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A symptom-based classification for shoulders with massive rotator cuff defects

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Abstract The aim of this prospective study was to propose a classification for shoulders with massive rotator cuff defects based on patients' clinical symptoms. A total of 100 shoulders with massive rotator cuff tears were evaluated clinically using the Constant score (CS) and with radiographs in two planes. Three types were defined and correlated with radiographic findings: (1) the arthritic type (type I), (2) the non-reactive type (type II) and (3) the necrotic type (type III). Significant differences in the overall CS (type I: 28.6 points, range: 4 – 61; type II: 18.8 points, range: 6 – 52; type III: 15.5 points, range: 6 – 31) and its subgroups and in shoulder motion were found between types I and II and between types I and III ($p < 0.05$). This classification may be helpful for the decision-making process with regard to the appropriate form of shoulder replacement surgery in patients with massive rotator cuff defects.

Résumé Le but de cette étude prospective est de proposer, pour les épaules présentant une rupture massive de la coiffe des rotateurs, une classification basée sur les signes cliniques. 100 épaules présentant une rupture massive de la coiffe des rotateurs ont été évaluées de façon clinique en utilisant le score de Constant (CS) et une radiographie dans les deux plans. 3 types d'épaule ont été définis et corrélés avec les découvertes radiographiques: le type 1 arthrosique, le type 2 non réactif, le type 3 nécrotique. Avec des différences significatives du score de Constant, dans le type 1, 28,6 points (4 à 61), dans le type 2,18,8 points (6 à 52) et dans le type 3,15, 5 points (6 à 31). Par ailleurs, des sous-groupes ont pu être également définis en fonction de la mobilité de l'épaule entre le type 1 et le type 2 et entre le type 1 et le type 3 (p<0,05). Cette classification permet d'améliorer le processus de décision et de réaliser un traitement adapté en ce qui concerne notamment le remplacement de l'épaule chez ces patients présentant une rupture massive de la coiffe des rotateurs.

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Introduction

The rotator cuff-deficient shoulder is a disabling condition leading to pain and loss of function. Next to the massive rotator cuff tear destruction of humeral and glenoid cartilage and bone can be found. These cases have been described in the past as osteoarthritis of the shoulder in combination with massive rotator cuff tears or as cuff tear arthropathy (CTA).

The term "cuff tear arthropathy" was introduced by Charles Neer in 1983 to describe an independent pathological condition of the shoulder joint [16]. A massive tear of the rotator cuff was described as the principal cause of this condition [16]. Neer et al. described mechanical and nutritional factors as feasible secondary causes [16].

Burkhart correlated kinematic patterns of the shoulder joint with known locations of rotator cuff tears from a biomechanical point of view [4]. An imbalance of the "force couple" between the anterior and posterior rotator cuff with destabilisation of the humeral head was described as a prognostic factor for developing a CTA [4].

In several longitudinal observations dealing with massive rotator cuff tears a CTA occurred in 4–20% of the patients [12, 16, 29]. In the past decades several classifications for shoulders with massive rotator cuff tears have been introduced [9, 12, 22, 23]. These classifications are all based on radiographic, morphological and biomechanical aspects, neglecting the patient's basic complaints and the functional deficits of the affected shoulders.

The aim of this study was therefore to propose a classification for shoulders with massive rotator cuff defects based primarily on the patient's complaints and only secondarily on the radiographic morphology of the shoulder joint with regard to the appropriate type of shoulder replacement surgery.

Materials and methods

Between June 1998 and December 2007, 100 shoulders with massive rotator cuff defects in 78 consecutive patients were examined at our institution and included in a prospective study. To be included, patients had to have: (1) irreparable degenerative full-thickness ruptures of at least the supraspinatus and the infraspinatus tendon of the rotator cuff of Patte grade 3 and 4 [18] and (2) an intact deltoid muscle. Exclusion criteria were (1) rheumatism or other systemic inflammatory disease, (2) a history of infection in the affected shoulder, (3) a history of fracture of the proximal humerus or the glenoid and (4) joint replacement in the affected shoulder. The diagnosis of a rotator cuff-deficient shoulder was established in all cases based on clinical examination, radiographs in two planes and magnetic resonance imaging (MRI) scans. The authors jointly performed the clinical examinations and analysed the radiological data.

