Radiographic Determinants of Early Failure After Posterior Wall Acetabular Fracture Fixation

SWAPNIL B. SHAH, MD; THEODORE T. MANSON, MD; JASON W. NASCONE, MD; MARCUS F. SCIADIINI, MD; ROBERT V. O’TOOLE, MD

abstract

A retrospective review was conducted at an academic trauma center to determine whether fracture characteristics or aspects of native anatomy are predictive of early failure after fixation of posterior wall acetabular fractures. A chart review of posterior wall acetabular fractures treated from 2004 to 2009 yielded the study group that met the inclusion criteria. The study group included 18 consecutive patients who had clinical failure. The control group included 27 patients who did not have clinical failure. Operative notes were reviewed and axial view computed tomography scans were analyzed to determine 8 fracture descriptors (dislocation, comminution, marginal impaction, femoral head injury, incarcerated fragments, involvement of the subchondral arc, proximal-to-distal fracture extension, and size of the fracture measured by 3 methods) and 6 native anatomy descriptors (transverse plane acetabular anteversion, anterior acetabular sector angle, 2 measures of the posterior acetabular sector angle, and 2 measures of change in the posterior acetabular sector angle). Failure of treatment (n=18) was defined as the need for total hip arthroplasty (n=5) or the development of symptomatic posttraumatic arthritis (n=13). Fisher’s exact test and Student’s t test were conducted. The only variable that was predictive of failure of operative treatment of posterior wall fractures was extension of the fracture into the subchondral arc (12 of 18 patients in the failure group vs 7 of 27 patients in the nonfailure group, P=.01). Native anatomy, fracture size, and marginal impaction did not play a significant role in predicting failure. [Orthopedics. 2016; 39(6):e1104-e1111.]

Posterior wall acetabular fractures are the most prevalent type of acetabular fracture, accounting for approximately one-third of all acetabular fractures.1-3 Treatment is commonly associated with poor early outcomes, with a failure rate of approximately 30% within the first year.4 Some authors argue that acute total hip arthroplasty is the best option for some patients with this type of fracture.5,6 However, little is known about which of these patients will tend to have early failure and which patients can achieve acceptable outcomes with fixation. Multiple imaging characteristics of posterior wall acetabular fractures have been proposed to be associated with poor outcomes, including malreduction, marginal impaction, comminution, and fracture location.5,7,8 However, previous studies examined only a few factors at a...
time and showed inconsistent results. Additionally, native anatomy has not been taken into account as a potential factor predictive of failure. The current authors hypothesized that the native anatomy (including acetabular version) and the details of the fracture pattern are predictive of clinical outcomes.

**Materials and Methods**

**Patient Selection Criteria**

After institutional review board approval was obtained, the authors identified 194 consecutive patients with posterior wall acetabular fractures treated with open reduction and internal fixation by a total of 9 staff fellowship-trained orthopedic trauma surgeons at the study institution between 2004 and 2009. Only fractures with posterior wall injury were included, although many patients had concomitant injuries. All other fracture patterns, even if they included the posterior wall as a component of a more complex fracture pattern, were excluded. Patients were treated with a Kocher-Langenbeck approach in a lateral position. Marginal impaction was treated with elevation of articular components and bone grafting with allograft chips. Mini-fragment screws were often used to “raft” marginal impaction. Postoperatively, patients were allowed restricted foot-flat weight bearing at 8 to 12 weeks, at the surgeon’s discretion, and all received enoxaparin prophylaxis for deep vein thrombosis. Posterior hip precautions were rarely implemented, and implementation was determined by surgeon discretion.

The study group of clinical failures was created by reviewing the electronic records of all 194 patients. The definition of clinical failure included the need for total hip arthroplasty or the development of radiographic signs of arthritis and the need for total joint arthroplasty, as clinically determined by the attending orthopedic surgeon. This review yielded 18 patients with clinical failure (5 who underwent arthroplasty and 13 who had radiographic signs of arthritis, such as joint collapse). Failure occurred 1 to 21 months postoperatively (mean, 9.3 months). The failure group included 15 male and 3 female patients, with an average age of 46 years (range, 17-81 years) at the time of injury.

