Radiographic prediction of early failure in femoral neck fracture

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We studied the primary radiographs of 56 patients treated with osteosynthesis for a displaced femoral neck fracture. The radiographic findings were subjected to a multiple regression analysis together with the results 3 months postoperatively. A primary fracture displacement of more than 20 mm on the AP film and a defect of the calcar due to fracture comminution were associated with a failed osteosynthesis.

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Since the first description of a femoral neck fracture by Paré in the 16th century (Hilleboe et al. 1970) and of the first screw osteosynthesis (Langenbeck 1878), the prognosis of this problematic fracture has been unforeseeable, and several classifications have been developed (Nieminen 1975). The most popular one in recent times has been the grading by Garden (1961), which has been associated with the prognosis of the fracture (Nieminen 1974). Its principal merit seems, however, to be its ability to discriminate between displaced and nondisplaced fractures (Editorial 1988).

Many factors affect the outcome of fractures in general, such as the state of soft tissues, displacement, comminution, and instability. In the femoral neck fractures, osteoporosis has importance for the incidence in elderly patients (Høiseth et al. 1990). Further, the blood circulation has prognostic importance (Strømquist 1983), as well as the quality of reduction (Alberts et al. 1990).

The purpose of the present analysis was to correlate the primary radiographic findings in femoral neck fractures with the early failure of the osteosynthesis in order to develop means for prognosticating the need of salvage by endoprosthetic replacement.

Patients and methods

In 1988–89, a series of 84 femoral neck fractures were treated with two types of osteosynthesis: a Richards® sliding hip screw or two Olmed® screws. Three fractures where satisfactory reduction was not obtained were treated primarily with a Hastings® hemiendoprosthesis. For inclusion in the present analysis, two conditions had to be satisfied: adequate primary radiographs in two planes and a follow-up period of at least 3 months. Ten patients died during the first 3 postoperative months. In 14 of the remaining patients, only a single AP radiograph of the preoperative fracture state was available, and in 4 patients the axial radiograph was of poor quality.

Forty-two of the remaining 56 patients were women, with a median age of 81 (63–97) years, and 14 were men, with a median age of 78 (56–88) years. Forty-six fractures were operated on within 24 hours and the remainder within 3 days. The fractures were classified according to Garden (1961), with a group of 6 surgeons performing the classifications. For the present analysis, 2 of the authors (AA and JB) studied the radiographs anew and reclassified 20 fractures as follows: one stage I and III as stage II, one stage II and IV as stage III, and 16 stage III as stage IV. Thus, the final classification of the 56 fractures was two stage I, five stage II, 15 stage III, and 34 stage IV. The patients were all examined 3 months after the operation.

The presumably predictive variables were age, sex (1 female, 2 male), time from injury to operation (hours), Garden's stage (I to IV), shortening of the leg (the distance of trochanter minor from the ischial tuberosity line [mm] in 52 available AP pelvic radiographs), fracture displacement on AP radiograph (mm), fracture displacement on axial radiograph (mm), calculated total displacement (mm), varus or valgus of the head (degrees), posterior angulation of the head (degrees), Pauwels' angle (< 45°, > 45°), size of the head fragment, length of intact calcar in the proximal fragment, length of intact calcar in the distal fragment (Figure 1), defect of the calcar (comminution; Figure 2), type of fracture fixation (one Richards,

