Initial post-fracture humeral head ischemia does not predict development of necrosis

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We evaluated the functional outcome and the occurrence of avascular necrosis in 51 consecutive patients (26 women) with intracapsular fractures of the proximal humerus treated with open reduction and internal fixation between February 1998 and December 2001. Mean age was 44 years (range, 21-60 years). Forty-one heads were initially perfused (group A), and 10 were ischemic (group B). Seven patients were lost to follow-up. Forty-four were evaluated using the Constant-Murley score and the Subjective Shoulder Value; 40 patients consented to a radiographic evaluation. The mean follow-up was 5 years (range, 3.3-7.3 years). In group A, 20 of 30 heads had no sign of structural alterations, 6 had signs of structural alterations of the cancellous bone, and 4 showed collapse of the subchondral bone plate of varying degrees. In group B, 8 of 10 heads were structurally altered, and 2 had collapsed. The median uncorrected Constant-Murley score was 80 (range, 37-98) for patients without structural alterations, 81 (range, 53-93) for patients with structural alterations, and 68 (range, 48-74) for patients with collapsed heads. The median Subjective Shoulder Value was 95 (range, 50-100), 90 (range, 50-100), and 55 (range, 40-80), respectively. Eight of 10 initially ischemic heads did not develop avascular necrosis, indicating that revascularization may indeed occur. The reason for late necrosis in some of the initially perfused heads remains unclear. Collapse was associated with a significantly worse clinical outcome. We conclude that osteosynthesis with preservation of the humeral head is worth considering when adequate reduction and stable conditions for revascularization can be obtained. (J Shoulder Elbow Surg 2008;17:2-8.)

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There is little evidence and no consensus concerning the optimal treatment for complex fractures of the proximal humerus.[22] The prognosis is determined by the risk of nonunion, malunion, stiffness, persistent pain, and avascular necrosis.[13,18]

The risk for avascular necrosis depends on the vascular supply of the head fragment and whether revascularization or creeping substitution, or both, are possible.[15] In previous investigations, predictors of humeral head ischemia were established. The most relevant factors determining ischemia were the length of the dorsomedial metaphyseal extension and the integrity of the medial hinge.[11,19] This long-term follow-up study of the same patient cohort focused on the development of avascular necrosis. In addition, the functional outcome and the subjective satisfaction of patients treated with osteosynthesis were evaluated.

MATERIALS AND METHODS

Patients and initial assessment of the humeral head perfusion

Between February 1998 and December 2001, 100 shoulders (57 right) in 98 patients (55 women) with intracapsular fractures of the proximal humerus were included in a prospective surgical evaluation protocol. Their median age was 60 years (range, 21-88). Fractures with at least 1 fragment proximal to the surgical neck were termed intracapsular fractures. Patients with these fractures were treated at 1 institution by 1 surgeon.

The choice of the treatment was based on the Codman-LEGO description system,[11] the intraoperative assessment of humeral head perfusion by means of bore hole drillings, by laser-Doppler flowmetry, or both,[1,8,9,11,16,17] and the feasibility of an adequate osteosynthesis. Fractures with a dorsomedial metaphyseal extension of less than 8 mm, with a disrupted metaphyseal hinge, and a specific Codman-LEGO fracture pattern (types 2, 7, 8, 9, 10, and 12) were considered at a high risk of humeral head ischemia.[11] The mean time from injury to assessment of head perfusion

