Predictors of clinical and radiological outcome in patients with fractures of the acetabulum and concomitant posterior dislocation of the hip

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We aimed to identify variables associated with clinical and radiological outcome following fractures of the acetabulum associated with posterior dislocation of the hip. Using a prospective database of 1076 such fractures, we identified 109 patients with this combined injury managed operatively within three weeks and followed up for two or more years. The patients had a mean age of 42 years (15 to 79), 78 (72%) were male, and 84 (77%) had been involved in motor vehicle accidents. Using multivariate analysis the quality of reduction of the fracture was identified as the only significant predictor of radiological grade, clinical function and the development of post-traumatic arthritis ($p < 0.001$). All patients lacking anatomical reduction developed arthritis whereas only 25.5% (24 patients) with an anatomical reduction did so ($p = 0.05$).

The quality of the reduction of the fracture is the most important variable in forecasting the outcome for patients with this injury. The interval to reduction of the dislocation of the hip may be less important than previously described.

Factors predicting the clinical and radiological outcome in patients following fractures of the acetabulum associated with posterior dislocation of the hip have been debated.[1-9] Several authors have recommended urgent reduction of the dislocated hip as one of the most important factors to avoid the complications of arthritis, avascular necrosis and chondrolysis,[1-4,6,7,9] but there is a lack of agreement with respect to the allowable timing, with recommendations ranging from less than six hours to within 24 hours.[1-4,6,7,9,10] Others have found that the time to relocation has no effect on the outcome.[5,8] Letournel and Judet,[11] in a review of 167 cases of posterior dislocation, found no difference in the rate of avascular necrosis in patients relocated within six hours, between six and 24 hours, and two to three days after injury, suggesting that the fate of the femoral head is decided at the moment of injury.

In addition to the time of relocation, the outcome has been related to the quality of reduction of the fracture,[11-16] the age of the patient,[11,13,17] damage to the femoral head,[11,13] incarcerated fracture fragments,[18] associated injuries,[1,6,7] and the type of fracture.[16] However, studies have been inconsistent in their assessment of these variables, and the majority have not addressed the effect of all variables simultaneously on the outcome. Our objective was to identify the variables associated with clinical (pain, walking ability and range of movement) and radiological (the development of arthritis) outcome.

Patients and Methods

Fractures of the acetabulum database. From June 1980 to June 2003, the senior author (JM) treated 1076 patients with fractures of the acetabulum. At the time of injury, details of the patient's age, gender, comorbidity, mechanism of injury, associated injuries, fracture type, dislocation and any nerve palsy were entered into a database.[13] An operative report was completed for every patient to document the surgical approach, the duration of operation, blood loss, damage to the femoral head, bone impaction, the presence of intra-articular bone fragments and residual displacement of the fracture following fixation. Complications arising in hospital, such as wound infection, haematoma, loss of reduction, deep venous thrombosis, pulmonary embolus and mortality, were recorded. The clinical and radiological outcomes were assessed at six months, one year, two years, and annually thereafter if osteoarthrosis was identified. Patients without complications after two-years were reviewed every two years thereafter.

Identification of patients with posterior fracture-dislocations of the acetabulum. We identified all skeletally mature patients with a posterior dislocation of the femoral head

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doi:10.1302/0301-620X.88B12.17309 $2.00

J Bone Joint Surg [Br] 2006;88-B:1618-24.
Received 14 October 2005; Accepted after revision 23 June 2006

associated with a fracture of the acetabulum who were treated within three weeks of their injury, and who had two or more years of follow-up. We included patients with less than two years follow-up if they had a clearly definable poor result requiring joint replacement, or had a failure of fixation. We also identified all patients with a posterior dislocation who were treated more than three weeks from injury, and those with less than two years of follow-up. One author (MB) conducted an additional manual review of the records of all patients in the database to ensure that none had been omitted from the computerised queries.

Identification of prognostic factors. Evidence from the previous literature[11] and the experience of the senior author[13-15] suggested that the quality of reduction, the age of the patient, associated injuries (including to the head, chest, abdomen, genitourinary tract, spine and extremities), damage to the femoral head, acetabular impaction, the time to relocation of the dislocation and the type of fracture according to the Letournel classification,[11] were potentially prognostically important.

