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Nonoperative treatment of select LC-II pelvic ring injuries (OTA/AO 61B2.2) results in a low rate of radiographic displacement

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Abstract

Objectives: to quantify radiographic outcomes and identify predictors of late displacement in the nonoperative treatment of LC-2 pelvic ring injuries.

Design: Retrospective review.

Setting: Two level 1 trauma centers

Patients/Participants: Thirty eight patients ≥18 years old with LC-2 pelvic ring injuries.

Intervention: Nonoperative treatment.

Main Outcome Measurements: Crescent fracture displacement measured on initial axial Computed Tomography. Change in pelvic ring alignment measured by the Deformity Index, Simple Ratio, Inlet and Outlet Ratios on successive plain radiographs.

Results: Patients in this study had minimally displaced LC-2 pelvic ring injuries, with median initial crescent fracture displacement of 2mm and median initial Deformity Index of 2%. No patient had a ≥10 percentage point change in Deformity Index over the treatment period, but small amounts of displacement were seen on the other ratios. No patients initially selected for nonoperative treatment converted to operative treatment. No radiographic predictors of late displacement were identified. Bilateral pubic rami fractures and the presence of a complete sacral fracture ipsilateral to the crescent fracture were not associated with late displacement.

Conclusions: A spectrum of injury severity and stability exists in the LC-2 pattern. Nonoperative treatment of LC-2 injuries with low initial deformity and crescent fracture displacement results in minimal subsequent displacement.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Key Words: Pelvic fracture; Pelvic ring injury; LC-2; Deformity; Nonoperative treatment

Manuscript

Introduction

The Young-Burgess Lateral Compression Type II (LC-2; OTA/AO 61B2.2) injury is usally considered an unstable pelvic ring injury. In the LC-2 pattern, a posterior iliac “crescent” fracture, with variable disruption of the sacroiliac (SI) joint, allows internal rotation of the hemipelvis through the anterior ring injury. The crescent fragment maintains its normal anatomic relationship to the sacrum through attachments to the posterior SI ligaments, while the anterior iliac segment displaces from the crescent fragment. However, uninjured ligamentous and muscular tissues of the pelvic floor may provide some limitation to displacement of the hemipelvis.

LC-2 pelvic ring injuries encompass a spectrum of injuries depending on the magnitude and exact vector of force applied at the time of injury. Variation is seen in the size of the crescent fragment, the orientation and initial displacement of the fracture, the amount of injury to the remaining ligaments and in the anterior ring injury.

Operative treatment of displaced LC-2 injuries is often recommended based on perceived pelvic ring instability. Indications range from injuries with excessive deformity, to those unstable on examination under anesthesia, to those with any displacement, to a general recommendation

for surgery because of potential instabilility[1–4]. For injuries with little initial deformity or displacement, however, there is no consensus for or against operative management.

Nonoperative treatment of pelvic ring injuries is considered successful when the pelvic ring heals without excessive deformity. There is a subset of minimally displaced LC-2 injuries that may have acceptable outcomes with nonoperative treatment if further displacement does not occur. Currently, the radiographic predictors of instability and late displacement in the LC-2 injury that may help guide conservative management are unknown.

The purposes of this study were to report on the radiographic outcomes of nonoperative treatment of LC-2 injuries and to identify predictors of late displacement. Our hypothesis was that minimally displaced LC-2 injuries are amenable to nonoperative treatment with a low rate of late displacement.

Patients and Methods

Subjects

The electronic medical records at two Level 1 trauma centers were searched for patients ≥18 years old with pelvic fractures treated between January 1, 2016 and December 31, 2018. Initial radiographs and CT scans were reviewed to classify the injuries according to the Young-Burgess classification.

The LC-2 injury was defined as a pelvic ring injury caused by a lateral compression mechanism with a posterior crescent fracture or posterior sacroiliac fracture-dislocation[4–6].

Injuries with flexion or extension deformities of the pelvis were included, as these are recognized components of the deformity seen in LC injuries[7–9].

Injuries with obvious cranial or caudal translation of the hemipelvis were considered to represent Vertical Shear or combined mechanism injuries and were excluded. Patients with pathologic fractures, contralateral sacroiliac injury (LC-3) or combined pelvic ring and acetabular fractures were also excluded.

Isolated pelvic ring trauma and polytrauma patients were included.

