Subscapularis Release in Shoulder Replacement Determines Structural Muscular Changes

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Abstract

Background Osteotomy of the lesser tuberosity in shoulder arthroplasty allows bony healing of the subscapularis tendon but does not prevent fatty degeneration in its muscle. Occurrence or increase in fatty degeneration may depend on the surgical technique.

Questions/purposes We (1) assessed fatty degeneration in the subscapularis muscle and its cross-sectional area after a C-block osteotomy of the lesser tuberosity with minimal mobilization of the subscapularis muscle, and (2) determined whether this technique had any adverse effect on

function, fatty degeneration, and cross-sectional area of the subscapularis muscle.

Methods We retrospectively examined 36 patients with shoulder replacements who had C-block osteotomies. Constant-Murley scores and clinical signs of subscapularis insufficiency were recorded. We radiographically assessed prosthetic placement. On CT scans, lesser tuberosity healing, fatty degeneration, and cross-sectional area of the subscapularis muscle were determined. The minimum followup was 13 months (mean, 18 months; range, 13–33 months).

Results The mean absolute Constant-Murley score was 71.2. Two patients had weakness of the subscapularis muscle without loss of active motion. All tuberosities healed anatomically. A normal glenohumeral relationship was found in all cases. Fatty degeneration was Grade 0 in 44%, Grade 1 in 39%, Grade 2 in 14%, and Grade 3 in 3%. The subscapularis muscular cross-sectional area decreased from 16.7 cm² preoperatively to 14.5 cm² postoperatively (13%).

Conclusions The C-block osteotomy with minimal dissection of the subscapularis is associated with a low incidence of fatty degeneration in the subscapularis muscle after shoulder arthroplasty although the muscular cross-sectional area of the subscapularis decreased.

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

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Introduction

Failure of the subscapularis tendon repair after total shoulder arthroplasty results in lower DASH scores [20], loss of strength [28], and anterior instability [27]. To

improve subscapularis tendon healing, some authors advocate an osteotomy of the lesser tuberosity as bone-to-bone healing is more reliable than tendon-to-bone [12, 31]. Osteotomy of the lesser tuberosity reportedly is associated with a lower rate of subscapularis tendon tears after total shoulder arthroplasty when compared with subscapularis tenotomy [29, 35], and consequently with superior subscapularis function [29].

Despite more reliable subscapularis tendon reattachment, degeneration of the subscapularis muscle after open surgical release remains a concern [12, 20, 26, 29, 36]: fatty infiltration of the subscapularis muscle progresses by at least one stage in 45% of cases postoperatively [12]. Fatty muscular degeneration negatively influences strength, mobility, and overall Constant-Murley scores [7, 12]. The reason for progression of fatty infiltration of the subscapularis muscle is unknown, but denervation during surgical approach has been suggested [26]. Muscular damage during surgical approach with release and mobilization of the subscapularis muscle also may explain the degeneration [28]. Preservation of the subscapularis muscle requires maximum protection of the neurovascular structures at the anterior and inferior surfaces during release [29, 36, 39].

To minimize the risk of harm to the neurovascular structures and muscle, we introduced the bone block osteotomy of the lesser tuberosity without ligation of the anterior humeral circumflex vessels if possible and with minimal mobilization of the inferior part of the subscapularis. Furthermore, the axillary nerve remains unexplored, and release of the subscapularis tendon and muscle unit is restricted to the intraarticular part, superiorly to the subcoracoid bursa and anteroinferiorly to the capsule at the glenoid rim. However, it is unclear whether this new approach achieves the goals of low risk to the neurovascular structures and minimal progression of fatty degeneration, without introducing any adverse effects.

Therefore we examined (1) the clinical integrity of the subscapularis tendon and the shoulder function with the Constant-Murley score, and radiographically the prosthetic fixation, (2) the occurrence of specific complications, (3) healing of the lesser tuberosity, (4) progression of fatty degeneration in the subscapularis muscle, and (5) the effect on AP rotator cuff balance.