The quality of reduction was graded as the maximum residual displacement of the fracture on any of the three post-operative radiographs (anteroposterior, 45° iliac and obturator oblique views). Patients were categorised as having an anatomical (0 mm to 1 mm displacement), imperfect (2 mm to 3 mm displacement) or poor (> 3 mm displacement) reduction.[13] The femoral head was inspected both radiologically and intra-operatively for evidence of wear, abrasion and defects of the articular cartilage. The fractures were classified into one of five simple patterns: posterior wall (PW), posterior column (PC), anterior wall (AW), anterior column (AC), transverse (T), or five associated patterns (PC+PW, T-shaped, T+PW, AC+hemi-T, both columns) according to the classification of Letournel and Judet.[11] Previous studies have shown this classification to be reliable.[19,20] Orthopaedic surgeons (GM, TF, MB) assessed the radiographs for the quality of the reduction. To ensure inter-observer error was kept to a minimum, a sample of 15 radiographs was randomly selected to compare the results from the assessors and those of the senior author (JMM).

Clinical and radiological outcome. The information obtained at the most recent follow-up visit was used. The primary outcomes evaluated included the post-operative development of radiologically-graded arthritis, patient function and post-operative complications.

For the radiological assessment of the development of osteoarthritis, a grading system was followed.[13] A normal radiological appearance was considered excellent; mild changes consisting of small osteophytes, joint narrowing up to 1 mm in width and minimal sclerosis were considered good; intermediate changes with moderately-sized osteophytes, less than 50% joint narrowing and moderate sclerosis were considered fair; and advanced changes with large osteophytes, joint narrowing exceeding 50%, severe sclerosis, femoral head collapse and wear and acetabular wear, were considered poor.[13] The same method of checking for inter-observer error with a sample of radiographs was applied for this evaluation as was used for assessment of reduction.

Clinical evaluation utilised a modification of the grading system of Merle d'Aubigne and Postel.[13,14] This 18-point scale (minimum score = 4) evaluates pain, walking, and range of movement[13,14] and has been shown to have a significant correlation with the radiological indices.[21]

We examined complications including avascular necrosis, wound infection, haematoma, loss of reduction, deep venous thrombosis, pulmonary embolus and mortality.

Data analysis. All data were analysed using SPSS version 10 (SPSS Inc., Chicago, Illinois). The continuous variables of age, length of follow-up and blood loss were summarised with means and ranges. When the data were skewed, the medians were used as the measure of central tendency. The categorical variables of gender and fracture type were summarised as percentages. Chi-squared tests were used to compare proportions, i.e. the difference in percentage between the quality of reduction and the development of arthritis. Analysis of variance was used to compare multiple means and the Bonferroni correction for multiple comparisons.

We constructed multiple regression models to examine the association between predictor variables and outcomes. For example, logistic regression was used to identify variables associated with the development of arthritis. Initially, we conducted a series of univariable analyses to determine whether any independent variables such as the quality of the reduction, the age of the patient, associated injuries, damage to the femoral head, acetabular impaction, time to relocation of the femoral head and the type of fracture, were significantly associated with the dependent variable of arthritis. Variables that revealed an association in the univariable model were entered simultaneously into a multivariable regression model. Multiple linear regression was applied to test the association between our independent variables and the radiological and clinical grades. All regression analyses were adjusted for the length of follow-up. In addition, the variance (r^2) accounting for the variables in the analysis was reported. Kaplan-Meier survival curves were constructed to evaluate the difference in absence of arthritis or good to excellent clinical grades at follow-up and the quality of reduction. To ensure an adequate sample size to detect associations among seven independent variables, we required at least 70 patients (ten per variable tested).[22] We considered a p-value of 0.05 to be statistically significant. All tests were two-tailed.

Results

Of the 1076 patients with fractures of the acetabulum, 163 were associated with a posterior dislocation of the femoral head. A total of 45 patients who had less than two years follow-up were excluded and nine had been treated more than three weeks after injury, leaving 109 patients in the final analysis.