Demographic and Clinical Data

Age, gender, body mass index (BMI), mechanism of injury, Injury Severity Score (ISS), treatment type (operative or nonoperative) and weightbearing status were recorded from chart review.

Indications for Treatment

Fellowship-trained orthopaedic trauma surgeons at two urban level-1 trauma centers selected individual patient treatments based on preference and experience. Patients were assessed based on the treatment plan. Weightbearing status was determined by the treating surgeon while taking into account concomitant injuries.

Radiographic Review

Initial radiographs and CT were evaluated on the Picture Archiving and Communications System (PACS, IntelliSpace, Philips, Andover, MA, USA) for the presence of a posterior iliac crescent fracture, ipsilateral anterior sacroiliac (SI) displacement, sacral fractures and pubic rami fractures.

Crescent fractures were classified by the Day classification[4]. In this classification, Day Type I fractures enter the anterior third of the SI joint, Day Type II fractures enter the middle third, and Day Type III fractures enter the posterior third **(see Figure – Supplemental Digital Content 1, which illustrates the Day Classification,** http://links.lww.com/JOT/B463**).**

Crescent Fracture Displacement (CFD) was measured on axial CT as the maximum posterior cortical displacement between the crescent fragment and the iliac fragment using the PACS digital measurement tool **(Figure 1).**

Ipsilateral anterior SI displacement was recorded as present or absent. Concomitant sacral fractures were classified by the Denis classification[10]. Denis Zone I fractures are in the region of the ala, Zone II through the foramina, and Zone III through the central sacral canal region.

Pubic rami fractures were classified according to the OTA/AO classification by adding the qualifier “a” for ipsilateral fractures (OTA/AO 61B2.2a), “b” for bilateral fractures (OTA/AO 61B2.2b) or “c” for contralateral fractures (OTA/AO 61B2.2c)[11].

Measurement of Pelvic Ring Deformity

Pelvic ring deformity was quantified using the Deformity Index, which is based on the cross-measurement method of Keshishyan modified by Lefaivre[12,13]. In this method, a measurement between the inferior SI joint and the inferior aspect of the contralateral "teardrop" is made for one side (X) and the other side (Y) on the anteroposterior (AP) radiograph. The Deformity Index (DI) is then calculated as [ABSOLUTE (X-Y)/(X+Y)]. Therefore, a perfectly symmetric pelvis, where X = Y, will have a DI of 0. Higher DI represents greater deformity **(Figure 2).**

The DI has two advantages over absolute measurements. First, its use of a measurement ratio mitigates the effects of radiographic magnification differences between subjects and for repeated measurements in the same subject. Second, DI attempts to control for film obliquity by summing the two radiographic measurements in the denominator.

Since DI uses an absolute value in its calculation, it does not indicate the vector of displacement. In order to capture this information, the Simple Ratio (SR) described by Lefaivre was used. SR is calculated as X/Y, using the same cross-measurements. By convention in this series, the numerator (X) is the measurement including the teardrop ipsilateral to the crescent fracture. Therefore, SR < 1 represents an internal rotation deformity on the side of the crescent fracture, and SR >1 represents an external rotation deformity. In the LC-2 injury pattern, SR < 1 would be expected if radiographic technique was optimal.

The Inlet and Outlet Ratios were measured on their respective radiographs, as previously described[14]. By convention in this series, measurements on the side of the crescent fracture were chosen as the numerator in the Inlet and Outlet Ratios.

Radiographic outcomes of nonoperatively treated injuries

Patients included in the analysis of nonoperative treatment were ≥18 years old, had an LC-2 injury and a final outcome captured by electronic health record review. Final outcome was defined as a healed fracture or radiographic evidence of bridging callus. Initial and final radiographs were compared to assess for displacement over the treatment period. Significant displacement was defined as a 10 percentage point or greater change in any of the radiographic ratios between the initial and final radiographs. Ten percentage points was chosen because it corresponded to an approximately 1-1.5cm displacement in the average sized pelvis in this series. Although there are no validated, clinically significant thresholds for the pelvic ring deformity measurements included in this study, the choice of 1-1.5cm of displacement is consistent with previous literature describing pelvic ring instability and malunion[1,2,15–19].

The displacement group was compared to the non-displacement group to determine if there were demographic factors and/or injury characteristics that were predictive of displacement risk.