Patients and Methods

Between November 2006 and January 2009, we performed 37 shoulder arthroplasties in 36 patients at the University Hospital Ghent. There were 26 women and 10 men. The average age of the patients at the index procedure was 68 years (range, 52–79 years). Primary osteoarthritis with an intact rotator cuff was the indication in all patients,

confirmed by radiography, CT, or MRI. One patient was lost to followup at 12 months. This left 35 patients with 36 shoulders for the study. Minimum followup was 13 months (mean, 18 months; range, 13–33 months). No patients were recalled specifically for this study; all data were obtained from medical records and imaging. Ethical approval was cleared from the ethics committee University Hospital Ghent.

Preoperatively we evaluated patients clinically with the Constant-Murley score [5]. The mean absolute score was 39.2 (range, 13–73). The preoperative glenoid erosion was classified with the CT scan, according to Walch et al. [38]: there were three type A1 glenoids, eight type A2, four type B1, and 15 type B2. Fatty degeneration in the rotator cuff muscles was assessed on these CT scans according to Goutallier et al. [13]. For the subscapularis muscle, fatty degeneration was absent in 12, Grade 1 in 14, and Grade 2 in four (Table 1). These preoperative radiologic results involve only the 30 patients who underwent preoperative CT.

All procedures were performed by the senior author (LDW). We used a deltopectoral approach in all cases. After lateralization of the cephalic vein, the clavipectoral fascia was opened between the coracoacromial ligament cranially and the pectoralis major tendon caudally. The humeroscapular motion interface was freed of adhesions, not dissecting further than 1 cm medial to the conjoined tendon. We performed tenodesis of the long head of the biceps tendon to the superior part of the pectoralis major tendon using Ethibond™ 2 sutures (Ethicon Inc, Somerville, NJ, USA). The tenodesis was always between 5 cm and 6 cm from the top of the humeral head. Care was taken not to violate the anterior circumflex vessels. We incised the transverse humeral ligament toward the rotator cuff interval, progressing medially to the basis of the coracoid process. The long head of the biceps tendon was exposed and sectioned at its insertion on the glenoid. The tendon proximal of the tenodesis was delivered from the sulcus intertubercularis and resected. We delineated the superior and inferior borders of the lesser tuberosity with diathermy (Fig. 1). With an oscillating saw, the marked cortices were

Table 1. Grade of fatty degeneration

Grade*	Subscapularis					Infraspinatus					Supraspinatus				
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
Preoperative (n = 30)	12	14	4	0	0	16	12	2	0	0	13	16	1	0	0
Postoperative (n = 36)	16	14	5	1	0	19	13	3	1	0	19	12	4	1	0

* According to Goutallier et al. [11]; Grade 0 = no fat; Grade 1 = traces of fat; Grade 2 = fat less than muscle; Grade 3 = fat equal to muscle; Grade 4 = fat greater than muscle.

Fig. 1 An intraoperative photograph of the C-shaped osteotomy of the lesser tuberosity is shown. The insert in the upper left corner shows a cadaveric specimen with the C-shape delineated on the lesser tuberosity (red line).

cut and both cuts were connected with a vertical cut in the sulcus intertubercularis weakening the lesser tuberosity in a controlled way. We placed an osteotome into the cut of the sulcus intertubercularis and created a fracture of the lesser tuberosity with a levering maneuver. The fracture line was consistently located at the anatomic neck of the humeral head without harming the humeral head itself, even in the presence of large osteophytes. A bone block of 1 cm to 1.5 cm thickness thereby was created without fracturing or weakening the osseous insertion of the subscapularis tendon. The lesser tuberosity block osteotomy was tagged with a TiCronTM 5 suture (Covidien, Mansfield, MA, USA) at the tendinoosseous transition of the superior part of the subscapularis tendon and reflected over its soft tissue envelope together with the anterior circumflex vessels. In continuity with the inferior capsule, we released the subscapularis farther off the medial side of the humeral shaft until the insertion of the latissimus dorsi was encountered. When present, osteophytes were removed from the humeral head with a nibbler until the true borders of the humeral head appear. We then dislocated the joint anterosuperiorly to perform the cut at the anatomic neck of the humeral head. Without harming the rotator cuff tendons, the humeral head was extracted and the humeral medullary canal opened and prepared with the appropriate reamers. During reaming, usually a defect the width of the reamer occurred