A second potential definition of failure that used only radiographic criteria was explored, and these criteria also were applied to all 194 patients. Anteroposterior radiographs of the pelvis, obtained at initial postoperative examination and at 1-year follow-up, were reviewed in a random blinded fashion by an orthopedic surgeon with fellowship training in both trauma and arthroplasty. For patients who received a total joint, the surgeon reviewed the last radiograph obtained before definitive joint surgery. If treatment failure occurred before 1 year postoperatively, the surgeon reviewed the radiograph obtained closest to the 1-year follow-up. The surgeon who reviewed the radiographs was unaware of the clinical outcomes.

Tönnis grading was assigned to each radiograph as follows: grade 0, no signs of osteoarthritis; grade 1, increased sclerosis, slight joint space narrowing, no or slight loss of head sphericity; grade 2, small cysts, moderate joint space narrowing, moderate loss of head sphericity; and grade 3, large cysts, severe joint space narrowing, severe deformity of the head. A Tönnis grade of 2 or greater was defined as relevant disease.

This alternate definition of the study group yielded an identical outcome for the 18 patients with clinical failure but added 2 additional patients with radiographically evident failure who did not have early clinical failure. As described later, the results were unchanged when either definition of the study group was used, so the study group defined by clinical failure is used for the remainder of the article.

The control group was created by conducting a review of the remaining 176 patients. Patients who had less than 1 year of documented clinical outcomes were excluded, leaving 27 patients with more than 1 year of follow-up and no documented clinical symptoms. Mean follow-up was 18 months (range, 12-53 months). The nonfailure group included 20 male and 7 female patients, with an average age of 39.6 years (range, 16-73 years) at the time of injury.

**Imaging Descriptors**

For each patient in the study, 14 imaging characteristics were evaluated. Of these characteristics, 8 related to descriptions of the fracture and 6 related to the native bony anatomy and the change in anatomy caused by the fracture. All imaging parameters were measured by an orthopedic trauma fellow (blinded for review), based on axial view computed tomography (CT) scans of the injury. The images were viewed on computer workstations with an electronic picture archiving and communication system (IMPAX system; IMPAX Laboratories, Inc, Hayward, California), and this is the same way that clinical images are viewed at the study institution. Standard measuring tools were used within the software.

**Fracture Descriptors**

Characteristics of the fractures were noted according to 8 imaging parameters, yielding a total of 10 variables: dislocation, comminution, marginal impaction, femoral head injury, incarceration, depth, extensile nature, and size. Dislocation was noted on CT scans and in the electronic medical records, indicating dislocation that may have been reduced before the CT scans were obtained. Comminution was defined as at least 3 distinct fracture fragments discernible on CT scans. Marginal impaction was noted if it was present either in the medical records or on CT scans. Incarceration of fracture fragments in the joint was recorded as present only if a fragment larger than 5 mm was noted within the joint on CT scans.
The depth of the fracture was determined with a method described by Saterbak et al. First, the vertex of the acetabulum was defined as the top of the joint and the section directly above the first visualization of the subchondral arc (Figure 1). Involvement of the subchondral arc was defined as a fracture line traversing the joint on the CT section at which the roof was first visible as a complete arc (Figure 2). In all cases, the arc was visualized 1 section below the vertex.

The proximal-to-distal extent of the fracture was evaluated by splitting the acetabular region into 4 zones, similar to those described by Saterbak et al: zone 1, 3 sections above the vertex to the subchondral arc; zone 2, the subchondral arc to the fovea; zone 3, the fovea to the ischial facet; and zone 4, below the ischial facet (Figure 3). If the fracture line involved at least 3 of the zones, it was defined as extensile.