There were 59 (76%) women and 19 (24%) men. The dominant shoulder was involved in 62 cases. Nine female and two male patients had bilateral rotator cuff-deficient shoulders. The patients' mean age at the time of examination was 72 years (range: 52–89 years). Fifteen patients (15 shoulders) had undergone previous operations on the affected shoulders. In twelve cases one operation was performed, in two cases two and in one case three. Of the patients with one operation, five underwent rotator cuff repair and seven arthroscopy with subacromial débridement. The two patients with two previous operations primarily underwent rotator cuff repair and afterwards arthroscopic subacromial débridement. The patient with three previous operations primarily underwent arthroscopic débridement for a calcifying tendinitis, followed by two subacromial débridement procedures.

Patients' subjective complaints and clinical shoulder function were evaluated using the Constant score (CS) [5], and adjusted for age and gender. Moreover, patients were asked about the main complaint of their affected shoulder. Additionally, active range of motion was recorded for shoulder flexion and abduction in degrees. Each patient's pain, activity, mobility and strength were graded using the CS: pain, 0 points (severe pain) to 15 points (no pain); activity, 0 points (no activity) to 20 points (full activity); mobility, 0 points (no mobility) to 40 points (full mobility); and strength, 0 points (0 kp) to 25 points (12.5 kp)).

Radiographs of the shoulders were taken in standardised fashion in anteroposterior and axillary views.

Statistics

Statistical analysis was performed using SPSS 15.0. First of all the global null hypothesis (no differences between the three types of cuff-deficient shoulders) was tested using the Kruskal–Wallis test for the overall CS, its subgroups, shoulder flexion and abduction. If the level of significance was not reached, the parameter examined was excluded from the local tests. Local tests were then performed using the two-sided Wilcoxon test to identify significant differences between the three types in the overall CS, its subgroups, and shoulder flexion and abduction. $P<0.05$ was considered significant.

Results

Based on patients' clinical symptoms and radiographic findings, three different types of shoulders with massive rotator cuff defects could be discerned (types I, II and III). Characteristic clinical symptoms and shoulder morphologies as seen on radiography were found for each of these types.

Type I: arthritic type

The main clinical symptom of patients with type I was pain under load and motion, with only slight pain at rest. The active range of motion was tolerable and in several cases an active shoulder flexion and abduction of 90° or more could be reached (Table 1). Activities of daily living were often possible. In some cases the patients had remaining power in the 90° elevated shoulder. Passive range of motion was often restricted, with a painful blocking at the end of motion. Some radiographic findings were comparable to those of end-stage osteoarthritis. Narrowing of the joint space, glenoid wear and subchondral sclerosis of the humeral head and glenoid were found. Osteophytes on the caudal humeral head and joint incongruency were characteristic. The area of contact between the humeral head and the acromion increased because of cranial migration of the humeral head. Ossification of the coracoacromial arch led to acetabularisation of the shoulder joint (Fig. 1a and b).

Type II: non-reactive type

The main clinical symptom of patients with type II was extremely limited function, with pseudoparalysis of the

Table 1 Overall CS and subgroups for the whole cohort and the different types of cuff-deficient shoulders

	Mean type I	Range type I	Mean type II	Range type II	Mean type III	Range type III
CS (points)	28.6	4–61	18.9	6–52	15.6	6–31
CS %	39.8	5–80	26.2	9–75	23	10–45
Flexion (°)	87.7	60–180	46.5	0–70	39.5	20–70
Abduction (°)	76.6	60–180	43.5	0–70	35.5	20–70
Pain (points)	3.6	0–10	3.8	0–15	1.8	0–5
Power (points)	1.5	0–15	0	0	0	0
Activity (points)	8.7	0–17	6.8	0–17	5.9	3–10
Mobility (points)	14.9	0–34	8	0–30	7.6	2–18

