Value of 3-D CT in Classifying Acetabular Fractures During Orthopedic Residency Training

JEFFREY GARRETT, MD; JASON HALVORSON, MD; Eben CARROLL, MD; LAWRENCE X. WEBB, MD

abstract

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The complex anatomy of the pelvis and acetabulum have historically made classification and interpretation of acetabular fractures difficult for orthopedic trainees. The addition of 3-dimensional (3-D) computed tomography (CT) scan has gained popularity in preoperative planning, identification, and education of acetabular fractures given their complexity. Therefore, the authors examined the value of 3-D CT compared with conventional radiography in classifying acetabular fractures at different levels of orthopedic training. Their hypothesis was that 3-D CT would improve correct identification of acetabular fractures compared with conventional radiography.

The classic Letournel fracture pattern classification system was presented in quiz format to 57 orthopedic residents and 20 fellowship-trained orthopedic traumatologists. A case consisted of (1) plain radiographs and 2-dimensional axial CT scans or (2) 3-D CT scans. All levels of training showed significant improvement in classifying acetabular fractures with 3-D vs 2-D CT, with the greatest benefit from 3-D CT found in junior residents (postgraduate years 1-3).

Three-dimensional CT scans can be an effective educational tool for understanding the complex spatial anatomy of the pelvis, learning acetabular fracture patterns, and correctly applying a widely accepted fracture classification system.

Figure: Obturator oblique (A), iliac oblique (B), and anteroposterior (C) plain radiographs of a transverse posterior wall fracture case example. Arrows identify the injury.
Pelvic and acetabular fractures can occur frequently in the multiply-injured patient. Initial evaluation in the emergency department includes plain radiographs of the pelvis. These images, most frequently the obturator and iliac oblique (Judet) views, are often suboptimal and can be uncomfortable for the patient. In the trauma setting, a 2-dimensional (2-D) computed tomography (CT) scan including the pelvis is now routinely performed. The capability to perform 3-dimensional (3-D) CT reconstructions is also becoming more common at larger medical centers. The use of multiplanar 2-D and 3-D CT reconstructions may improve identification of intra-articular fragments and fracture lines and assist in understanding the complex 3-D anatomy of the pelvis and acetabulum. This understanding is crucial to the nontreating surgeon when attempting to classify the fracture to facilitate communication with referral centers.

The Letournel classification of acetabular fractures is widely used. The original classification system was described using plain anteroposterior (AP) and Judet view radiographs. It enables functional communication among surgeons and provides an effective management algorithm for acetabular injuries. It is generally assumed that interobserver reliability of fracture classification correlates with level of experience: those with less experience usually have poorer interobserver reliability scores than those with greater experience.

The use of 3-D imaging in orthopedic training can improve familiarity with the complex spatial anatomy of the pelvis and acetabulum. The hypothesis of this study was that 3-D CT scans would be a more effective tool for orthopedic residents to classify acetabular fractures than a combination of plain radiographs and 2-D CT.

**Materials and Methods**

Following completion of Health Insurance Portability and Accountability Act documentation and Institutional Review Board approval, acetabular fractures were identified from the hospital database operative reports of 1 university-affiliated Level I trauma center. Ten acetabular fracture case examples were selected that were felt to accurately represent the 5 simple and 5 combined fracture types as described by Letournel-Judet: posterior wall, posterior column, posterior column/wall, anterior wall, anterior column, transverse, T-type, transverse/posterior wall, anterior column/posterior hemitransverse, and both columns.

Two fellowship-trained orthopedic traumatologists (E.C., L.X.W.), one with >20 years of experience managing acetabular injuries, reviewed each fracture case example. Classification was assigned based on plain radiographs, 2-D and 3-D CT scans, and intraoperative findings (for fractures treated surgically). A mutual consensus was reached for each fracture case example. Any case with disagreement was disregarded during the preliminary patient database search. Only cases with plain radiographs (AP and Judet views), axial 2-D CT scans, and 3-D CT scans obtained from the same patient were used. Case examples were then divided into 2-D and 3-D scans, making 20 total cases. These images were organized in PowerPoint (Microsoft, Redmond, Washington) format, without patient identifiers, for presentation.