The size of the fracture was determined with the 3 measurement methods described by Moed et al. Although these authors used the measurements to correlate the size of the fracture with instability, the current authors used them to measure the size of the fracture thoroughly. First, the authors used the Calkins method, which measures the smallest intact remaining posterior acetabulum and compares it with the length of the posterior acetabular arc of the uninjured side (Figure 4). The ratio of the injured side to the uninjured side multiplied by 100 yields the percentage of wall that is left intact by the fracture. The higher this number, the smaller the fracture. Next, the current authors used the Keith method with the subtraction technique, which estimates the fracture size at the level of greatest foveal involvement (Figure 5). The smallest remaining intact posterior acetabular wall at any foveal level is measured on the injured side. This value is subtracted from the measurement of the matched uninjured side to produce the fracture size. The fracture size is then divided by the measurement of the uninjured side and multiplied by 100 to determine the percentage of wall that is fractured. The third method used was the Moed method with the subtraction technique, which yields the fracture size at the level of greatest posterior wall deficit (Figure 6). The smallest remaining
intact posterior wall at any level of the fracture is measured on the injured side. This value is subtracted from the measurement of the matched uninjured side, producing the fracture size. The fracture size is then divided by the measurement of the uninjured side and multiplied by 100 to determine the percentage of wall that is fractured.

Native Anatomy

The authors also obtained 6 measurements of the acetabular anatomy on both the uninjured and injured sides. The study hypothesis was that the amount of native femoral head coverage and anteversion of the acetabulum might be related to the propensity to fail.

Transverse plane anteversion was measured on the intact acetabulum, as described by Anda et al. First, the intercapital center line is marked on the image through the femoral heads at the level of the fovea. Next, a line is drawn perpendicular to the intercapital center line. The transverse plane anteversion angle is the angle between this perpendicular line and a line connecting the anterior and posterior acetabular margins (Figure 7).

For the uninjured side, the anterior acetabular sector angle was measured at the level of the fovea, as described by Anda et al. The anterior acetabular sector angle is the angle between the anterior acetabular margin, the center of the femoral head, and the intercapital center line (Figure 8).

For both the uninjured and injured sides, the posterior acetabular sector angle was measured at the level of the fovea and at the level of greatest wall involvement. The posterior acetabular sector angle is the angle between the posterior acetabular margin, the center of the femoral head, and the intercapital center line (Figure 9). In this section, 2 measurements were obtained: the posterior acetabular sector angle fovea and the posterior acetabular sector angle fracture.

Also measured was the percent change in the posterior acetabular sector angle that occurred at both the level of the fovea and the level of greatest wall involvement to delineate how much posterior wall coverage had been decreased as a result of the injury (Figure 10). In this section, 2 measurements were obtained: the change
in the posterior acetabular sector angle fovea and the change in the posterior acetabular sector angle fracture. The percent change in the posterior acetabular sector angle can be calculated by the following formula: (posterior acetabular sector angle uninjured-posterior acetabular sector angle injured)/posterior acetabular sector angle uninjured×100.

Statistical Analysis

Univariate and multivariate comparisons between the failure and nonfailure groups were made with Fisher’s exact test and Student’s t test. A P value of .05 was defined as statistically significant. All calculations were performed with Microsoft Office Excel (Microsoft Corporation, Redmond, Washington).

Post hoc power analysis was conducted for all 18 variables. Power was set at 80%, with alpha set at 0.05, and for each variable, a minimum clinical difference that the study could detect was calculated.

RESULTS

Extension of the fracture into the subchondral arc was predictive of clinical failure. This feature was present on CT scans of 67% of patients in the failure group (12 of 18 patients) vs only 26% (7 of 27 patients) in the control group (P=.01). Acetabular version and all other parameters were not predictive of failure (P>.20). All 5 patients who received a total joint had extension of the fracture into the subchondral arc (Tables 1-2).

With this sample size, the study had 80% power (alpha=.05) to detect absolute differences in proportions between 44% (for a baseline rate of 22%) and 34% (for a baseline rate of 50%). As noted in the Materials and Methods section, the use of radiographic criteria for failure did not change the outcomes.

DISCUSSION

Posterior wall acetabular fractures are the most common type of acetabular fracture, and they have devastating outcomes for many patients. Several factors have been studied to determine which fractures have worse outcomes. This information may allow surgeons to counsel patients on the likelihood of clinical success and may even guide surgeons to change the initial management of these injuries.