Table I. Baseline characteristics of the study cohort (n = 109)

Mean age in years (range)	42.0 (15 to 79)
Male (%)	78 (*72*)
Mechanism of injury (%)	
Motor vehicle accident	84 (*77*)
Motorcycle	4 (*4*)
Fall	9 (*8*)
Bicycle	3 (*3*)
Other	9 (*8*)
Acetabular fracture type (%)	
Simple	42 (*38.5*)
Posterior wall (PW)	35 (*32*)
Posterior column (PC)	5 (*4.5*)
Transverse	2 (*2*)
Associated (%)	67 (*61.5*)
PC + PW	5 (*4.5*)
Transverse + PW	45 (*41*)
T-type	3 (*3*)
Anterior column posterior hemitransverse	1 (*1*)
T-type + PW	13 (*12*)
Associated injuries (%)	
Head	0
Abdominal	6 (*6*)
Chest	19 (*17*)
Genitourinary	2 (*2*)
Extremity	41 (*38*)
Spine	5 (*5*)
Pelvic ring	2 (*2*)
Associated nerve injuries (%)	
Sciatic	8 (*8*)
Femoral	0
Common peroneal	14 (*13*)
Superior gluteal	0
Hours from injury to relocation of dislocated femoral head (median, SD)	18.0 (176)
Days to surgery from injury (mean, range)	6.7 (0.5 to 17)
Surgical approach (%)	
Ilioinguinal	1 (*1*)
Kocher-Langenbeck	100 (*92*)
Extended iliofemoral	8 (*7*)
Mean follow-up in years (range)	5.9 (2 to 19)

Patient characteristics. The majority of patients were male (78; 72%) the mean age of the whole patient group was 42 years (15 to 72), and the most frequent cause of injury was a motor vehicle accident (84; 77%) (Table I). Posterior dislocations of the femoral head were associated with 42 simple fracture patterns (38.5%) and 67 (61.5%) associated patterns. The most common types of fractures were of the posterior wall (35; 32%) and transverse with associated posterior wall fractures (45; 41%) (Table I). Dislocations were reduced at a median of 18 hours from the injury (mean 70; 1 to 480) and in advance of definitive surgery in 95% (104) of patients. All fractures were treated surgically, the majority through a Kocher-Langenbeck approach (100; 92%) (Table I). The mean follow-up was for 5.9 years (2 to 19).

At operation, damage to the femoral head as a consequence of the initial injury was apparent in 51 patients (47%). Impaction of the acetabulum was less common, occurring in 26 patients (24%) (Table II).

Radiological and clinical outcome. An anatomical reduction of the fracture was achieved in 96 patients (88%) (Table III). At their most recent follow-up, 86 patients (78%) maintained a good to excellent radiological grade. We completed the clinical grading scale on 94 patients (86% follow-up), of whom 79 (84%) achieved good (15 to 17 points) or excellent (18 points) outcomes with respect to pain, walking and range of movement in the hip (Table III). The radiological grades correlated significantly with the clinical scores (r = 0.59, p < 0.001) (Table IV). The overall

Table II. Intra-operative findings involving the femoral head and acetabulum (n = 109) (%)

Damage to the femoral head	51 (*47*)
Acetabular impaction	26 (*24*)
Incarcerated acetabular fragments	62 (*56*)
Mean number of incarcerated fragments (range)	2.2 (1 to 6)

radiological grade correlated with each aspect of the clinical grade, including walking (r = 0.59, $p < 0.001$), range of movement (r = 0.31, $p < 0.001$) and pain (r = 0.63, $p < 0.001$). Absolute agreement for a specific radiological grade with a corresponding clinical grade was substantial (intraclass correlation 0.60, 95% confidence interval (CI) 0.43 to 0.70).

Arthritic changes had developed in 11 patients (10%) at follow-up. Of these, five fractures were associated transverse-posterior wall, three were associated T-type posterior wall, one was of the posterior column, and two were of the posterior wall. Wear occurred in three patients, two with imperfect reductions and one with a poor reduction. One patient with an associated transverse-posterior wall fracture and anatomical reduction developed wear from a late subluxation of the femoral head. Another patient with an associated T-type posterior wall fracture developed a deep infection resulting in the development of arthritis.

Avascular necrosis (AVN) was noted in three patients (3%) and 23 (21%) developed moderate to severe heterotopic bone formation (Table III). Of those patients, three had been treated using an extended iliofemoral approach and 20 through a Kocher-Langenbeck approach, giving a proportional occurrence of heterotopic bone of 38% and 20%, respectively for these incisions. We identified four (4%) patients with combined arthritis and heterotopic bone formation. The mean clinical outcome scores of these patients were not significantly different from those of the remainder (14.8 (7 to 17) *vs* 16.1 (9 to 18) points, respectively; p = 0.28).

Total joint replacement was required in nine patients (8%), four owing to loss of reduction (44%), two for wear, one for AVN and two for arthritis. Among these patients, five sustained posterior wall fractures, three associated T-type and posterior wall fractures and one an associated posterior column and posterior wall fracture.