Statistical Analysis

Continuous variables were checked for normality using histograms. Descriptive statistics were reported (mean and standard deviation, medians and interquartile ranges, and counts and percentages for normally distributed continuous data, non-normally distributed continuous data, and categorical data, respectively). T-tests or Wilcoxon rank-sum tests were used for continuous

normally distributed or non-normally distributed data, respectively. Differences between patients who displaced and those who did not were determined using Fisher's exact test for categorical variables and exact Wilcoxon rank-sum tests for non-normally distributed data.

P-values less than 0.05 were considered statistically significant. SAS version 9.4 (SAS Institute, Inc. Cary, NC, USA) was used for all analyses.

Results

Patient Demographics

Imaging review identified a total of 95 patients with LC-2 pelvic ring injuries. One patient was excluded from analysis due to death on hospital day 2, prior to initiation of treatment, leaving 94 patients for analysis. Of these, 31 were treated operatively and 63 were treated nonoperatively.

38 of 63 patients (60%) treated nonoperatively had radiographs after 6 weeks sufficient for full radiographic review.

No patients underwent dynamic stress examination prior to initiation of nonoperative treatment, and no patients crossed over from the nonoperative to the operative group.

Median patient age was 51.5 (IQR 33-76). Fifty-three percent were male. Median BMI was 25.79 (SD=4.05). Injuries were caused by high energy mechanisms in 31 patients, a crush mechanism in 2 patients and low energy mechanisms in 5 patients. Mean ISS was 18 (IQR 12-26).

Injury Description

Radiographic review demonstrated a spectrum of injury within the LC-2 pattern.

As one of the defining features of this pattern, posterior iliac crescent fractures were present in all 38 patients. There were 12 Day Type I fractures, 15 Day Type II fractures, 8 Day Type III fractures, and 3 patients with Day Type II variant patterns as described by Calafi and Routt[20]. Median initial crescent fracture displacement (CFD) was 2mm (IQR 1-3.9). Anterior SI displacement on the side of the crescent fracture was present in 18 patients (26%).

Concomitant sacral impaction fractures were present in 31 patients (82%). Of patients with sacral fractures, the majority (77%) were incomplete Denis Zone I fractures ipsilateral to the crescent fracture. Complete sacral fractures made up 10% of concomitant sacral fractures. Contralateral sacral fractures occurred, although less commonly (7%).

All 38 patients had pubic rami fractures. Rami fractures were ipsilateral to the crescent fracture in 20 patients (54%), bilateral in 15 patients (41%) and contralateral in 2 patients (5%). Disruption of the pubic symphysis was not seen in any patients.

The patients included in this study had minimal initial pelvic ring deformity as measured by the Deformity Index, Simple Ratio, Inlet and Outlet Ratios. The median initial Deformity Index, in which higher values indicate greater deformity, was 2% (IQR 1-5%). The mean initial Simple Ratio, in which values less than 1 indicate internal rotation deformity, was 0.95 (SD=0.08). The mean initial Inlet Ratio, in which values less than 1 indicate internal rotation deformity, was 0.98 (SD=0.11). The mean initial Outlet Ratio, in which values less than 1 indicate a flexion deformity of the hemipelvis on the side of the crescent fracture, was 0.99 (SD=0.16).

Radiographic Outcomes

Deformity Index

The median final Deformity Index was 4% (IQR 2-5%), and the median change in Deformity Index over the treatment period was 1.74 percentage points (IQR 1.03-3.02). No patient had a change in Deformity Index ≥10 percentage points from initial radiograph to final radiograph, indicating that the nonoperative patients did not develop progressive deformity over the treatment period when using this method to quantify displacement **(Figure 3) (also see Figure – Supplemental Digital Content 2, which shows a second case example,** http://links.lww.com/JOT/B464**)**.

Simple, Inlet and Outlet Ratios

The median change in Simple ratio over the treatment period was 4% (IQR 2-6.9%), and no demographic or injury characteristics were associated with displacement.

The median change in Inlet Ratio was was 8.7% (IQR 3.7-13.1%), and among those patients who displaced ≥10 percentage points, there were no demographic or injury characteristics associated with displacement.

The median change in outlet ratio was 8.1% (IQR 3-17.7%), and those who displaced ≥10 percentage points had greater initial Crescent Fracture Displacement (3.25mm vs. 1.65mm, p=0.03).