CS % Constant score adjusted for age and gender

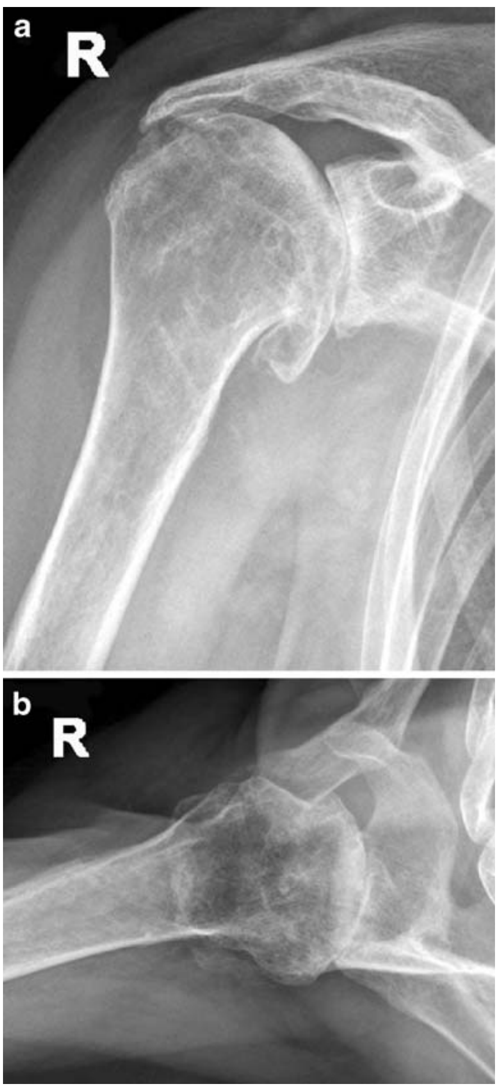

Fig. 1 **a**, **b** Anteroposterior and axillary radiographs of a 72-year-old man with typical signs of an arthritic type I shoulder. The joint space is narrowed; the humeral head migrated cranially with acetabularisation of the coracoacromial arch and joint incongruency

affected shoulder. A hugely limited active range of motion and complete loss of strength of the shoulder were characteristic. In most cases, activities of daily living could not be performed with the affected shoulder. Temporary or permanent glenohumeral dislocation in different directions associated with severe pain was found in some cases. Only slight or no rest pain was typical. In most cases the passive range of motion of the affected shoulder joint was free, except in cases with permanent dislocation. Radiographically, the configuration of the glenohumeral joint was normal without osteoarthritic changes of the humeral and glenoid. Furthermore, the joint space was typically wide, without wear (Fig. 2a and b). Cranial migration of the humeral head was frequently found.

Type III: necrotic type

The main clinical symptom of patients with type III was permanent rest pain and also pain under load and motion. The active and passive ranges of motion were extremely limited, causing pseudoparalysis of the shoulder, and joint congruency was disrupted. The arm could not be raised to shoulder level actively or passively. Strength was extremely limited in the affected shoulder. Activities of daily living were often impossible to perform. Destruction of the humeral head with subchondral fractures and collapse of the joint surface were typical radiographic findings. Erosion of the glenoid up to the coracoid base was frequently detected. A thinning of the acromion occurred in several cases due to cranial humeral migration and wear (Fig. 3a and b). Permanent or recurrent swelling of the shoulder occurred in combination with synovialitis, bursitis and calcification in some cases. This type widely corresponds with Neer's definition of CTA.

In 65 cases (65%) type I was found, in 24 cases (24%) type II and in 11 cases (11%) type III. All patients with bilateral rotator cuff-deficient shoulders had the same type in both shoulders: type I in ten patients (eight female and two male) and type III in one patient (female). The average CS of the whole cohort (types I, II and III) was 24.8 points

