralisation was the most effective combination for delaying inferior scapular impingement, while allowing well-balanced rotation ROMs with the elbow by the side.

In contrast to this variety of suggested solutions, the influence of scapular shape has received little research attention. The studies conducted to date focussed chiefly on determining the best sites for implanting the inferior baseline fixation screws. Middernacht et al. [19] described a position with posterior offset of the scapular pillar relative to the surgical axis of the glenoid cavity. Torrens et al. [20] identified posterior position of the most prominent part of the scapular pillar as a relevant feature and separated scapulae into two groups depending on whether the neck was long or short. These studies seem to support a posterior direction of the inferior glenoid baseplate screw. In contrast, Humphrey et al. [21] advocated an anterior direction of this screw, after demonstrating the existence of an anterior buttress of the scapular pillar. Finally, these studies provide a volumetric description of the scapular pillar, in the antero-posterior direction, but fail to identify specific scapular morphological features associated with the development of notching after reverse shoulder arthroplasty.

The primary objective of our work, which relied on two-dimensional computed tomography (CT), was to analyse scapular pillar morphology in order to determine its influence in the risk of inferior notching and the rotation ROMs. Our secondary objective was to verify that the 12-mm rule devised by Kelly et al. [8] was independent from scapular anatomic features.

2. Materials and methods

2.1. Materials

2.1.1. Shoulders and prosthesis

We studied 40 cadaver shoulders (20 from left and 20 from right upper limbs) that had no detectable evidence of prior injury (no internal fixation material or malunions) or overt osteoarthritis (no glenoid cavity deformities to the naked eye). Mean age at death was 79.1 years (range: 61–95 years) and there were 21 men and 19 women. We had no information on the height or weight of the donors.

Before CT, the Aequalis Reversed II® (Tornier Inc., Edina, MN, USA) prosthesis was implanted into each shoulder.

2.1.2. Computed tomography (CT)

We used a Somatome® Definition AS+ machine (Siemens S.A.S., France).

2.2. Methods

2.2.1. Prosthesis implantation and range-of-motion (ROM) measurements

The reverse shoulder prosthesis was implanted according to a detailed and reproducible protocol, by a single operator, on the cadaver specimens. Each specimen included the scapula-humeral girdle with the clavicle, forearm, and hand.

A modular metallic holder (Sawbones, Malmö, Sweden) was devised. A vise was clamped onto the scapula and an articulated arm was attached to the rest of the upper limb via an intramedullary nail screwed into the humeral implant. This device allowed us to replicate shoulder movements in all planes. ROMs were measured using protractors in the coronal and horizontal planes. The goal of the assembly was to allow modifications of the degree of humerus elevation while enabling ROM measurements.

On the glenoid cavity side of the shoulder, a baseplate of 25 mm in diameter was combined with a 36-mm centred glenosphere, after preparation of the glenoid cavity around a threaded drill guide held perpendicularly to the joint surface and in compliance with the 12-mm rule described by Kelly et al. [8]. On the humeral side, we used a stem measuring 6.5 mm in diameter with a metaphysis measuring 36 mm in diameter and an insert of the same diameter. Humeral retroversion was adjusted using a guidewire positioned relative to the axis of the forearm.

Once preparation of the shoulder prosthesis assembly on the metallic articulated holding device was complete, a crucial preliminary to performing the various measurements was adjustment of glenoid cavity alignment to ensure that the centre of rotation of the gleno-humeral joint was on the same axis as that of the metallic holder (Figs. 1 and 2). The plane of reference was the plane of the scapula: rotation was considered neutral when the forearm with the elbow flexed to 90° was perpendicular to the plane of the scapula.

For each of the 40 cadaver shoulders bearing the reverse prosthesis, we measured the maximal ROM values in forward elevation in the plane of the scapula, adduction, internal rotation, and external rotation [17,18]. The maximal ROMs were defined as ROMs at which superior, inferior, anterior, and posterior impingements occurred. Rotation ROMs were measured with the humerus in 20° of abduction. This angle was defined based on the gleno-metaphyseal angle, which reflects the position of the glenosphere relative to the humeral implant. In a study by Falaise et al. [22], the mean gleno-metaphyseal angle of 46.9° in patients with notching indicated 20° of humerus abduction; whereas the mean angle of 37.5° in patients without notching indicated 52° of humerus abduction with a strictly vertical orientation of the glenoid. We therefore selected this low value to ensure detection of impingements during rotation.

2.2.2. Computed tomography (CT)

After removal of the prostheses, each scapula was imaged by CT. All specimens were in exactly the same position on a stiff support. A laser beam was aimed at the middle of the central peg anchoring the glenoid baseplate before image acquisition (Fig. 3).

The image acquisition protocol was the same for all CT scans. We used a standardised protocol appropriate for bone imaging, with a slice thickness of 0.6 mm, 0.3 mm increments, and mutiplanar reconstruction. The total radiation dose delivered was 140 kV, i.e., the same as the dose used to examine living patients.

2.2.3. Image analysis and processing

The CT scans of each scapula were obtained in DICOM (Digital imaging and communications in medicine) format. They were visualised and analysed using Osirix® software (version 3.7.1, GNU General Public License).

2.2.4. Data collection

We elected to study only two-dimensional CT acquisitions. This choice was based on the difficulties encountered in identifying reliable parameters that can be used and measured on three-dimensional acquisitions.