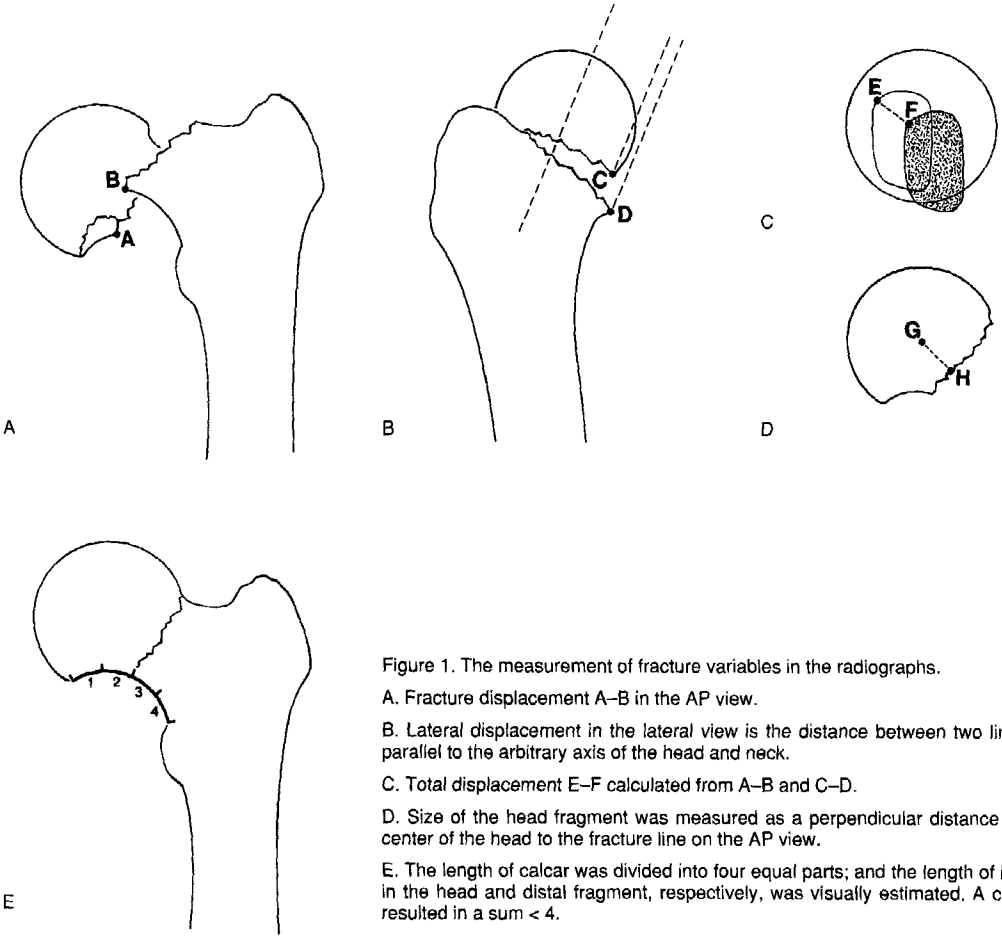

Figure 1. The measurement of fracture variables in the radiographs.

A. Fracture displacement A–B in the AP view.

B. Lateral displacement in the lateral view is the distance between two lines that are parallel to the arbitrary axis of the head and neck.

C. Total displacement E–F calculated from A–B and C–D.

D. Size of the head fragment was measured as a perpendicular distance G–H of the center of the head to the fracture line on the AP view.

E. The length of calcar was divided into four equal parts; and the length of intact calcar in the head and distal fragment, respectively, was visually estimated. A calcar defect resulted in a sum < 4.

two Olmed), result of fracture reduction (1 to 3). One point was subtracted from a maximum of 3 for each of the following findings: varus angulation, displacement of the distal fragment so that the proximal fragment is not engaged, and posterior angulation of the head. No corrections were made for the radiographic magnification effect of 10–20 percent.

The outcome variables were as follows:

1. Progressive healing without shortening or malalignment.
2. Shortening, i.e., compression of the fracture by more than 20 mm (Alho et al. 1988).
3. Malalignment, i.e., change of the position of the screws in relation to each other by more than 5°.
4. Salvage with a hemiprosthesis or a total prosthesis.

The outcome variables were ranked according to a probable prognostic importance of the findings from 1 to 4 in the order of listing above.

It was found important to include the nondisplaced fractures (Garden's stages I and II) in the analysis, because they had a number of factors that were also measured in the displaced fractures, such as valgus and posterior angulation of the head, Pauwels' angle, site of fracture (length of intact calcar), and head size. Their exclusion would have precluded the use of these factors in the multifactorial analysis.

Statistical analysis

First, a multiple correlation analysis was performed in order to avoid including highly correlated results in the regression analysis. The Poisson regression was applied to regress outcome (on the scale 1, 2, 3, and 4) on the predictors.

Figure 2. An 82-year-old man fell in the street and sustained a fracture of the left femoral neck.

A. The calcar line from the upper shaft connection of the lesser trochanter to the femoral head was traced. To check the delineation, the fractured side was compared with the unaffected hip. The main fracture divided the calcar into two so that two fourths remain proximally and two fourths were connected to the shaft fragment. The second of the two proximal one fourths is comprised of a large butterfly fragment, which can also be seen in E and F. The vertical distance between the main fracture components (from the end of the second fourth to the beginning of the third fourth) was 27 mm.

B. The axial radiograph showed a sagittal displacement between the fragments of 3 mm.

C and D. The immediate postoperative radiographs showed a good reduction of the fracture and a good position of the implants.

E and F. Follow-up radiographs at 3 months showed failure of the osteosynthesis with lost alignment and backing out of the screws. The butterfly fragment of the calcar is displaced.