in the proximal humerus anterior in the bicipital groove. Cautious reaming is warranted as the proximal humerus is weakened to an extent the greater tuberosity can fracture as well, especially in osteoporotic conditions. The circumference and thickness of the humeral head were measured to choose the best fitting prosthetic head. The trial prosthetic head was connected to the trial prosthetic stem in a position to cover the humeral cut. Before preparing the glenoid, the humeral trial prosthesis was removed and two cerclage wires (Number 5 TiCronTM suture nonabsorbable polyester fiber surgical suture) were placed around the surgical neck of the humerus for later repair of the osteotomy. Exposure of the glenoid usually was facilitated through the defect anterior in the bicipital groove. The soft tissues around the glenoid process were released circumferentially and removed until the muscle fibers were seen. The access gained to the glenoid through the defect in the anterior humerus, especially in patients with posterior subluxated shoulders and biconcave glenoids, facilitated the soft tissue release. With the arm internally rotated, tension on the posterior cuff was reduced in the absence of the humeral head, and the posterior structures were readily accessible. We similarly cleared the subcoracoid recess taking care not to harm the tendon of the subscapularis. The anterior and inferior capsules were not resected but released from the inferior glenoid tubercle. These releases do not endanger the axillary nerve, because it is protected by the tendinous insertion of the long head of the triceps in continuity with the inferior capsule. When present, exuberant inflamed synovial lining was debrided using a serrated curette up to the capsule, leaving the capsule itself intact. We did not explore the axillary nerve. The glenoid was prepared with the reamers according to the surgical technique of the Anchor Peg Glenoid prosthesis (DePuy Orthopaedics Inc, Warsaw, IN, USA). The lesser tuberosity window allows the use of straight reamers and drills without excessive traction to the soft tissues (Fig. 2). After implantation of the cementless glenoid, the cementless humeral prosthesis was assembled with the same offsets as the trial prosthesis for the best coverage of the humeral cut and subsequently implanted. Both cerclage wires were delivered through the inferior $\frac{2}{3}$ of the subscapularis tendon at its tendinoosseous transition and tied to fix the block osteotomy to the proximal humerus. At the superior part of the subscapularis, we placed a third suture transosseously behind the sulcus intertubercularis for optimal anatomic reduction. Occasionally the cancellous bone of the lesser tuberosity required sculpting to fit to the anterior fin of the humeral component. We closed the superior part of the subscapularis and the rotator interval with three EthibondTM 2 sutures with the arm held in external rotation. In all cases, the reduction of the lesser tuberosity appeared clinically stable throughout full ROM. After thorough lavage, we closed the deltopectoral approach

Fig. 2A–B (A) Access to the glenoid vault through the lesser tuberosity window allows the use of straight reamers. (B) Exposure of the glenoid is shown after preparation for the prosthetic implant.

over a suction drain. All shoulders were treated with a total shoulder arthroplasty (cementless Global[®] Advantage[®] humeral prosthesis; DePuy; cementless Anchor Peg Glenoid prosthesis; DePuy).

The drains were removed the day after surgery. From the first day after surgery, patients were encouraged to move the shoulder girdle and the arm passively and actively. Slings or splints were not used. Patients were discharged from the hospital when they were able to use their arm independently for simple activities of daily life such as feeding, dressing, or writing, usually achieved after 3 to 4 days. Further active rehabilitation was encouraged, first in the prone position and afterward standing, as much as possible without restriction unless pain was experienced. At 6 weeks, a nonsupervised physical therapy program was started, with daily progressive muscle strengthening exercises of the shoulder girdle.

Postoperatively, patients were examined routinely at 3, 6, and 12 months, and yearly thereafter, clinically and radiographically (true AP in neutral rotation, AP in internal rotation, and scapular Y view). At each visit we obtained Constant-Murley scores [5]. Subscapularis strength was examined with (1) a qualitative press belly test [9], in which the patient is asked to press the belly with both hands and bring the elbows forward, (2) the internal rotation lag sign [16], in which the hand of the patient is brought behind his back, from below with the elbow at 90°, and instructing the patient to keep the hand positioned free, and (3) the lift-off test [10], in which the patient is asked to bring the hand behind the back, from below, and position it himself as far backward as possible. Plain radiographs were used to evaluate the prosthetic implants. The method