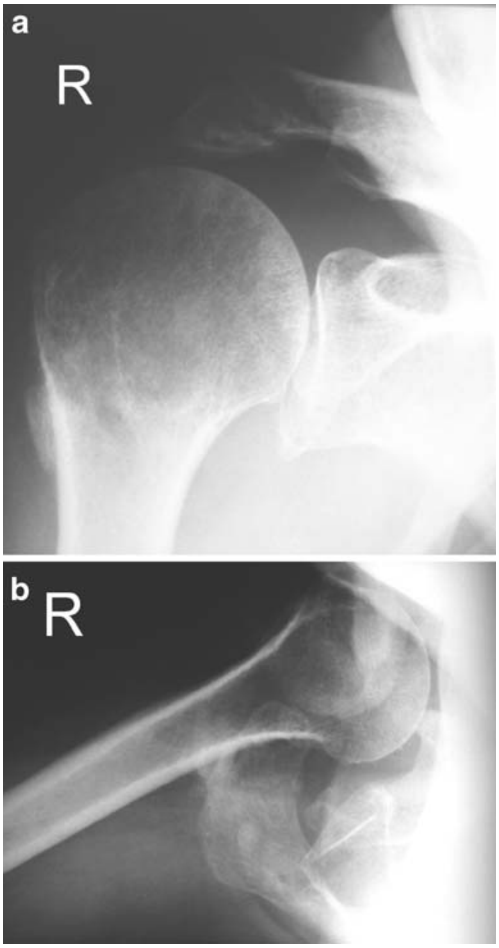

Fig. 2 **a**, **b** Anteroposterior and axillary radiographs of a 67-year-old woman with a non-reactive type II cuff-deficient shoulder. This patient had undergone a failed reconstruction of the rotator cuff several years previously. In the anteroposterior view the humeral head is decentred and migrated cranially. In the axillary view the humeral head is dislocated anteriorly. There is no narrowing of the joint space or joint incongruency

(range: 4–61 points), adjusted for age and gender 34.7% (range: 5–80%). The overall CS and its subgroups for each type are shown in Table 1. Testing the global null hypothesis, significant differences among the three types were found for shoulder motion (flexion/abduction) and the CS with its subgroups except for pain ($p<0.05$; Table 2). The results of the local tests for the different types are shown in Table 3. Significant differences between types I and II and between types I and III were found for the absolute and relative CS, activity, mobility, power, flexion and abduction. All of these scores were higher in type II than in type III, but the differences were not significant (Table 3). The different types are summarised in Table 4.

Discussion

Various classifications for shoulders with massive rotator cuff tears and CTA have been introduced in recent decades [9, 12, 22, 23]. All of them were based primarily on the radiological morphology of the shoulder joint rather than the patient's complaints.

Hamada et al. performed arthrography in shoulder joints with massive rotator cuff tears [12]. The grade of the disease was based chiefly on the acromiohumeral interval, which has been considered a sensitive indicator for full-thickness tears [6, 26]. Five radiographic grades were classified. Frequent arm elevation in activities of daily living, rupture of the long head of the biceps tendon, an abnormal fulcrum of the humeral head against the acromion and the coracoacromial ligament, and weakness of external rotation were described as plausible factors in the development of CTA. No comparison of patients' complaints with the radiographic findings was performed. The authors did not state what therapy concept would be useful in each grade of their classification.

Favard et al. classified three types of CTA based on the radiological morphology of the shoulder joints [9]. Forty-six cases were analysed using anteroposterior radiographs. Of these 46 cases, 23 underwent hemiarthroplasty ($n=17$) or unconstrained total shoulder arthroplasty ($n=6$) [19]. At an average follow-up of 20 months, the CS had increased from 16 points preoperatively to 43 points. The authors reported that about half of the patients still had significant pain after surgery. They hypothesised that the use of an excessively large prosthetic humeral head could be the main reason for these findings. Moreover, complete radiolucent lines around the glenoid components were found in two cases. These findings were attributed to the "vertical rocking glenoid effect". The authors did not recommend therapy options for the types of CTA in their classification, except to state that total shoulder replacement is inadvisable for this condition.

Four types of glenoid erosion in CTA were defined by Sirveaux et al. using anteroposterior X-rays [22]. In their analysis of 77 reversed shoulder arthroplasties the authors concluded that loss of bone from the superior part of the glenoid leads the surgeon to position the baseplate on the top, which increases the risk of impingement. No special recommendations with regard to different shoulder implant concepts were stated.