Results

Forty-four fractures showed progressive healing without major shortening or malalignment. None of them were reoperated on. In eight fractures the position was lost either by varisation or rotary malalignment, whereas four fractures had shortened by more than 20

Table 1. Prediction of early failure of the osteosynthesis in femoral neck fractures. The results of the Poisson regression of the outcome. See text for the rankings. [a]

Predictor	Coefficient	*SE*	Student's *t*-test	*P*
Constant	−12.78	8.80	−1.45	0.15
Age	9.29E−04	5.29E−02	−0.02	0.39
Sex	7.67E−01	8.14E−01	0.94	0.35
Time	−0.32E−02	3.72E−02	−0.86	0.39
Garden's stage	1.95	2.06	0.95	0.35
Displacement	1.63E−01	5.15E−02	3.17	0.003
Varus	1.14E−02	1.64E−02	0.69	0.49
Valgus	4.03E−01	2.11E−02	1.91	0.06
Calcar defect	9.08E−01	3.54E−01	2.58	0.01
Reduction	−3.31E−01	3.09E−01	−1.07	0.17
Fixation	4.72E−01	6.00E−01	0.79	0.44

[a] E−01 = x 10^{-1}.

mm. Five of the patients with failure of the osteosynthesis and poor functional status were reoperated on within 3 months ($P < 0.001$, Fisher's test).

A calcar defect of varying size was observed on 12 primary AP radiographs (Figure 2). The distal fragment was displaced cranially more than 15 mm in 12 cases.

Based on correlation analyses, the presumably predictive variables that were not interrelated were selected to test their predictive value. The displacement variables were strongly interrelated. Of them, the fracture displacement on the AP radiograph was chosen for the regression analysis because it showed the strongest correlation with the outcome. Only two factors were significantly predictive: the fracture displacement in the AP radiograph and the comminution of the calcar (Table 1).

Discussion

The preoperative features of the femoral neck fractures showed some important correlations with the prognosis as judged 3 months postoperatively. At that time, primary mechanical failures occur (Husby et al. 1989), and they constitute one half of all the failures (Nieminen et al. 1974, Barnes et al. 1976).

Previously, failures of osteosynthesis have been found to be correlated with fracture reduction (Alberts et al. 1990, Wihlborg 1990). Such correlations were not found in the present study. Two explanations may be given. First, the observation time in the present series was short. Secondly, it is usual that the results of fracture reduction are improved in a prospective series and a larger number of findings would be necessary to find significant correlations between the reduction and osteosynthesis findings and the outcome. This does not reduce the value of the fact that prognostically important preoperative findings could be made.

Several studies have focused on the importance of the type of osteosynthesis for the prognosis. In a separate, randomized study (Benterud et al., unpublished data), we had more reoperations after the sliding hip screw than after fixation with two 6-mm screws that were used in the present study.

Not unexpectedly, the extent of dislocation was a predictive factor. A very large displacement is obviously a sign of great local trauma. How the extent of trauma is associated with circulatory disturbances of the femoral head (Strömquist 1983) was not studied. However, an assumption may be made: viz., that with increasing displacement, the risk of a circulatory catastrophe is increased. Therefore, a mechanical explanation does not exclude a circulatory one.

To our knowledge, the present report is the first one to document the importance of calcar comminution for the outcome. Failures occurred in cases without such comminution, and all the fractures where comminutions were found did not fail. However, the splintering of the calcar femorale had individual importance. This factor was not easy to appreciate on occasionally poor radiographs. Also, the rotation between the fragments impeded the full analysis. This emphasizes the importance of good quality radiographs taken in standardized projections.

Previously, the failure of osteosynthesis has been reported to correlate with fracture reduction (Alberts 1990, Wihlborg 1990). Such a correlation was not found in the present study. It may be that the variation of the standard of fracture reduction becomes small in a prospective series. Thus, a negative result does not reduce the prognostic value of fracture reduction.

The present study suggests that single radiographic findings, displacement of the fracture, and comminution of the calcar may be more predictive than a classification that tries to combine several features of the fracture and becomes difficult to reproduce from one observer to another (Frandsen et al. 1986). The value of the Garden classification seems to be limited to its ability to discriminate between the undisplaced and displaced fractures (Frandsen and Frigaard 1980, Editorial 1988). The simple explanation of its lacking correlation with the other predictive variables in the present analysis is that the Garden stages I–IV do not present a continuous ranking scale.

Whether or not it is possible to combine several adverse factors to calculate a prognostic score or to make an algorithm to select patients for primary prosthetic replacement will be the subject of future studies. If we could predict the failures and treat the heads at risk with a primary endoprosthesis, the patients would be spared from a reoperation.

No final conclusions should be made concerning the relative importance of predictive factors in the present preliminary study. The purpose of the report is only to draw attention to the fact that good quality radiographs and a close scrutiny of them is as important in the femoral neck fractures as in other fractures to prognosticate the outcome and to choose the best primary treatment.

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