**Study Participants**

Fifty-seven orthopedic trainees, postgraduate year 1 through 5, and 20 fellowship-trained orthopedic traumatologists participated in the study. Participants were included from 3 separate orthopedic training programs, the 2009 Southeastern Fracture Symposium, and the 2009 Arbeitsgemeinschaft für Osteosynthesefragen (AO) resident’s basic fracture course.

**Study Design**

The 10 original acetabular cases were divided into their respective 2-D and 3-D scans, making a total of 20 acetabular fracture case images. These 20 case images were presented in lecture/quiz format via PowerPoint presentation to participants. A case image included (1) plain radiographs and 2-D CT scans or (2) 3-D CT scans. Plain radiographs included AP and Judet views (Figure 1), whereas axial 2-D CT scans encompassed the pelvis from the superior iliac wing through the inferior pubic ramus in 1-mm increments (Figure 2). Reconstructed 3-D scans included AP and Judet views, with rotational views around the involved hemipelvis (Figure 3).

Prior to quiz administration, a computer was used to randomly generate the order of 2-D and 3-D scans of the fracture case examples. Each case was fully automated.
in PowerPoint format to ensure time standardization. Five seconds were allotted to view each of the 3 radiographs, immediately followed by 7 seconds each to view them a second time. Axial CT scans followed the plain radiographs for the 2-D scans and scrolled at a rate of 0.5 seconds per image. Images began at the iliac wing and scrolled through the inferior pubic ramus in 1-mm increments. The axial 2-D CT scans of the entire pelvis were viewed a total of 3 times. The 3-D scans were also automated, with each rotational view timed at 1 to 3 seconds. All 3-D CT scans were viewed a total of 2 or 3 times. Therefore, at the end of quiz administration, each participant viewed the uncoupled 2-D and 3-D scans 1 time for each of the 10 original acetabular fracture case examples.

The fracture example quiz was administered by an attending orthopedic traumatologist at each respective program and by a single resident at the Southeastern Fracture Symposium and AO basic course. The case examples began with a study introduction.

Figure 2: Axial 2-dimensional computed tomography scans from the same transverse posterior wall fracture case example, representative of the 42 total axial computed tomography images shown for this particular fracture case example (A-F). Arrows identify the injury.

Figure 3: Anterior (A), posterior (B), obturator oblique (C), and iliac oblique (D) 3-dimensional computed tomography scans from the same transverse posterior wall fracture case example.
and description of specific aims. Informed consent was obtained from each participant. An acetabular fracture example sheet with depictions of each of Letournel’s classic patterns was given to each participant. Time was then taken to review the correlation of 6 AP radiographic lines (anterior and posterior acetabular wall, iliopectineal line, ilioischial line, acetabular roof, and the teardrop) with related acetabular injury. Participants were informed that each of Letournel’s fracture patterns could be represented once, more than once, or not at all. For each case example, 30 to 120 seconds (depending on the number of images) was given for review, followed by 15 seconds to record an answer.

Statistical Methods

Participants were divided into 3 groups for data analysis: group 1 (n = 20) included fellowship-trained orthopedic traumatologists, group 2 (n = 17) included senior orthopedic residents (postgraduate years 4-5), and group 3 (n = 40) included junior orthopedic residents (postgraduate years 1-3). Group 1 was used as a control to validate the quiz and account for the limitations caused by lack of participant control of viewing time and image sequence. Paired t test was used to calculate percentage of correct answers for both 2-D and 3-D scans compared with the original assigned fracture classification for that image. Bonferroni corrections were done to account for the multiple comparisons between groups.

Interobserver reliability among groups was also calculated. The simple kappa statistic measure of agreement was first introduced by Cohen6 in the case of 2 raters. It was later modified by Fleiss7 to apply to cases with >2 raters. It is scaled to be 0 when the amount of agreement is what would be expected to be observed by chance and 1 when there is perfect agreement. For intermediate values, Landis and Koch8 suggested the following interpretations: <0.0; poor; 0.00-0.20, slight; 0.21-0.40, fair; 0.41-0.60, moderate; 0.61-0.80, substantial; and 0.81-1.00, almost perfect.