Predictors of outcome. In the univariable regression analyses we found that the quality of reduction ($p < 0.001$) and the time to relocation of the dislocation (p = 0.05) were significant variables associated with the development of arthritis. However, only the quality of reduction predicted the development of arthritis when all variables were entered simultaneously into a multivariable model (Table V). The quality of reduction of the fractures accounted for 22% of the variance of the dependent variable (arthritis). By 8 and 11 years following the injury all patients with poor and imperfect reductions had developed arthritis (Fig. 1). In contrast, only 10% (10) of patients with an anatomical reduction had developed arthritis at eight years, and only 25.5% (24) by 12 years (p = 0.05).

The quality of reduction of the fracture ($p < 0.001$), the time to relocation of the dislocation (p = 0.04), and damage to the femoral head (p = 0.03) were all significantly associated with the radiological score in the univariable regression analysis. In the multivariable regression model only the quality of fracture reduction remained a significant predictor of radiological grade at follow-up (Table V).

The clinical grade at follow-up was also significantly associated with quality of reduction of the fractures (Table V). Anatomical reductions resulted in the greatest proportion of good or excellent clinical results (Fig. 2). Moreover, 70% (72) of patients with anatomical reductions continued to have a good or excellent clinical outcome beyond 12 years from surgery. No patient with a poor or imperfect reduction experienced good or excellent clinical outcomes beyond 8 and 12 years, respectively (Fig. 2).

Discussion

In assessing 109 patients with fractures of the acetabulum and posterior dislocations of the hip, we found that an anatomical reduction was obtained in the majority of patients (88%), with good or excellent clinical function in 84%. The radiological outcome correlated significantly with the clinical outcome, and the quality of reduction of the fracture was the single most important predictor of clinical function, radiological grade and the development of arthritis.

Our data were derived from a large ongoing prospective comprehensive database of acetabular fractures with standardised procedures for its collection and patient management since its inception. The follow-up for the subgroup of patients with dislocations is high (86%). The outcomes are well defined and easy to interpret, with a sample size sufficient to make important inferences regarding predictor variables. However, the validity may be limited by a retrospective study and the experience of a single-centre. We do not know whether our results can be generalised. Our decision not to examine pre-operative fracture displacement and radiological outcome in the uninjured hip joint may limit our inferences in these areas. We may also have introduced measurement bias by not formally testing whether the outcomes achieved by the reviewers were acceptable in agreement beyond chance (i.e. κ statistic).

We used the Merle d'Aubigne and Postel clinical grading scale because of its application in several previous studies and our consistent use of this scale since 1980 for all patients with fractures of the acetabulum.[1,10,12-14] Rice et al[21] have cautioned against the use of this assessment in patients with acetabular fractures, reporting poor agreement between radiological and clinical grades. They did find, however, that the walking ability of patients (a subset

Table III. Radiological and clinical outcomes (*percentage*)

Quality of fracture reduction (n = 109 patients)	
Anatomical (0 mm to 1 mm)	96 (*88*)
Imperfect (2 mm to 3 mm)	12 (*11*)
Poor (> 3 mm)	1 (*1*)
Radiological grade (n = 109 patients)	
Poor	8 (*7*)
Fair	15 (*14*)
Good	33 (*30*)
Excellent	53 (*49*)
Modified Merle d'Aubigne and Postel clinical grading scale (n = 94 patients)	
Poor (scores < 13)	7 (*7*)
Fair (scores 13 to 14)	8 (*9*)
Good (scores 15 to 17)	44 (*47*)
Excellent (score = 18)	35 (*37*)
Complications (n = 109 patients)	
Pulmonary embolus	1 (*1*)
Loss of reduction	4 (*4*)
Infection	1 (*1*)
Wound haematoma	1 (*1*)
Avascular necrosis	3 (*3*)
Arthritis	11 (*10*)
Wear	3 (*3*)
Nonunion	1 (*1*)
Heterotopic bone (moderate/severe)	23 (*21*)
Resolution of nerve injuries (n = 22)	6 (*27*)
Revision to total hip replacement	9 (*8*)

Table IV. Correlation between clinical and radiological outcomes

Correlation	Radiological grade	Clinical score (3 to 18)	Degree of pain (1 to 6)	Walking ability (1 to 6)	Range of movement
Radiological grade	1.00	0.59*	0.63*	0.59*	0.31*
Clinical score (3 to 18)	0.59*	1.00	0.83*	0.85*	0.79*
Degree of pain (1 to 6)	0.63*	0.83*	1.00	0.75*	0.42*
Walking ability (1 to 6)	0.59*	0.85*	0.75*	1.00	0.47*
Range of movement	0.31*	0.79*	0.42*	0.47*	1.00