An analysis was performed in order to identify demographic or injury characteristics that were associated with displacement on the Simple, Inlet or Outlet ratios. A "displacement" group (n=21) was formed consisting of patients who displaced ≥10 percentage points on any one of the Simple, Inlet or Outlet Ratios, and this was compared to a "non-displacement" group (n=17) consisting of patients who did not displace on any of the ratios. There were no differences in age (median 59 vs. 41, p=0.09), Body Mass Index (median 26.31 vs. 24.17, p=0.48), mechanism of injury (76% high energy vs. 88% high energy, p=0.67) or ISS (median 18 vs. 19, p=0.64). A higher proportion of patients in the displacement group were female (62% vs. 29%, p=0.046).

In this series of minimally displaced LC-2 injuries, we were not able to identify an association between the following injury characteristics and late displacement on the Simple, Inlet or Outlet Ratios: initial crescent fracture displacement, Day classification, concomitant sacral fractures, or anterior ring injury pattern. Median initial crescent fracture displacement (CFD) was 2.3mm (IQR 2-4) in the displacement group and 2.0mm (IQR 1-3.1) in the non-displacement group (p=0.31). Day Type did not differ between the displacement and non-displacement groups (p=0.53). Concomitant sacral fractures were present in 81% in the displacement group and 82% in the non-displacement group (p=1.0). Complete sacral fractures were not associated with displacement (6% of displacement group vs. 21% of non-displacement group, p=0.32).

Anterior ring injuries were similar between the groups. As compared to unilateral (ipsilateral or contralateral) pubic rami fractures, bilateral pubic rami fractures (47% of the non-displacement group and 35% of the displacement group) were not associated with displacement (p=0.46). Anterior SI displacement was observed at a low rate in both groups and was not associated with displacement (p=1.0).

Weightbearing status was recorded for 36 of the 38 patients in the analysis. Four patients, all in the non-displacement group, were allowed to weightbear immediately on the leg ipsilateral to the crescent fracture. Thirty two patients were treated with restricted weightbearing, with mean time to full weightbearing of 2.2 months (SD=0.69). Because no patients in the displacement group were allowed to weightbear immediately, immediate weightbearing was not associated with displacement.

Discussion

Nonoperative treatment of select LC-2 injuries, with median crescent fracture displacement of 2mm and low radiographic deformity, resulted in minimal subsequent displacement. The Deformity Index was used as the primary measurement to quantify initial and final pelvic ring displacement because this measurement best controls for radiographic technique differences such as magnification and film obliquity. A change in Deformity Index ≥10 percentage points, chosen to represent 1-1.5cm of displacement in the average pelvis size in this study, did not occur in any patients between initial and final radiographs.

Considerable variation in injury characteristics was identified, similar to that seen in other lateral compression mechanism injuries[21]. Crescent fracture subtypes appeared in similar frequency to previous studies[4,22,23]. Concomitant sacral compression fractures were seen in 82%, and 10% of these were complete. Anterior SI disruption was noted in 26%. Rami fractures occurred in all patients and were bilateral in 41%.

Although no patients showed displacement on the Deformity Index, displacement was observed on the Simple, Inlet or Outlet ratio in some patients. This study did not identify any demographic or injury characteristics that were associated with displacement. In contrast to the findings of a study of minimally displaced LC-1 injuries, complete sacral fractures and bilateral rami fractures were not associated with late displacement in this series of minimally displaced LC-2 injuries[19].

Patient reported clinical outcomes were not available to correlate with radiographic outcomes. Severe deformity can cause nonunion, pain, leg length discrepancy, gait abnormality and sitting imbalance[1]. Residual posterior displacement has been reported to influence outcomes, with poor results seen in pure sacroiliac joint dislocations and residual posterior displacement >1cm[18]. Although the low rate of late radiographic displacement seen in this series suggests minimally displaced LCII injuries may be amenable to nonsurgical treatment, clinical outcome data to recommend nonsurgical treatment of these injuries does not exist at this time.

The links between lesser deformity and clinical outcomes are not fully established. Pastor et al. found that improved reduction quality, assessed with the cross-measurement method and Deformity Index, correlated modestly with functional outcome[25]. Mean postoperative pelvic Deformity Index was 0.041 (4.1%), similar to final Deformity Index in the present series (4%). The authors emphasized the importance of anatomic restoration of pelvic symmetry. Hoffmann et al. reviewed 119 patients with surgically treated lateral compression pelvic ring injuries, all of which had been restored within 1cm of posterior displacement, and found no difference in Short Musculoskeletal Function Assessment between those under 5mm of residual displacement and those between 5 and 10mm of residual displacement[18]. The radiographic outcomes of the

nonoperativel LC-2 injuries in this series are comparable to the radiographic outcomes in these series of operative lateral compression injuries.