Visotsky et al. described a radiological classification for CTA on the basis of the biomechanics and the clinical outcome of arthroplasty [23]. The loss of the rotator cuff leads to superior migration of the humeral head in combination with destabilisation of the glenohumeral centre of rotation. Based on these findings, four types of CTA were differentiated by the degree of superior migration from the glenohumeral centre of rotation and the amount of instability of the centre of rotation: 60

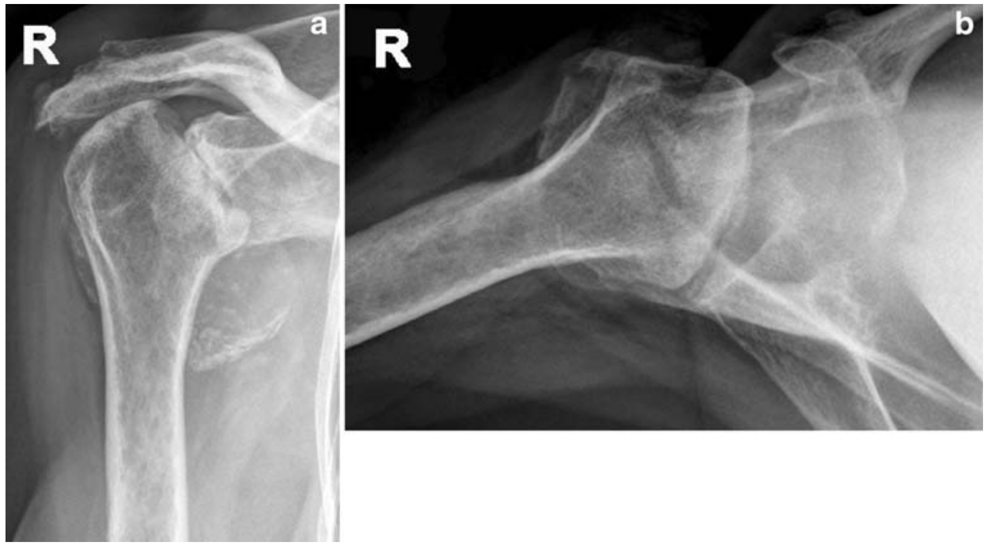

Fig. 3 **a**, **b** Anteroposterior and axillary radiograph of an 81-year-old woman with a necrotic type III cuff-deficient shoulder. The humeral head has collapsed and migrated cranially. The joint is incongruent because of the destruction of the humeral and glenoid bone stock. Peri-glenohumeral calcifications were detected in this case

shoulders with CTA were treated with a hemiarthroplasty with an extended humeral head. A substantial improvement in pain relief, range of motion and functional goals was stated. Only in unstable and decentred cases was the use of a reverse prosthesis recommended.

With all these classifications it has not been possible to definitely distinguish between osteoarthritis with massive rotator cuff tears and CTA. Furthermore, the gradations did not respect the patient's major complaints and functional limitations.

Multiple treatment options such as physiotherapy, arthroscopic débridement or muscle transfers have been described for this condition [13]. In some cases shoulder replacement seems to be the treatment of choice, especially if joint congruency is lost or shoulder dislocation occurs. Where the preoperative range of motion is tolerable, reversed arthroplasty seems to be a relatively hazardous procedure in terms of early and late complications. There follows our attempt to establish surgical treatment options for cuff-deficient shoulders from a theoretical point of view with regard to shoulder replacement surgery.

Hemiarthroplasty has been an established treatment for osteoarthritis of the shoulder with massive rotator cuff tears for several years [1, 10, 11, 20, 27]. Satisfactory results have been described with a low

Table 2 Global differences (Kruskal–Wallis test) between CS and subgroup

Variable	p value
CS	0.00019
CS %	0.00020
Pain	0.19049
Activity	0.00764
Mobility	0.00001
Power	0.00150
Flexion	0.00000
Abduction	0.00000

CS % Constant score adjusted for age and gender
The variable pain did not reach the level of significance ($p<0.05$) and was excluded from the local tests

Table 3 Local differences (two-sided Wilcoxon test) between the three types of cuff-deficient shoulders in overall CS and subgroups

Comparison between types of cuff-deficient shoulders (I to III)	Variable	p value
I – II	CS	0.00116
	CS %	0.00068
	Activity	0.03111
	Mobility	0.00002
	Power	0.00000
	Flexion	0.00000
	Abduction	0.00003
I – III	CS	0.00178
	CS %	0.00312
	Activity	0.00709
	Mobility	0.00276
	Power	0.00000
	Flexion	0.00002
	Abduction	0.00013
II – III	CS	0.42227
	CS %	0.66859
	Activity	0.62871
	Mobility	1.00000
	Power	0.18731
	Flexion	0.34412
	Abduction	0.39353