### RESULTS

All groups showed improvement in assigning correct fracture classification with 3-D vs 2-D scans. Group 2 improved from 42.4% to 57.6% (P = .0045). Group 3 improved from 36.3% to 52.5% (P = .0001) (Table 1). The percentage of correct answers was significantly higher in group 1 (orthopedic traumatologists) than in group 2 (senior residents) with respect to 3-D (P = .0341) and 2-D (P = .0412) imaging. This improvement was also significant between group 1 and group 3 (junior residents) (3-D, P = .0001; 2-D, P = .0001). The difference between groups 2 and 3 was not significant (3-D, P = .6265; 2-D, P = .5461). Although the improvement in scores using 3-D CT vs plain radiographs and 2-D CT was significant in all groups, the benefit was most evident at the junior resident level (postgraduate years 1-3), where the increase was 16.2%.

With regard to interobserver reliability, moderate agreement was seen in senior residents with 3-D imaging (kappa P = .44) and fair agreement with 2-D imaging (kappa P = .29). Junior residents also showed moderate agreement with 3-D imaging (kappa P = .42) and fair agreement with 2-D imaging (kappa P = .27) (Table 2).

The most commonly misclassified fractures with both 3-D and 2-D imaging were T-type, posterior column, and anterior wall. Fractures most often classified correctly were posterior wall, anterior column, and transverse/posterior wall.

### DISCUSSION

The Letournel classification system for acetabular fractures is widely used and has been shown to be reliable. It enables functional communication among surgeons and provides an effective management algorithm for acetabular injuries.5 The classification system was described using plain AP and Judet view radiographs.3,4 Beaulé et al3 reported substantial intra- and interobserver reliability classifying acetabular fractures with plain radiographs in surgeons who were highly experienced. However, in their study, surgeons with less experience showed a trend toward improved accuracy with 2-D axial CT.5 Using plain radiographs, Petrisor et al9 reported poor agreement among 3 orthopedic trainees (postgraduate years 2-3) and moderate agreement among 3 community orthopedic surgeons classifying acetabular fractures.

Other studies have shown a benefit with 2-D and 3-D imaging in classifying acetabular fractures. Ohashi et al2 found a

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### Table 1

<table>
<thead>
<tr>
<th>Residents</th>
<th>n</th>
<th>2-D</th>
<th>3-D</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Junior</td>
<td>40</td>
<td>36.3±15.5</td>
<td>52.5±14.3</td>
<td>&lt;.0001</td>
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<tr>
<td>Senior</td>
<td>17</td>
<td>42.4±17.1</td>
<td>57.6±14.4</td>
<td>.0045</td>
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### Table 2

<table>
<thead>
<tr>
<th>Imaging</th>
<th>Junior Residents</th>
<th>Senior Residents</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-D</td>
<td>0.27</td>
<td>0.29</td>
</tr>
<tr>
<td>3-D</td>
<td>0.42</td>
<td>0.44</td>
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significant improvement in interobserver agreement with the addition of 2-D and 3-D CT scans. In 10 orthopedic residents, Hüfner et al\textsuperscript{10} showed an improvement from 30\% to 65\% in correctly classifying acetabular fractures using 3-D CT vs plain radiographs and 2-D CT. In the same study, more experienced surgeons also showed improvement using 3-D imaging, but the trend was not significant.\textsuperscript{10} These studies included relatively small numbers of participants.