A limitation of this study is the exclusion of 40% of the nonoperatively treated LC-2 injuries due to inadequate radiographs at follow up. Although some patients were lost both to radiographic and clinical follow up, many patients were followed clinically without obtaining subsequent radiographs. Analysis of demographics and initial injury characteristics showed no differences between the LC-2 injuries included and those excluded due to inadequate radiographs at follow up.

Conclusion

A spectrum of injury severity and stability exists in the LC-2 pattern. Nonoperative treatment of LC-2 injuries with low initial deformity and crescent fracture displacement results in minimal subsequent displacement.

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Legend of Supplemental Digital Content

Figure – Supplemental Digital Content 1, which illustrates the Day Classification of crescent fractures

Figure – Supplemental Digital Content 2, which shows a case example of a nonoperatively treated LC-2 injury

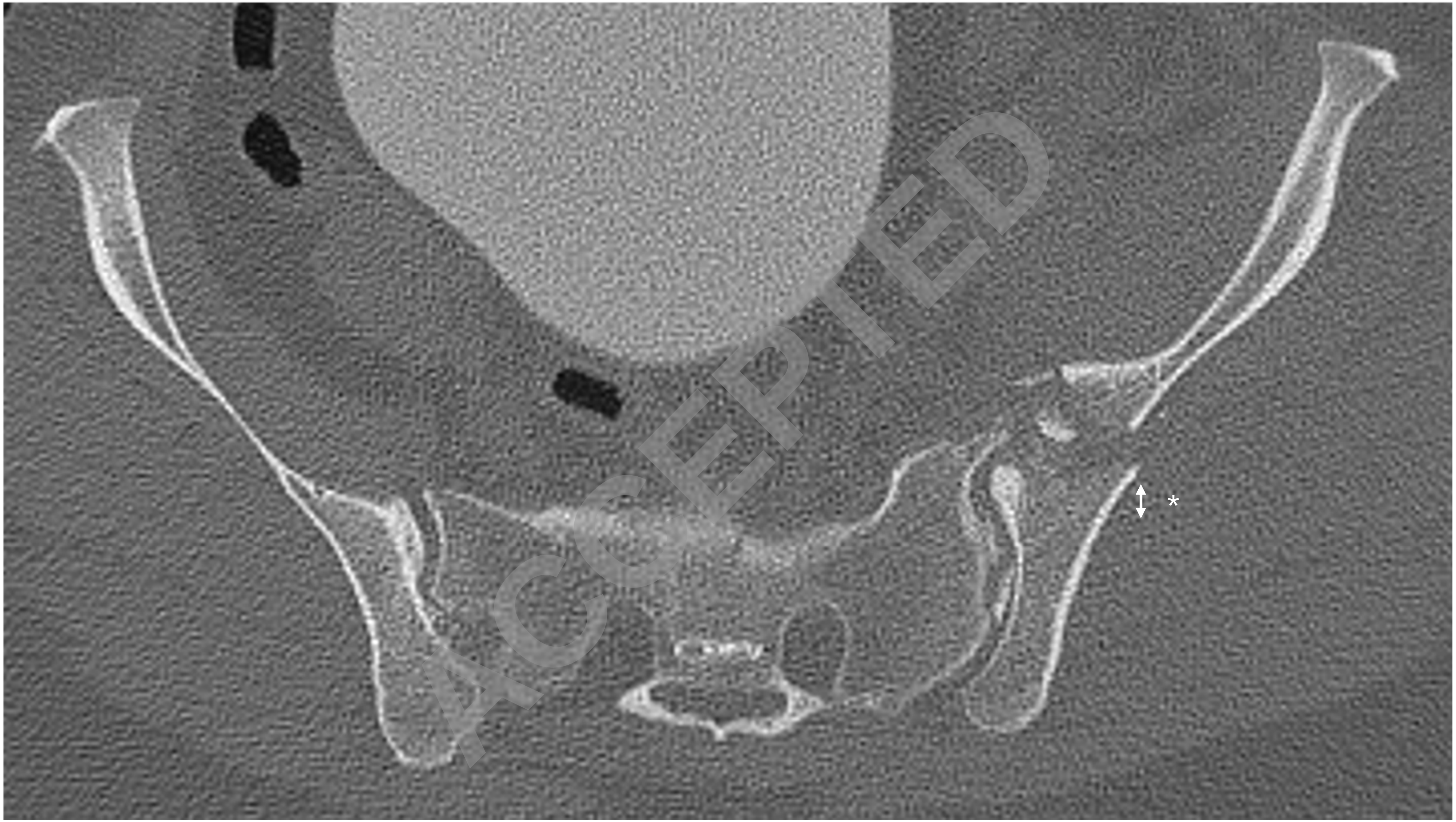


Figure 1. Initial crescent fracture displacement (CFD) was measured between the posterior cortices of the crescent fragment and iliac fragment at the point of maximal displacement on axial CT cuts (asterisk).