described by Lazarus et al. [23] was used to evaluate fixation of the glenoid component: radiolucencies about the pegs of the glenoid component were observed and graded on a numeric scale from 0 (no radiolucency) to 5 (grossly loose). According to the method described by Sanchez-Sotelo et al. [34], subsidence and tilt of the humeral component was measured to evaluate fixation of the humeral component. The radiographs were examined for areas of bone loss or osteolysis. At last followup, we obtained CT scans of the shoulder for all patients. The glenohumeral relationship was evaluated according to Walch et al. [38]: the ratio of subluxation is the ratio between the section of the humeral head posterior to the center of the glenoid to the greatest head diameter on the horizontal slices; a centered head has a ratio between 45% and 55%. Bony consolidation of the lesser tuberosity, defined as the disappearance of the osteotomy line, was evaluated on the CT scans. Finally, the CT scans were used to grade fatty degeneration according to Goutallier et al. [13], and to quantify the cross-sectional area of the anterior and posterior muscle bellies. Preoperative CT scans were available for 30 patients. For preoperative and postoperative CT scans the patient was in the same supine position with a cushion on the belly ensuring the backside of the thorax was in the coronal plane and the forearm in the sagittal plane with the elbow tight to the body [6].

Two of us (TDC, FDN) evaluated all CT scans and performed the measurements. On the sagittal image, the infraglenoidal plane was determined (Fig. 3). On the according axial image, the subscapular and infraspinatus and teres minor muscles were identified (Fig. 4). Healing of the lesser tuberosity was defined as cortical continuity

Fig. 3 The infraglenoid tubercle is shown on this sagittal image. The orange line through the infraglenoid tubercle indicates the level of the axial CT image used for the measurement of the cross sectional areas of the rotator cuff muscles.

Fig. 4 The contours of the subscapularis (green) and infraspinatus/teres minor muscles (orange) are shown.

between the lesser tuberosity and the surrounding cortex of the proximal humerus. The glenohumeral relationship was evaluated on the axial CT scan according to the method of Walch et al. [38], in which the position of the head in relation to the glenoid is determined. The cross-sectional area of the subscapular and infraspinatus muscles was measured preoperatively and at latest followup. The cross-sectional area of the subscapular and infraspinatus and teres minor muscles was evaluated by the region of interest (ROI) method [4]. A freehand ROI was determined around the muscle, giving a quantified measurement of the cross-sectional area of the muscle in square centimeters. The ratio of the cross-sectional area of the anterior versus

Table 2. Interobserver reliability

Measurement of cross-sectional area of muscle	Intraclass correlation coefficient	p value
Preoperative subscapularis	0.922	0.001
Postoperative subscapularis	0.819	0.001
Preoperative infraspinatus	0.919	0.001
Postoperative infraspinatus	0.836	0.001

Table 3. Intraobserver reliability

Measurement of cross-sectional area of muscle	Intraclass correlation coefficient	p value
Preoperative subscapularis	0.96	0.001
Postoperative subscapularis	0.936	0.001
Preoperative infraspinatus	0.988	0.001
Postoperative infraspinatus	0.916	0.001

posterior rotator cuff muscles also was calculated. This ratio corresponds to the AP force couple of the glenohumeral joint [17] if the shoulder is examined in the same position in the CT gantry before and after surgery [6]. To avoid a learning curve effect, the first 10 images were measured twice. All measurements were made by one investigator (TDC) on 30 patients preoperatively and 36 patients postoperatively. Intraobserver and interobserver variations were determined with the intraclass correlation coefficient (ICC) [37]. To calculate ICC, the measurements were performed in duplicate with a 2-week interval by two observers (TDC, FDN). ICCs ranged from 0.819 to 0.922 for interobserver reliability (Table 2) and from 0.916 to 0.988 for intraobserver reliability (Table 3).

Constant-Murley scores are reported in terms of means with ranges. Radiographic evaluation is descriptive for implant fixation [34], radiolucencies [23], and areas of osteolysis. We also report the ratio of subluxation as measured on CT scans. Evaluation of fatty degeneration is descriptive and the cross-sectional area of the subscapularis is reported with means and standard deviations. The cross-sectional areas were correlated to the Constant-Murley scores. To compare two paired groups of continuous variables, the Wilcoxon signed ranks test was used. SPSS Version 16 (SPSS Inc, Chicago, IL, USA) was used.