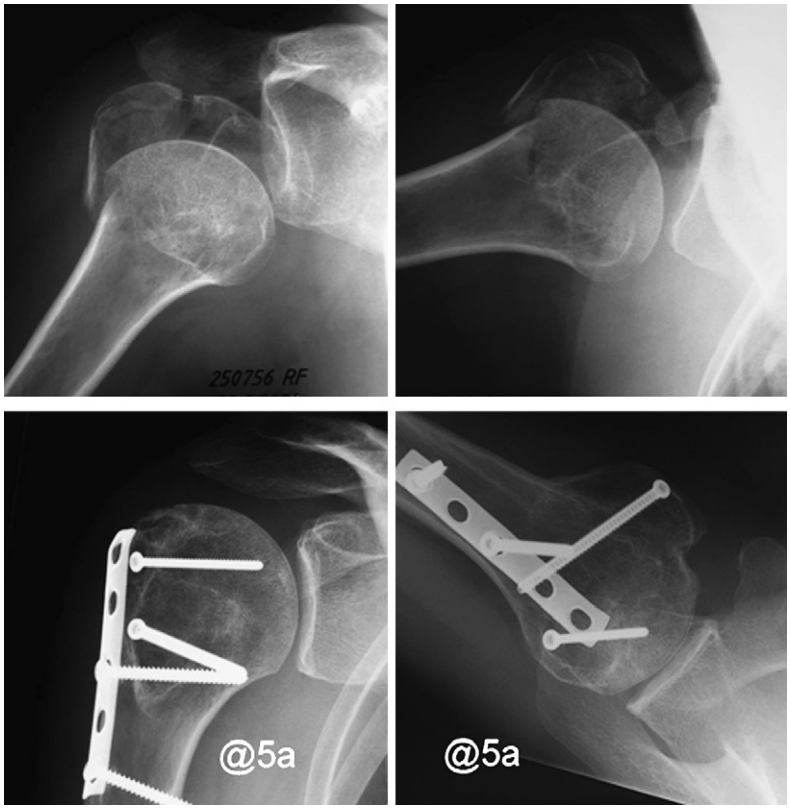

Figure 1 This 43-year-old woman had a 4-part fracture (Codman-LEGO type 12) with a calcar of 8 mm. Intraoperatively, the head was perfused (bleeding after bore hole drilling). Five years postsurgery, the patient's Constant-Murley score was 75 and her Subjective Shoulder Value was 95%. The radiologic analysis revealed structural alterations in the humeral head.

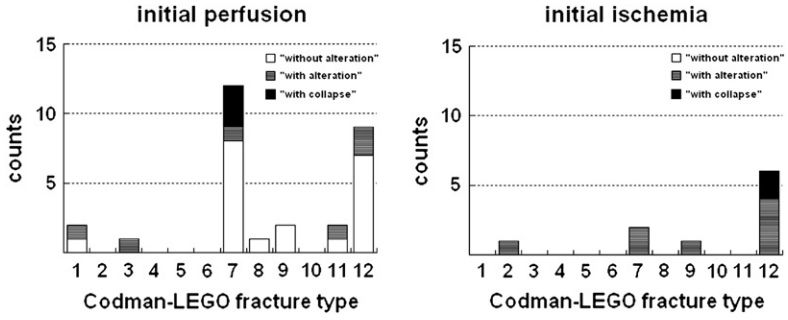

Figure 2 Distribution of the 12 basic fracture patterns of **(Left)** initially perfused heads and **(Right)** initially ischemic heads with the relative frequencies of structural alterations.

was 4 days (range, 0-10 days). Of 100 humeral heads, 45 were perfused, and 55 were ischemic. On the basis of the surgeon's judgement, 49 were treated with hemiarthroplasty and 51 with osteosynthesis, of which 41 were perfused (group A), and 10 were ischemic (group B).

Seven of 51 patients were lost to follow-up: 4 died of unrelated causes, 2 could not be traced, and 1 moved overseas. Thus, 44 patients (and shoulders) were available for long-term evaluation. The Constant-Murley score (CMS) was assessed in 28 of 41 in group A and in all 10 in group B. The Subjective Shoulder Value (SSV) was assessed in 34 in group A and in all 10 in group B. Radiographic evaluation of the humeral head structure was available in 40 of 51 patients (30 in group A and 10 in group B).

Clinical and radiologic evaluation

Patient evaluation was performed according to standardized protocol. We measured the CMS[3,7] according to the published guidelines. We determined the patients'