CS % Constant score adjusted for age and gender

Table 4 Three types of cuff-deficient shoulders based on clinical symptoms and radiographic morphology and characteristics

Type	Morphology	Characteristic	Symptoms	Radiographic findings
I 74% female 26% male	Arthritic	Stable	Pain under load and motion and on activities of daily living	Cranial migration of humeral head; acetabularisation of coracoacromial arch; joint space narrowing; arthritic deformities (osteophytes); joint incongruency
II 86% female 14% male	Non-reactive	Unstable	Highly limited range of motion; temporary or permanent glenohumeral dislocation	Cranial migration and decentration of humeral head; wide joint space; no or only minimal arthritic deformities; joint congruency; insufficient joint stability
III 100% female	Necrotic	Destructive	Permanent rest pain; extremely limited range of motion	Cranial migration and collapse of humeral head; glenoid erosion; joint incongruency

complication rate [1, 11, 20, 27]. In the study by Goldberg et al., 34 shoulders with CTA or osteoarthritis with massive rotator cuff tears were treated by hemiarthroplasty [11]. In 76% the limited goals criteria as described by Neer [17] were reached. Mean active forward elevation improved from 78° preoperatively to 111° postoperatively. Interestingly, pain relief, function and the mean American Shoulder and Elbow Society score was significantly better in patients who were able to elevate their arm to 90° preoperatively than in patients who could not reach shoulder level. Similar results were found by Williams and Rockwood [27]. The relatively good preoperative function of these shoulders seems to resemble that of those shoulders with arthritic type I in our study. These findings confirm our theoretical assumption that conventional hemiarthroplasty or a resurfacing implant may well be the treatment of choice. In our opinion, the main treatment goal for this cohort with regard to decreasing pain and improving function is restoration of joint congruency. This may be achieved with conventional hemiarthroplasty or a resurfacing implant. In several studies it was stated that hemiarthroplasty provides marked pain relief in 63–75% of patients with glenohumeral arthritis and massive rotator cuff tears [10, 20, 27]. These figures correspond approximately to the 65% of cases with type I in our study.

Promising results have been described for reversed shoulder arthroplasty in cases of CTA [3, 7, 14, 22]. Especially in cases with pseudoparalysis and instability of the shoulder, this implant with its lowered and medialised centre of rotation increases the moment arm of the deltoid muscle and is therefore able to stabilise the joint and improve the range of motion. Significant pain relief and improvement of function have been reported in several studies [1, 3, 7, 14, 22]. However, complication rates up to 60% and revision rates as high as 50% have been described [2, 8, 14, 15, 22, 24]. These rates are noticeably higher than those reported for hemiarthroplasty and total shoulder arthroplasty [2]. Therefore we restrict the use of this implant. We would not recommend the treatment of type I cuff-deficient shoulders as defined in this study with a reversed arthroplasty. We believe that this implant is a useful tool for patients with massive pain and or pseudoparalysis of the affected shoulder, as in types II and III, if the glenoid bone stock is sufficient to provide primary stability for the glenoid component.

CTA is the most common indication for a bipolar shoulder implant [21, 25, 28, 29]. Because of the limited range of motion between the shell and the inner head of the implant, only limited functional improvement can be expected. However, satisfactory results have been described by Sarris et al. in patients with CTA [21]. The complication rates described in the recent literature vary between 0 and 23% [25, 28, 29]. If the glenoid component of a reversed arthroplasty, which would be the implant of choice, does not achieve primary stability because of insufficient glenoid bone stock, we would recommend the bipolar prosthesis as a second line of defence implant. With this implant the humeral offset could partially be restored with a possible improvement in function and decrease in pain.

The main limitation of this study is that we are only able to deduce the appropriate treatment, such as shoulder replacement surgery, from a theoretical point of view. However, in the light of published findings and our own experience, we believe that these deductions may be helpful for the decision-making process for shoulder surgeons treating patients with cuff-deficient shoulders. To our knowledge this is the first study describing a classification for this pathological condition based primarily on the patient's clinical symptoms and only secondarily on the radiographic morphology of the shoulder. A prospective trial with regard to shoulder replacement surgery using the current classification will be necessary to confirm our theoretical assumptions.

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