Results

The postoperative mean absolute Constant-Murley score was 71.2 (pain, 12.5; activities of daily living, 17.3; range of movement, 33.3; power, 8.1) (Table 4). Postoperatively, two patients had a weak press belly test without a lag sign

Table 4. Constant-Murley scores

Constant-Murley score	Preoperative*	Postoperative*
Pain	4.2 (0–11)	12.5 (5–15)
Activity	9.9 (4–17)	17.3 (7–20)
Mobility	18.5 (4–36)	33.3 (18–40)
Strength	6.7 (0–25)	8.1 (0–24)
Total	39.2 (13–73)	71.2 (40–93)

* Range in parentheses.

Fig. 5 Osteolysis under cerclage wires is shown (red circle).

and one patient was unable to perform the lift-off test as a result of stiffness. The humeral prosthetic implant was firmly fixed in all cases. At the glenoid component, radiolucency was seen around three peripheral pegs and one central peg in two patients. In three shoulders we found small areas of osteolysis under the cerclage wires around the proximal humerus (Fig. 5). On CT scans, the ratio of subluxation was 50% in all cases.

We identified two complications. A fracture of the greater tuberosity occurred in a patient with sickle cell anemia. The fracture was repaired by bone suture but apparently with overtensioning. In addition, the large osteophytes in this shoulder were overlooked and not removed. Despite these aggravating factors, this patient is pain-free and has an absolute Constant-Murley score of 61 at 18 months. One patient had a huge postoperative hematoma develop, possibly as a result of a laceration of

Table 5. Ratios of cross-sectional areas force couples

Ratios of the cross-sectional areas	Number	Minimum	Maximum	Mean	SD
Preoperative force-couple*	30	0.561	1.716	1.05808	0.304374
Postoperative force-couple*	36	0.593	1.777	0.94473	0.252318

* Subscapularis/infraspinatus-teres minor.

the anterior circumflex vessels, which were not systematically explored or ligated (only four times). Although she refused a washout, additional progression was uneventful.

Anatomic healing of the lesser tuberosity occurred in all patients.

Postoperative fatty degeneration of the rotator muscles (36 shoulders) was progressive in, at most, two cases, one with Stage 2 and one with Stage 3 fatty degeneration, as in the six patients lacking preoperative CT scans, four had no fatty degeneration of the subscapularis postoperatively (Table 1). Removing these patients would result in equal findings preoperatively and postoperatively.

The cross-sectional area of the infraspinatus muscle was similar ($p = 0.155$) postoperatively compared with preoperative values. The cross-sectional area of the subscapularis muscle decreased ($n = 30$; $p = 0.004$) after surgery. The ratios of the cross-sectional area of the subscapularis versus the cross-sectional area of the infraspinatus and teres minor (relation between the anterior and posterior force couples) were 1.05 preoperatively and 0.94 postoperatively (Table 5). We found no difference ($p = 0.066$) in the preoperative and the postoperative ratios.

The Constant-Murley score correlated ($r = -0.496$; $p = 0.002$) with fatty degeneration of the subscapularis muscle and the ratio of the anterior to posterior cross-sectional area ($r = -0.600$; $p < 0.001$).

Discussion

Approaching the shoulder for an anatomic joint replacement requires violation of the subscapularis. The clinical outcome of shoulder arthroplasty is affected adversely by subscapularis insufficiency [7, 12, 24–26, 35, 36], whether a tear of the tendon or fatty degeneration of the muscle. Although healing of the subscapularis tendon is no longer an issue with osteotomy of the lesser tuberosity, fatty degeneration of the subscapularis muscle remains unsolved. The C-block osteotomy with only minimal mobilization of the subscapularis may minimize surgical damage to the neurovascular structures and subscapularis muscle during shoulder arthroplasty, and thus fatty degeneration. We assessed fatty degeneration in the subscapularis muscle and

its cross-sectional area after a C-block osteotomy, and determined whether this technique had any adverse effect on the Constant-Murley score, clinical function of the subscapularis muscle, prosthetic fixation, or glenohumeral relation between the prosthetic components, or gave rise to specific complications. We evaluated bony healing of the lesser tuberosity, progression of fatty degeneration, and the effect of this approach on AP rotator cuff balance.