In the current study, 3-D CT imaging was shown to significantly improve accuracy in classifying acetabular fractures. This benefit was most pronounced at the junior orthopedic resident level (postgraduate years 1-3); however, 3-D CT imaging also significantly improved accurate classification for senior residents. This improvement may suggest an increased appreciation of pelvic and acetabular spatial anatomy afforded by 3-D imaging. Several studies have shown 2-D and 3-D CT scans to be beneficial in understanding acetabular fractures, including the precise plane of the fracture, the degree of disruption of the articular surface, and spatial relationships of fragments.\textsuperscript{1,2,10}

In an increasing number of trauma centers, 3-D CT imaging has become readily accessible. Computed tomography reconstructions can be easily manipulated on an operator workstation inside and outside of the operating suite. Computer subtraction of surrounding anatomic structures can improve visualization and identification of subtle injuries. Templating and virtual fracture reductions can also be performed using computer-assisted planning tools.\textsuperscript{11} In treating acetabular injuries, the choice of surgical approach and stabilization method are critical. A thorough understanding of fracture patterns and spatial relationships is necessary for surgical planning. As residents gain a better appreciation of pelvic anatomy with reconstructive CT imaging, an effective educational tool for teaching surgical approaches and fracture fixation emerges. Also important to the orthopedic trainee is an ability to correctly identify Letournel’s fracture patterns to facilitate appropriate communication between fellows, residents, colleagues, attendings, and, eventually, referral centers.

Some authors have suggested that with the increasing availability of 2-D and 3-D CT scans, supplemental oblique Judet radiographs can be omitted from the standard acetabular fracture workup.\textsuperscript{2} This is not the practice at the current authors’ institution. Moreover, this study does not address the validity of that conclusion, but rather supports the idea of using 3-D imaging as an effective teaching tool for pelvic and acetabular anatomy. This study’s results also suggest that improvements in educating orthopedic trainees in radiographically assessing pelvic injuries are needed given the disparity between 2-D and 3-D fracture identification across all levels of training. Plain radiographs remain the standard for initial assessment of pelvic fractures and continue to be a valuable, informative tool for orthopedic surgeons identifying acetabular fractures. Although 3-D scans improved accurate fracture identification, continued emphasis on radiographic assessment of pelvic injury is necessary for the benefit and education of orthopedic trainees.

This study had limitations. The quality of some plain radiographs in the fracture example was not ideal. Obtaining appropriate Judet views can be a challenge and is often associated with significant patient discomfort. Thus, at the authors’ institution, multiple attempts to correct inadequate images in the emergency department are usually avoided. Also, the authors expected scores to be somewhat lower than they may otherwise have been because the quiz was fully automated. Thus, participants had no control over the sequence of images viewed nor the time spent on each. Attempts were made to give adequate and equal time to each fracture case example; however, a more ideal format would be for an individual participant to control the timing and sequence of images. The authors felt that enrolling a high number of orthopedic participants in this study would be difficult if the selected format was not used. All participants, including orthopedic traumatologists, took the quiz in the same format. The authors felt this would equalize the results. Thus, their emphasis was on the degree of improvement seen using 3-D vs 2-D imaging, not on the total percent of correct answers.

Another limitation was that the standards for quiz answers were determined by 2 fellowship-trained orthopedic traumatologists who came to a mutual consensus on fracture classification based on operative reports, radiographs, CT scans, and 3-D reconstructions. Given the moderate kappa values between the 20 fellowship-trained orthopedic surgeons in the current study, one could question the accuracy of the original diagnosis and standard that all others were then expected to match. An incorrect original diagnosis would subsequently skew statistical analysis. However, agreement was obtained in all cases between 2 fellowship-trained orthopedic traumatologists, one with extensive practice evaluating and treating acetabular fractures. All 3 imaging modalities, as well as the documented operative report for each case, were available at the time of classification. Also, no time limit to determine fracture classification existed. Given this information, in addition to the fact that no disagreement was seen between traumatologists for any case, it was felt the fracture classification obtained for each case was accurate.

**Conclusion**

Three-dimensional CT imaging can be an effective educational tool for understanding the complex spatial anatomy of the pelvis, learning acetabular fracture patterns, and correctly applying a widely accepted fracture classification system. This benefit may be more pronounced with junior orthopedic residents but can also improve accuracy in classification for senior orthopedic residents.
REFERENCES