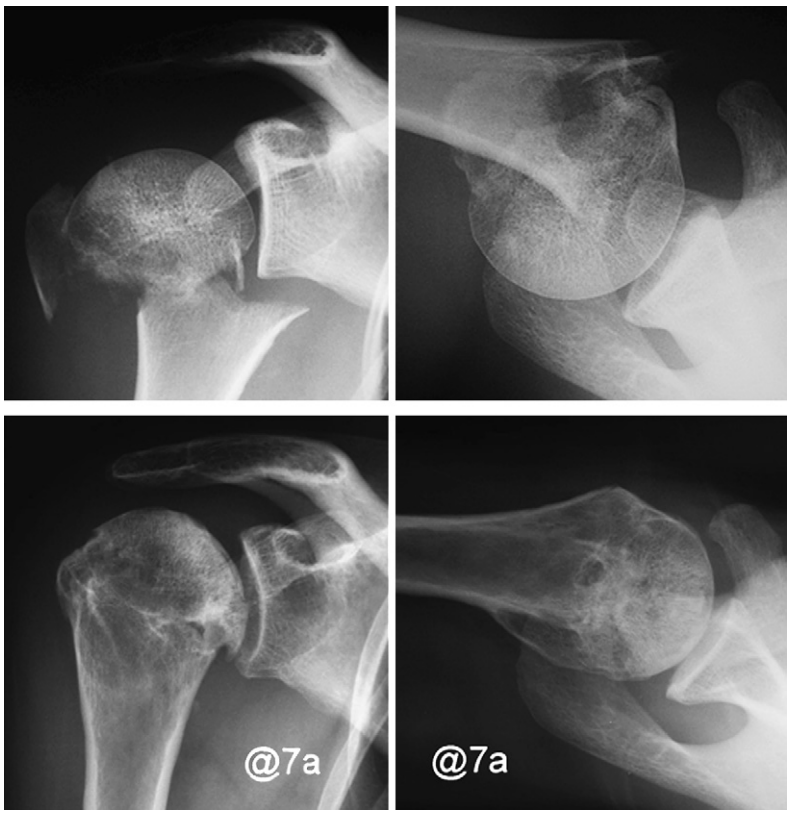

Figure 3 Radiographs show a 3-part fracture (Codman-LEGO type 7) with a calcar of less than 8 mm in a 31-year-old woman. Intraoperatively, the head was perfused (bleeding after bore hole drilling). Seven years postsurgery, the patient had a Constant-Murley score of 74 and a Subjective Shoulder Value of 80%. Despite initial perfusion of the head, ischemia occurred, leading to necrosis and collapse of the subchondral bone plate.

Subjective Shoulder Value (SSV)[6] by asking the question, "Assuming that a normal shoulder scores 100 points, how many points does your shoulder score today?"

Disorders of perfusion of the humeral head were assessed with conventional anteroposterior and axillary radiographs by using classic criteria for avascular necrosis of bone.[4,5] Increased radiodensity with cystic and sclerotic regions and coarse trabeculae were considered structural alterations. We used the radiographs to divide the cohort into 3 subgroups: a first group without structural alterations of the cancellous structure and of the subchondral bone plate, a second group with structural alterations but maintained sphericity, and a third group with collapsed, aspherical heads.

Surgical treatment and rehabilitation

Surgery was performed in the beach-chair position, using a deltopectoral approach without detachment of the deltoid muscle. For osteosynthesis, a thin implant (1/3 tubular AO-plate, Synthes, Inc, Paoli, PA) was used as a load-sharing, antiglide device. To provide stability, the key element was the reduction of the medial hinge. Secondary elements were the nearly anatomic reduction of the greater and lesser tuberosities. We considered the most important requirements to promote revascularization were the adequacy of reduction and the stability of fixation while avoiding additional iatrogenic devascularization of the tuberosities. Technical details have been presented elsewhere.[10]

After surgery of the subdeltoid space, we determined that immediate mobilization of the extremity was required to avoid adhesions and stiffness. For the first 6 weeks, patients performed simple pendulum exercises several times a day, assisted external rotation up to 10° less than the opposite side, assisted internal rotation up to the abdomen, and assisted elevation of the hand to the forehead. Between exercises, the arm was immobilized in a simple sling during the day and in a *gilet* (a removable Desault bandage) at night.

Statistical evaluation

Statistical analysis was performed using InStat 3a (2001) software (GraphPad Software, San Diego, CA). Data for the 3 subgroups were analyzed with ordinary analysis of variance using the Kruskal-Wallis Test; as a multiple comparison posttest, the Dunn test was used. Statistical significance was established at $P < .05$.