Our study has several limitations. First, although ultrasound is reliable in diagnosing subscapularis tendon tears [19, 26, 30, 35], we performed no sonographic investigation to confirm the integrity of the subscapularis tendon. CT is not accurate enough to evaluate the tendon. However, we found no decrease in the coracohumeral distance or anterior subluxation of the glenohumeral joint, implying an intact rotator cuff [33]. Second, we did not quantify the strength of the subscapularis muscle in the press belly test [9] and the lift-off test [10]. However, clinical testing is not reliable in evaluating dysfunction of the subscapularis muscle [20]. Third, followup is short; evaluation of the subscapularis muscle after mean 18 months of followup (range, 13–33 months) postoperatively might be too early. However, CT was validated as a method to evaluate rotator cuff function and fatty degeneration in studies with similar postoperative followups [14, 28].

The Constant-Murley scores and postoperative radiologic findings in our series agree with those in published series [2, 15, 32]. Therefore we believe this limited approach to the subscapularis muscle does not compromise the clinical and radiologic results. Moreover, exposure of the glenoid is improved through the C-shaped osteotomy and the use of straight reamers is facilitated, without harming the proximal humerus (Fig 2).

Two of our patients experienced complications: one had a postoperative hematoma and one had an intraoperative fracture of the greater tuberosity. Hematoma formation is associated with a high rate of poor Neer scores and deep infection requiring additional surgery [3]. In our series, the hematoma was not treated with drainage as the patient refused surgical treatment. Nevertheless, we speculated this complication was attributable to a laceration of the circumflex vessels, and suggest specific verification of their integrity before wound closure. To avoid potentially severe complications, the anterior circumflex vessels were ligated in four cases since then. Intraoperative periprosthetic fractures are rare: Athwal et al. reported an incidence of 1.5% in a combined series of primary total shoulder arthroplasty, hemiarthroplasty, and revision total shoulder arthroplasty, 42% of them involving solely the greater tuberosity [1]. The fractured greater tuberosity in our series can be explained by the fact that the C-block osteotomy weakens the proximal humerus by interrupting the subcapital cortical ring, and by the osteopenic condition of this

specific patient with sickle cell anemia. Although these fractures are associated with a high rate of healing [1], as in our patient, it is advisable to handle the proximal humerus with extreme care to prevent this complication.

In this study all osteotomies of the lesser tuberosity healed uneventfully in an anatomic position favoring the functional outcome and preventing progression of fatty degeneration [14]. Although in three shoulders, a small area of osteolysis was seen underneath cerclage wires (Fig. 5), complete and anatomic bony union occurred in all patients. Osteolysis can be explained by micromotion of metal implants for bone fixation [22], although cerclage wiring is not typically prone. Contrary to earlier findings [22], this phenomenon did not cause any symptoms such as pain in our patients, and therefore removal of the material has not been required. The long-term consequences of the osteolysis are not known, but no clinical implications have been observed to date.

The low incidence of fatty degeneration in the subscapularis muscle in our patients is attributed to intraoperative and postoperative factors. Intraoperatively, limited dissection of the subscapularis tendon and muscle is likely to be beneficial: on the articular side, the anteroinferior joint capsule is saved; extraarticularly, the subscapularis is only minimally dissected, most often without ligation of the anterior circumflex vessels, and the axillary nerve is not explored. Restricting the articular release to a circumferential capsulotomy with resection of the labrum but without resection of the capsule did not compromise the surgical exposure or postoperative ROM. The capsule was released on the humeral and glenoid sides for observation and removal of osteophytes. According to the literature, vascular factors are not suggested to influence fatty degeneration [36]. Conversely, the limited need to ligate the circumflex vessels (only four times and one postoperative hematoma) suggests that subtle manipulation and less dissection of the subscapularis might be an important factor for prevention of postoperative fatty degeneration. We believe not only protection of the nerves to the subscapularis muscle, but also complete muscular protection leaving the fascia as intact as possible extraarticularly and intraarticularly, explain our findings. Postoperatively, immediate active rehabilitation could contribute to the superior muscle condition and prevent postoperative scar formation. With a C-block osteotomy, the bone block is strong enough and fixation with cerclage wires and transosseous suture stable enough to allow immediate active movement.