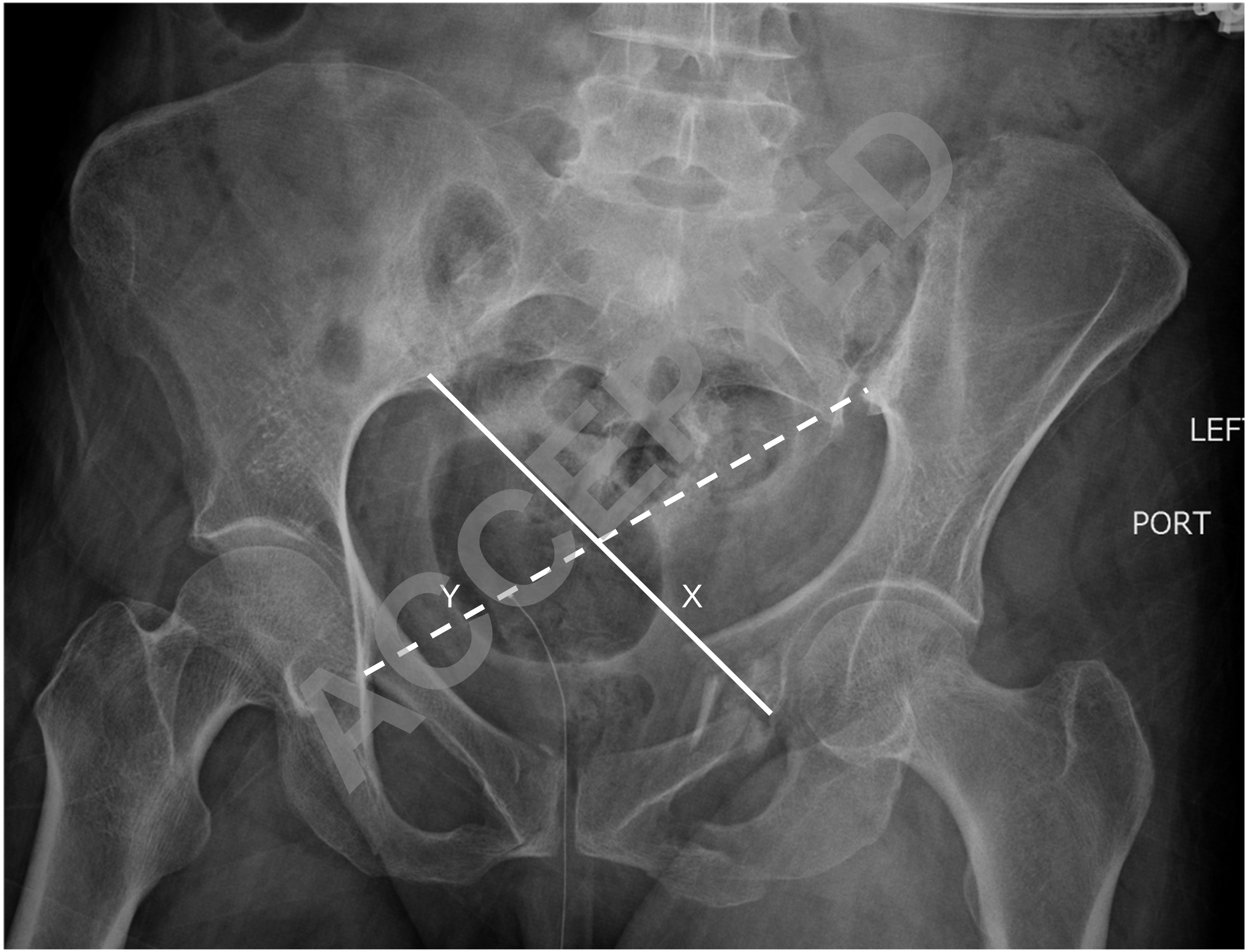

LEFT
PORT
Y
X

Figure 2. Legend

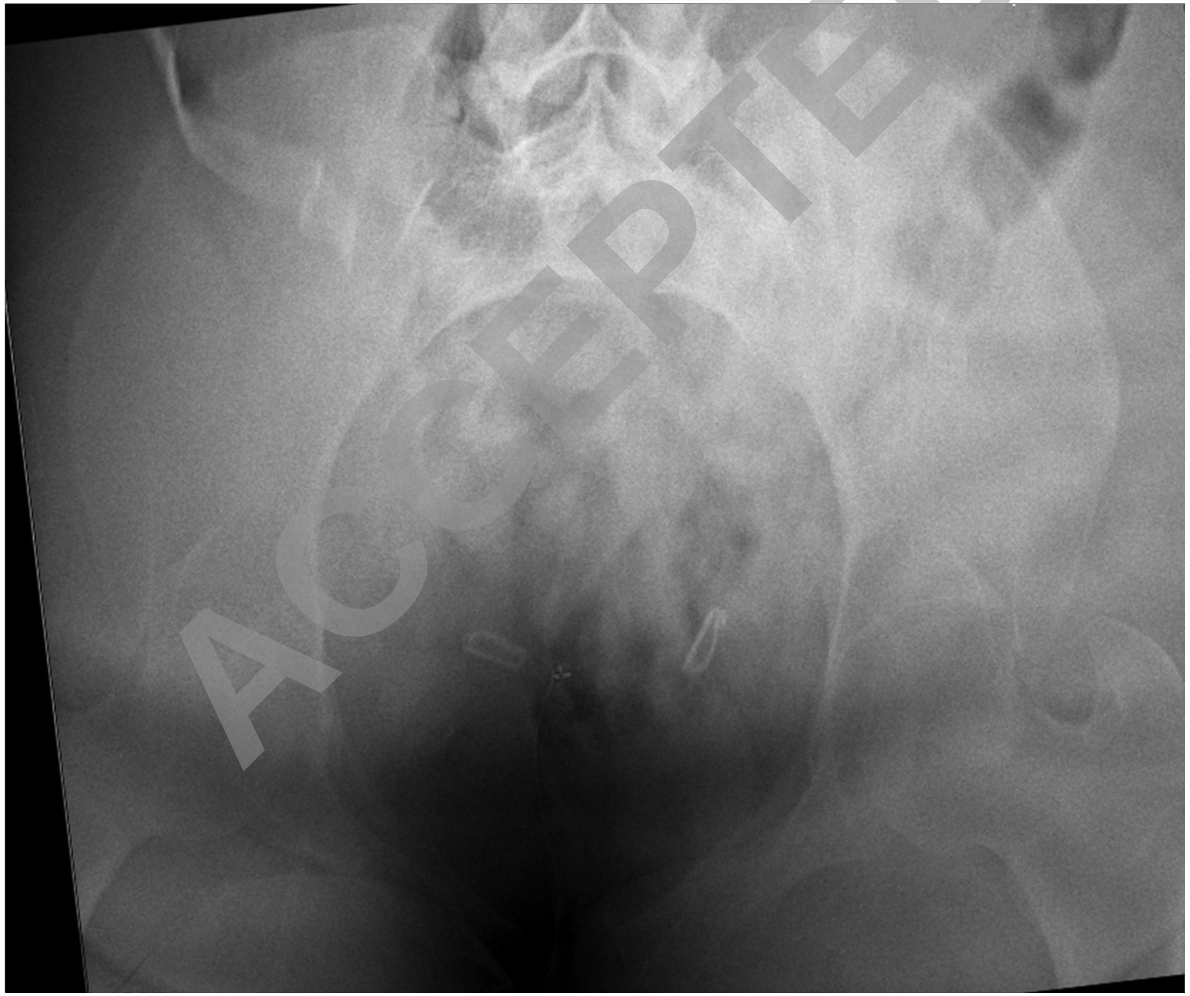
- The cross-measurement method of Keshishyan modified for adults by Lefaivre uses measurements between the SI joint and the inferior aspect of the contralateral teardrop.
- Deformity Index [ABSOLUTE (X - Y)/(X + Y)] is a measure of pelvic ring deformity that attempts to control for radiographic magnification and film obliquity.
- This patient was treated operatively.