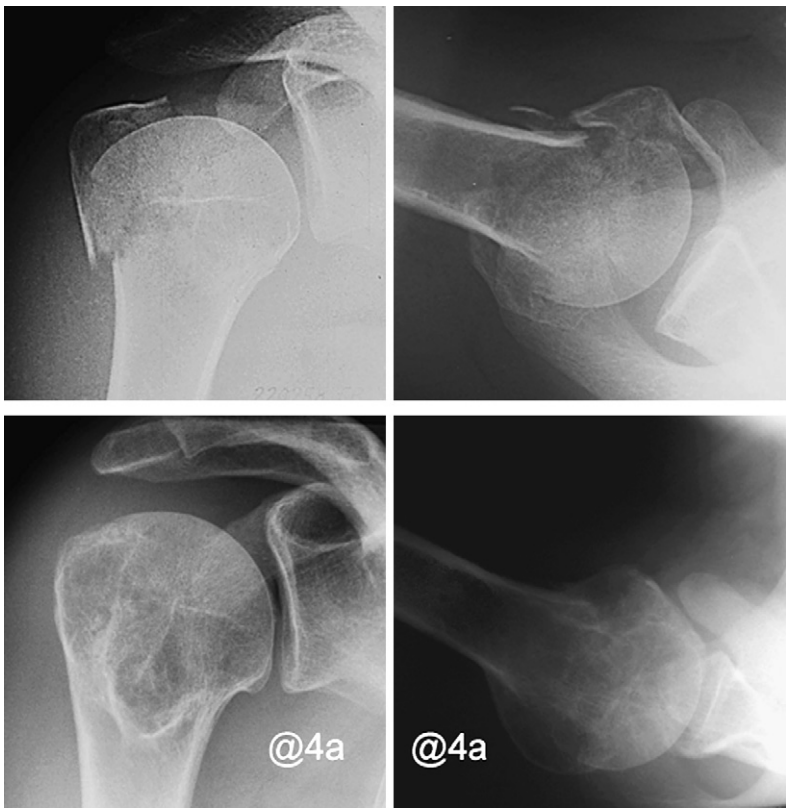

Figure 4 This 42-year-old man had a 4-part fracture (Codman-LEGO type 12) with a calcar of less than 8 mm. Intraoperatively, the head was not perfused (neither bleeding after bore hole drilling nor a pulsatile signal in the laser-Doppler flowmetry). Four years postsurgery, the patient had a Constant-Murley score of 59 and a Subjective Shoulder Value of 63%. The radiologic analysis revealed structural alterations in the humeral head but no collapse of the subchondral bone plate.

RESULTS

The radiologic assessment of avascular necrosis revealed no structural alterations in the humeral head in 20 of 40 shoulders, structural alterations in 14, and collapsed heads in 6. No signs of structural alterations were noted in 20 of 30 initially perfused heads in group A, 6 had signs of structural alterations (Figure 1), and 4 were collapsed (Figures 2 and 3). Of 10 initially ischemic heads in group B, 8 showed signs of structural alterations (Figures 4 and 5) and 2 were collapsed (Figure 2). All group B heads showed some sign of structural alterations. The probability of head collapse was 13% in group A (initially perfused) and 20% in group B (initially ischemic).

The median (range) total CMSs were 80 (37-98) for patients without signs of structural alterations, 81 (53-93) for patients with structural alterations, and 68 (48-74) for patients with collapsed heads (Figure 6). The median (range) SSVs were 95 (50-100), 90 (50-100), and 55 (40-80), respectively (Figure 7). Differences in SSVs between the group without signs of structural alterations and the group with collapsed heads were statistically significant ($P < .01$). The median (range) scores of the 4 items of the CMS for the groups without signs of structural alterations, with structural alterations, and with collapsed heads were, respectively, 15 (10-15), 15 (5-15), and 10 (5-15) for pain; 20 (13-20), 20 (13-20), and 17 (13-18) for activities of daily living; 34 (14-40), 35 (24-40), and 20 (18-36) for range of motion; and 11 (0-25), 13 (0-24), and 15 (4-20) for force. Statistically significant differences were seen for pain between the groups without structural alterations and collapsed head ($P < .01$) and for activities of daily living between the groups without structural alterations and with collapsed head ($P < .001$). Range of motion and force were similar in all groups ($P > .05$).