* significant at the 0.01 level (two-tailed)

Table V. Predictors of radiological and clinical outcomes from the multivariable regression model

Variables	Radiological score	Clinical score	Presence of arthritis
Quality of fracture Reduction	B = -0.32* P = 0.003	B = -0.24* P = 0.045	expB = 9.5* P = 0.01
Patient age (yrs) Reduction	B = -0.16 P = 0.16	B = 0.03 P = 0.85	expB = 1.01 P = 0.60
Damage to the femoral head Reduction	B = 0.18* P = 0.09	B = -0.001 P = 0.99	expB = 0.44* P - 0.39
Acetabular impaction Reduction	B = 0.15 P = 0.17	B = 0.03 P = 0.80	expB = 0.28 P = 0.34
Fracture type Reduction	B = -0.02 P = 0.85	B = -0.11 P = 0.39	expB = 0.97 P = 0.88
Hours to relocation Reduction	B = -0.19* P = 0.08	B = -0.15 P = 0.23	expB = 1.7 P = 0.19
Variance (R^2) predicted by significant variable(s) in the model (%)	*22*	*6*	*19*

* variables found to be significant in the univariable regression model. All analyses were statistically adjusted for differences in follow-up and associated extremity injuries between patients. Data represent those from the multivariable regression analysis accounting for all variables simultaneously (B, beta value, ExpB = exponent B (odds ratio)).

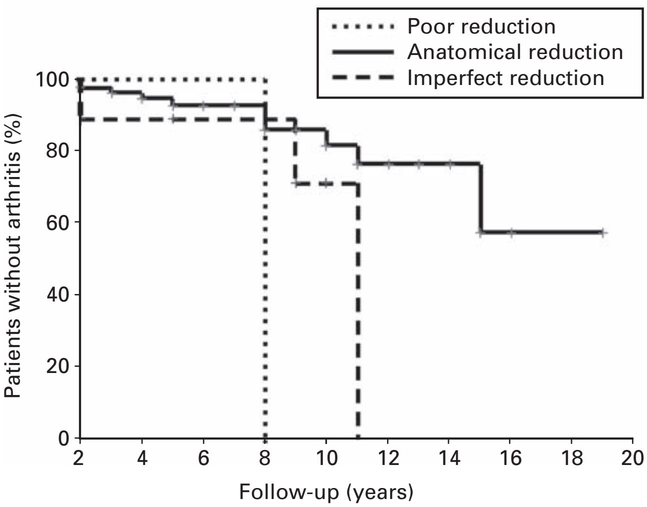

Fig. 1

Quality of reduction and developmental arthritis. Anatomical reduction of fractures resulted in a greater overall time to the development of arthritis (solid line) compared with imperfect (large dashed line) and poor (small dashed line) reductions.

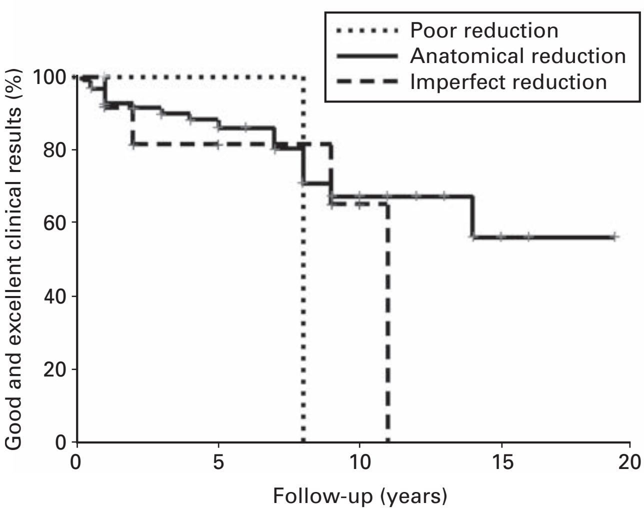

Fig. 2

Quality of reduction and clinical outcome. Anatomical reduction of the fractures resulted in a greater proportion of good and excellent clinical grades over time (solid line) compared with imperfect (large dashed line) and poor (small dotted line) reductions.

score with the d'Aubigne scale) correlated significantly with the radiological score. We found that the Merle d'Aubigne and Postel grading scale correlated well with the radiological scores which also correlated significantly with each domain of the scale, including pain, walking and range of movement. The agreement between radiological and clinical grades was good (intra-class correlation = 0.60) compared with the poor correlation identified by Rice et al[21] ($\kappa = 0.24$).