Figure 3

Initial radiographs (A,B,C) and CT (D) of a 29 year old female injured in a high speed motor vehicle crash show an LC-2 (OTA/AO 61B2.2c) pelvic ring injury with a Day Type II crescent fracture with 2.9mm displacement, ipsilateral incomplete Denis I sacral fracture, and contralateral superior pubic ramus fracture. After nonoperative treatment, 3-month follow up radiographs (E,F,G) show healing without progressive deformity.

A

B

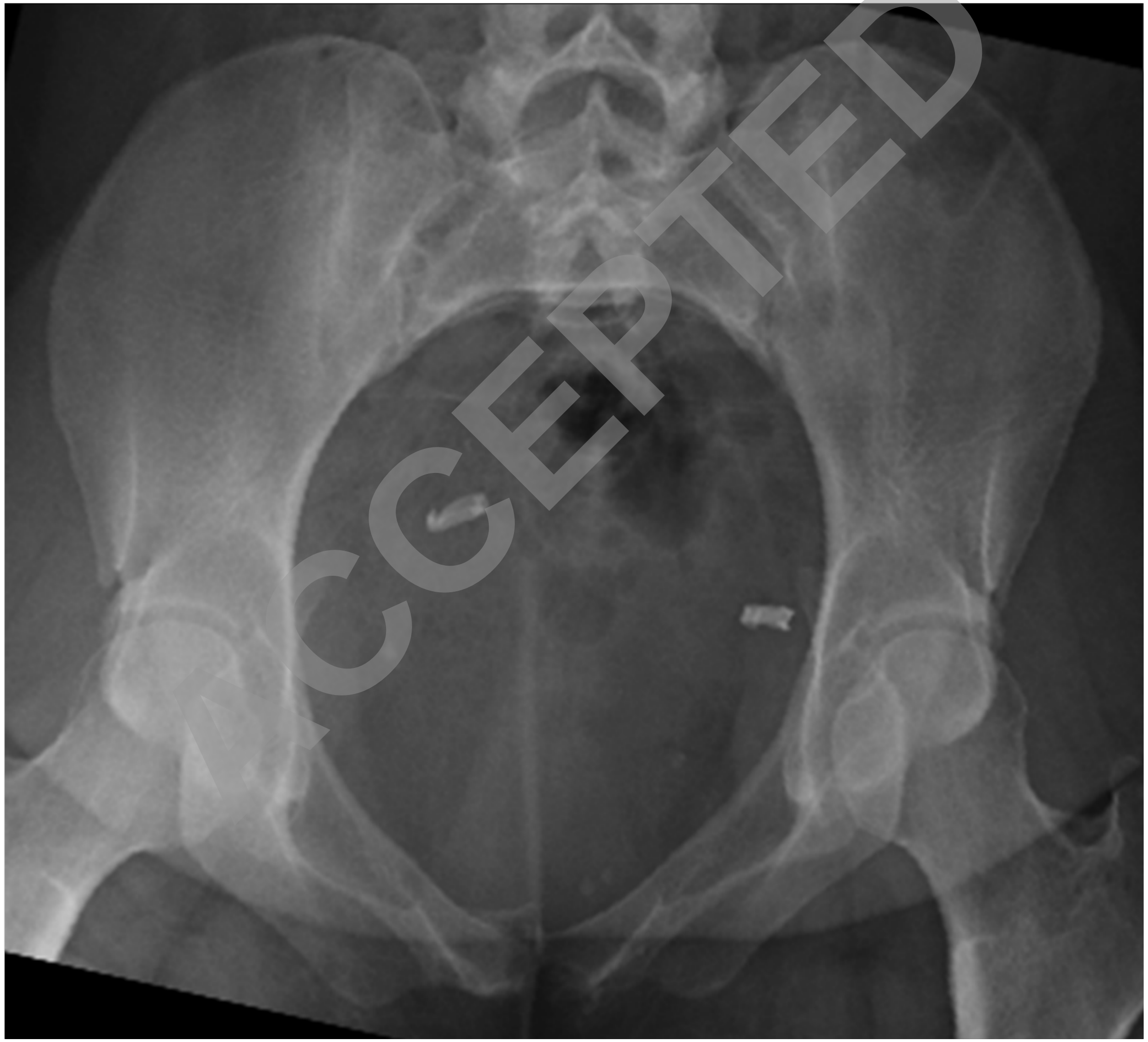


C

D

E

F



G