Revision surgery was required for 17 complications. These were combined arthroscopic intra-articular arthrolysis and open subdeltoid arthrolysis for the treatment of different degrees of postoperative stiffness in 10 shoulders (in these cases, the implants were also removed), early revision for the treatment

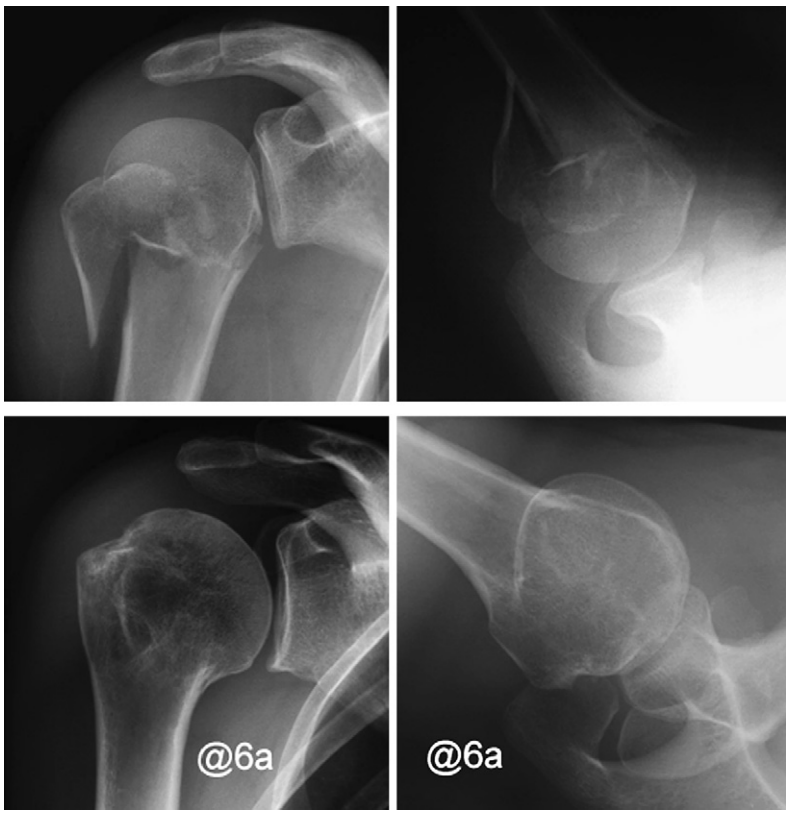

Figure 5 Radiographs for this 35-year-old woman show a 3-part fracture (Codman-LEGO type 7) with a calcar of 8 mm. Intraoperatively, the head was not perfused (nonpulsatile signal in the laser-Doppler flowmetry). Six years post-surgery, the patient had a Constant-Murley score of 93 and a Subjective Shoulder Value of 100%. The radiologic analysis revealed structural alterations in the humeral head.

of a hematoma in 1, revision and refixation of a displaced greater tuberosity in 1, and disengaged and migrated proximal screws in 5 (all removed under local anesthesia). An asymptomatic fatigue fracture of the plate occurred in 1 patient, but no revision was required because the fracture had consolidated soon after plate failure. No relevant intraoperative complications, neurovascular complications, or infections occurred.

DISCUSSION

The reported incidence of posttraumatic avascular necrosis varies between 1% and 34%.[12,21] In our study, 14 of 40 fractures subsequently developed radiographic structural changes (without collapse), indicating that a transient problem of perfusion had occurred, and 6 developed stage III avascular necrosis with collapse of the head. Comparison with other studies is jeopardized by differences in patient selection, follow-up periods, and fracture types, which is aggravated by the insufficient reliability of current classification systems.[2,20]

The total CMSs were similar among the groups without structural alterations, with structural alterations, and with collapsed heads. Only for pain and activities of daily living was a significant difference noted between the group with collapse and the group without structural alterations of the humeral head. Patients with collapsed heads had more pain and restrictions in their activities of daily living. The SSV ($P < .05$), but not the total CMS ($P > .05$), was significantly lower in patients with collapsed heads.

A limitation of the study is the 11 shoulders lost to radiographic follow-up. Fortunately, all lost patients belong to group A, the group with initially perfused heads. Four were traced for a telephone interview, and they stated that their shoulders were functioning normally. In group B (initially ischemic heads), which was the relevant group for the purpose of this study, all patients were available for long-term examination.