The ability to achieve an 88% anatomical reduction of the fractures in our patients probably reflects the higher proportion of posterior wall and transverse with posterior wall associated fractures, both of which have historically better rates of anatomical reduction.[13] This was further reflected in the finding that 84% of patients had good or excellent clinical outcomes.

Several studies have assessed the outcomes and prognostic factors in patients with posterior dislocations of the hip with or without fractures of the posterior wall, but few, if any, have identified the outcome in patients with a variety of acetabular fractures and posterior dislocation of the hip.[11] Acknowledging this difference, we have compared our results with the existing body of literature. Sahin et al[1] evaluated 57 patients with posterior fracture-dislocation of the hip, of whom 70% had a good clinical outcome as judged by d'Aubigne and Postel scores. At follow-up, ten patients (17.5%) had developed osteoarthritis and five (8.7%) avascular necrosis. The time to reduction of the fracture was identified as an important predictor of outcome in these patients. Moed et al[10] reviewed a series of 94 patients with displaced isolated fractures of the posterior wall at a mean of five years, of whom 85% had good or excellent clinical results (d'Aubigne and Postel). These authors identified a delay to reduction of more than 12 hours, older age and fracture comminution as important prognostic factors. Hougaard and Thomsen[7] examined the outcome in 98 patients with 100 posterior dislocations of the hip. The interval between injury and reduction was reported as a prognostic factor for clinical outcome, with 88% of the hips reduced within six hours obtaining a good or excellent result, compared with 44% that were reduced after more than six hours.

However, Letournel and Judet[11] discounted the prognostic value of time to reduction in patients with dislocations of the hip. There was no difference in the rate of AVN in patients who had their hips reduced within six hours, 7 to 24 hours, or two to three days (5%, 8% and 4%, respectively). They identified an overall rate of AVN of 7.5% in this population. Although AVN following dislocation can be the result of stretching the medial femoral circumflex artery, the trauma may be sufficiently violent to cause irreversible damage to blood flow to the femoral head which is not correctable by early reduction. The greatest stretching of the circumflex artery may actually occur in pure dislocation of the hip without associated fracture of the posterior wall. The defect in the posterior wall may allow the femoral head to rest in a position applying less tension to the artery.

Our findings agree with those of Letournel and Judet.[11] When evaluated simultaneously with multiple variables, time to relocation was not significantly associated with radiological grade, clinical grade or the development of arthritis.

The goal of operative treatment is to preserve a functional, mobile, painless hip joint. A successful outcome is based on the integrity and preservation of viable articular cartilage. If arthritis develops in the presence of viable cartilage, it is often the result of an altered distribution of load in the femoral head articulating with a malreduced acetabular surface. This functional loss of articulating surface between the femoral head and the surface of the acetabulum increases the force per unit area to the articular cartilage. The resultant loss of joint space is termed wear. The quality of fracture reduction was the single most important prognostic variable in this study. In our series, patients with anatomical fracture reductions had significantly more years of function without arthritis than did those with imperfect and poor reductions (Fig. 1).

Moed et al,[23] in a retrospective observational study of 67 patients who had undergone operative treatment for fractures of the posterior wall, recommended evaluation using post-operative computed tomography (CT). They concluded that CT provided a more accurate assessment of fracture reduction and was highly predictive of clinical outcome. Although the additional detail provided by CT is undisputed, our data support previous reports that plain radiological measurements can also predict outcome.[12-15] The additional detail available with CT may assist in providing prognostic information about joint incongruity and the later risk of arthritis, but the majority of patients who required total joint replacement in our series did not have arthritis. Early loss of reduction (44%) was the primary factor associated with the need for joint replacement.

The quality of reduction of the fracture remains the most important factor associated with outcome in patients with fractures of the acetabulum and posterior dislocation of the hip. The time to reduction of the dislocation may not be as important as previously thought. Dislocation of the hip should be reduced whenever possible, but early timing (less than 12 hours) is probably not an absolute determinant for a good outcome.

This study was funded by a research grant from Stryker Orthopaedics.

Although none of the authors has received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article, benefits have been or will be received but will be directed solely to a research fund, foundation, educational institution, or other nonprofit organisation with which one or more of the authors are associated.

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