The results of the current study confirm the findings of Saterbak et al and show that involvement of the subchondral arc is strongly associated with failure (P=.01). Interestingly, in contrast to previous work, no other fracture descriptors showed a correlation with poor clinical
In addition, none of the measures of native anatomy were predictive of failure. Many authors\textsuperscript{5,6,11} have shown that marginal impaction correlates with failure after fixation. Interestingly, the study by Saterbak et al\textsuperscript{7} did not include any patients with marginal impaction. In the current study, marginal impaction occurred in 9 of the 18 patients in the failure group and 12 of the 27 patients in the nonfailure group. In this study, the actual amount of marginal impaction, which may be a very important variable, was not studied because of lack of a well-defined measurement technique. Future studies are needed to examine marginal impaction and its role in failure.

Several studies\textsuperscript{5,11-13} have reported that age older than 50 years can be predictive of failure after fixation. Further, patients who receive total joints after failed fixation have poor Musculoskeletal Function Assessment scores, suggesting that the timing of total joint replacement may be important.\textsuperscript{5} In the current study, older age was not a predictive factor, and 7 of the 18 patients in the failure group and 7 of the 27 patients in the nonfailure group were older than 50 years at the time of injury.

Limitations

The current study is limited by its retrospective design, including loss of follow-up, and other potential sources of bias. The statistical analysis could be criticized because the authors did not correct for multiple comparisons. Further, although it is larger than most previous attempts to evaluate this topic, the study is still underpowered. In addition, the size and angle measurements obtained with the IMPAX system were assessed by only 1 examiner. Future studies should include validation of the measurement techniques described in this article. An important variable that was not considered in this study was the quality of articular surface reduction. Letournel and Judet\textsuperscript{2} and Matta\textsuperscript{14} showed that residual radiographic displacements greater than 1 mm are associated with long-term joint deterioration. Further, Moed et al\textsuperscript{8} showed that a fracture gap greater than 1 mm on CT scan was a risk factor for unsatisfactory results. The authors do not routinely obtain postoperative CT scans in these cases, so CT-based measures of reduction were not available. Although this study did not examine fracture reduction, all fractures were treated by orthopaedic surgeons with fellowship training in trauma. Variations in the quality of reduction may have played an important role in outcomes. This was not considered in this study and is a weakness of the current analysis. However, the study focused on the injury characteristics that predicted failure. Certain radiographic characteristics may serve as a surrogate for the difficulty in obtaining good reduction, but further study is needed to determine whether this is the case.

Conclusion

This study examined all previously studied variables that were hypothesized to predict failure after posterior wall ac-
Table 2

Measurement of Native Anatomy

<table>
<thead>
<tr>
<th>Anatomic Parameter</th>
<th>Failure Group (n=18)</th>
<th>Nonfailure Group (n=27)</th>
<th>P a</th>
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<tbody>
<tr>
<td>Transverse plane anteversion angle</td>
<td>16.9°±3.0°</td>
<td>18.2°±1.9°</td>
<td>&gt;.05</td>
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<tr>
<td>Anterior acetabular sector angle</td>
<td>66.1°±3.8°</td>
<td>66.1°±2.0°</td>
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<td>Posterior acetabular sector angle fovea</td>
<td>98.1°±4.1°</td>
<td>101.4°±3.5°</td>
<td>&gt;.05</td>
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<td>Change in posterior acetabular sector angle fovea</td>
<td>31%±9%</td>
<td>34%±7%</td>
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<td>Posterior acetabular sector angle fracture</td>
<td>113.6°±9.5°</td>
<td>108.4°±6.7°</td>
<td>&gt;.05</td>
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<td>Change in posterior acetabular sector angle fracture</td>
<td>47%±10%</td>
<td>45%±7%</td>
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</table>

aSignificance set at P<.05.

Table 3

Comparison of Studied Variables

<table>
<thead>
<tr>
<th>Study</th>
<th>Native Anatomy</th>
<th>Fracture Size</th>
<th>Fracture Depth</th>
<th>Fracture Extension</th>
<th>Marginal Impaction</th>
<th>Comminution</th>
<th>Femoral Head Injury</th>
<th>Age</th>
<th>Dislocation</th>
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Abbreviations: NP, variable was studied and found not to be a predictor of outcome; SP, variable was studied and found to be a significant predictor of outcome; –, variable was not studied.
REFERENCES