Another inherent weakness of the study was the lack of randomization. The choice of treatment

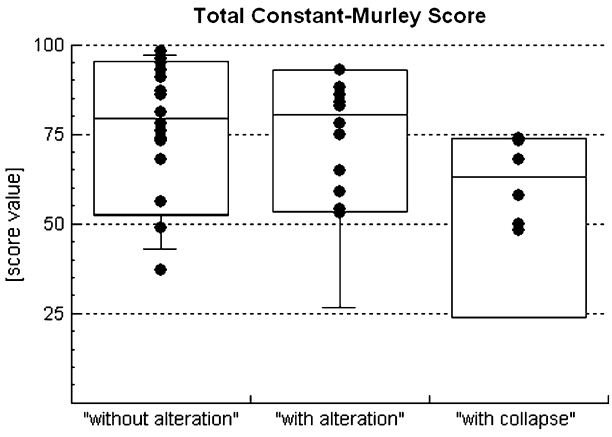

Figure 6 Box and whisker plots show Constant-Murley scores in patients treated with osteosynthesis. In the radiologic assessment, patients were divided in the subgroups "without structural alterations," "with structural alterations," and "collapsed head." The horizontal line indicates the median value, the top and bottom borders of the box show the 75th and 25th percentiles, the whiskers show the 10th and 90th percentiles, and the spots represent the single values.

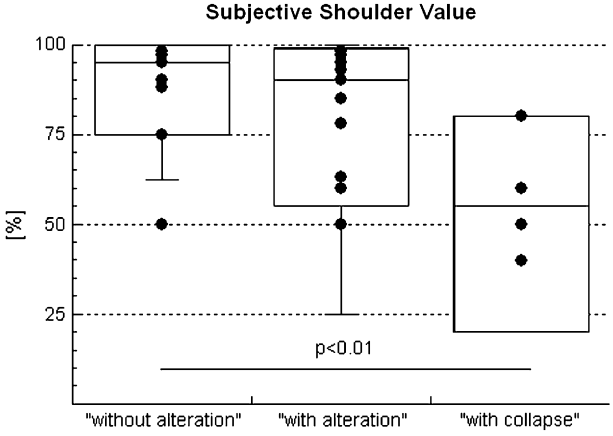

Figure 7 Box and whisker plots show the Subjective Shoulder Value in patients "without structural alterations," "with structural alterations" and "collapsed heads." The horizontal line indicates the median value, the top and bottom borders of the box show the 75th and 25th percentiles, the whiskers show the 10th and 90th percentiles, and the spots represent the single values.

(osteosynthesis or arthroplasty) was determined by the assessment of perfusion of the humeral head and the feasibility of an adequate osteosynthesis. According to this plan, randomization was not feasible.

The strengths of the study are the initial assessment of humoral head perfusion, the prospective data collection, and the relatively long follow-up period.

Stage III avascular necrosis (ie, collapsed; Figure 3) unexpectedly developed in 4 of 30 initially perfused heads. These were all Codman-LEGO pattern type 7 fractures,[11] and humeral head perfusion was certain initially. We could not determine a reason for the development of avascular necrosis in these initially perfused heads. It is possible that the measurement was false-positive because impaction on the metaphysis may have resulted in a weak pulsatile laser-Doppler signal, even though the head's vascular tree was disconnected. In the original publication,[11] a pulsatile laser-Doppler signal was considered proof for perfusion, despite an eventually negative result on a bleeding bore hole test. In retrospect, this might have been a mistake. Alternatively, it is possible that the perfusion of the head was disturbed after its measurement by manipulation, the osteosynthesis, or by occlusion (thrombosis) of the vascular tree in the postoperative period.

Two of 10 initially ischemic heads collapsed; however, 8 did not. Thus, initial ischemia after intracapsular fracture of the proximal humerus did not necessarily lead to the development of humeral head necrosis. As expected, collapse was associated with a significantly worse clinical outcome.

We conclude that despite acute ischemia, preservation of the humeral head may be a viable treatment option when adequate reduction and stable conditions for revascularization can be obtained. In agreement with others,[14,18] we believe that osteosynthesis with preservation of the humeral head is worth considering.

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