The magnitude of the ratio of the cross-sectional areas of the anterior versus the posterior muscles appeared more indicative for the Constant-Murley score than any parameter of the subscapularis alone. Considering the correlation between muscular volume and muscular strength [21], with strength being an important parameter

Table 6. Literature comparison

Study	Number	Grade 0 – no fat	Grade 1 – few traces of fat	Grade 2 – fat less than muscle	Grade 3 – fat equals muscle	Grade 4 – fat greater than muscle	Average preoperative grade
Gerber et al. [12]	34	19	12	3	0	0	0.53
Current study	30	12	14	4	0	0	0.73

Table 7. Literature comparison

Study	Followup (months)	Number	Grade 0 – no fat	Grade 1 – few traces of fat	Grade 2 – fat less than muscle	Grade 3 – fat equals muscle	Grade 4 – fat greater than muscle	Average postoperative grade
Gerber et al. [12]	39	39	14	9	4	4	3	1.1
Current study	18	36	16	14	5	1	0	0.75

in the Constant-Murley score [5], this finding is not surprising. Because AP rotator cuff force balance did not benefit from the C-block osteotomy in our series, we advise more specific intensive muscle strengthening exercises of the subscapularis muscle.

The dimensions of the osteotomized lesser tuberosity depend on the technique used. Gerber et al. [12], Ponce et al. [29], and Scalise et al. [35] advised a thickness of the osteotomized lesser tuberosity between 5 mm and 10 mm and a length between 3 cm and 4 cm. To create this osteotomy, a saw, drill, or chisel traditionally is used directed parallel to the subscapularis tendon. Only a few degrees off this parallel plane can substantially weaken the fragment. In the C-shaped osteotomy (Fig. 1), the saw and chisel are directed perpendicular to the bone, not parallel to the tendon. This technique appears technically easy in creating a consistent bony fragment. Another technical specificity of our osteotomy is reattachment of the lesser tuberosity with cerclage wires instead of a tension band [12, 35]. According to Frankle et al. [8], interfragmentary motion and strain theoretically are decreased, fragment stability is maximized, and postoperative rehabilitation facilitated.

In agreement with Greiner et al. [14], we confirm the correlation (although moderate, -0.496 to -0.600) between higher grades of fatty degeneration of the subscapularis and inferior clinical results [7, 18, 26]. Our study differs from the study of Gerber et al. [12] in that their followup was 39 months versus 18 months for our patients, and there was one supervising surgeon in their study versus one surgeon in ours, but these differences do not preclude comparison of the preoperative (Table 6) or postoperative results (Table 7). However, several differences in surgical technique can be identified. As indicated above, the direction of the osteotomy in the technique used by Gerber et al. [12] is parallel to the tendon insertion, whereas it is perpendicular to the bone with our technique. Second, mobilization of patients was more aggressive with release

of the subscapularis in the subscapularis fossa and mobilization to the base of the coracoid process [11], whereas with our technique, dissection was limited to perilabral capsulotomy and resection of the labrum. We found no progression of muscle degeneration in 94.5% of patients versus 45% reported by Gerber et al. [12]. If we include all 36 postoperative CT scans, progression of fatty degeneration was evident in 5.5% (two patients, one with Stage 2 fatty degeneration and one with Stage 3 fatty degeneration), because in the six patients without preoperative CT scans, four did not have fatty degeneration of the subscapularis.

We described a C-block osteotomy of the lesser tuberosity with reflection and minimal dissection of the subscapularis for total shoulder arthroplasty in osteoarthritic shoulders. This technique did not compromise implantation of the prosthetic components and allowed aggressive and early postoperative rehabilitation. Good clinical and radiologic results were obtained and no major complications were encountered. Furthermore, the subscapularis muscle showed a low incidence of fatty degeneration. Finally, we introduced the ratio of the cross-sectional area of the anterior to the posterior rotator cuff components as a parameter, correlating better with the Constant-Murley score after a shoulder arthroplasty than the degenerate condition of the subscapularis muscle.

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