Preliminary Trauma Radiographs Misrepresent Pubic Diastasis Injuries

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abstract

The goal of this study was to evaluate the role of portable primary trauma survey radiographs in the evaluation and management of anteroposterior (AP) compression pelvic injuries. A retrospective analysis was conducted at a level I academic trauma center. Twenty-seven adults with AP compressive class pelvic ring injuries who received both portable pelvic radiographs and pelvic computed tomography (CT) imaging in an unbound pelvic state were included. Three orthopedic surgeons performed independent measurements of diastasis on portable pelvic radiographs and coronal pelvic CT reconstructions. Measurement techniques were standardized among observers and were repeated after 8 weeks to assess intraobserver reliability. Nonoperative vs operative treatments were correlated with the initial magnitude of pelvic injury on CT and portable radiographic images. Independent measurements of diastasis on both radiographs and CT scans showed excellent intraobserver reliability (average correlation coefficient, 0.986) and interobserver reliability (average correlation coefficient, 0.979). Compared with diastasis measurements on CT scans, portable pelvic radiographs overestimated diastasis by an average of 49%, or 12.6 mm (P<.0001; 95% confidence interval, 9.6-15.6). Portable pelvic films were less precise than standard pelvic radiographs in measuring the size of femoral head controls (R²=0.919 vs 0.759; P=.004). In 12 of the 27 patients evaluated, radiographic indications for operative pelvic fixation were met by portable radiographs but not CT scans, and 11 of these patients ultimately underwent operative fixation. Portable AP pelvic radiographs may distort and exaggerate pelvic bony injuries, especially those involving anterior pelvic structures. Surgeons should use caution when making management decisions based on preliminary portable pelvic radiographs. [Orthopedics. 2015; 38(3):e229-e233.]
Diastasis of the pubic symphysis, known informally as an “open book” pelvis, is a ligamentous dissociation of the pubic symphysial joint. Pubic diastasis injuries are accompanied by sequential disruption of the pubic symphysis, the sacrospinous and sacrotuberous ligaments, and finally the sacroiliac complex. This severe injury pattern most commonly results from high-energy anteroposterior (AP) compressive and external rotatory forces to the pelvis. The magnitude of symphysial separation on radiographic imaging is used to classify these injuries and dictate both prognosis and treatment. More than 25 mm diastasis on plain radiograph is a widely accepted indication for operative fixation of the pubic symphysis. This distance is considered the threshold above which sacroiliac ligamentous rupture occurs, thus differentiating a stable pelvis from a rotationally unstable pelvis. Generally, stable AP pelvic injuries are treated nonoperatively, whereas unstable pelvic injuries are treated with open reduction and internal fixation (ORIF) of the pubic symphysis and sometimes the sacroiliac joint.

After high-energy injury, pubic diastasis is often first recognized on AP pelvic radiographs, which are recommended adjuncts to the Advanced Trauma Life Support primary survey for patients with suspected pelvic injuries. In the acute setting, portable pelvic radiographs are acquired rapidly, often with nonstandard distance and/or nonorthogonal alignment among the radiographic source, receptor, and patient. Although the authors acknowledge the importance of trauma radiographs for early recognition and intervention in potentially life-threatening pelvic injuries, they hypothesize that such provisional imaging techniques distort and exaggerate pelvic injuries compared with patient-matched computed tomography (CT) images. The authors propose that portable pelvic radiographs are inferior to standardized pelvic radiographs from radiographic suites when measuring static structures.

**MATERIALS AND METHODS**

For this retrospective study, the authors identified 36 adults with traumatic pubic diastasis from a database of patients with orthopedic injuries who were treated at their level I trauma center between January 2008 and December 2012. Approval for the retrospective radiograph and chart analysis was granted by the authors’ institutional review board. Initially, 2 patients were excluded because they had CT pelvic imaging but did not have initial pelvic radiographs and were excluded because they had pelvic radiographs but not pelvic CT scans. An additional 4 patients were excluded because a pelvic compression device had been applied in the interval between radiograph and CT scan. Thus, 27 patients were analyzed who had undergone both portable pelvic radiographs and pelvic CT imaging without interval binder intervention. Figure 1 outlines the patient inclusion and exclusion processes.

Three orthopedic surgeons (T.T.R., J.P.T., T.P.D.) performed independent measurements of diastasis on AP pelvic radiographs and coronal pelvic CT reconstructions. Measurements were performed a second time by the same physicians after an 8-week interval to assess intraobserver reliability. Techniques were standardized among observers. Diastasis distance was measured on AP radiographs and CT coronal reconstructions “sliced” between points located at the vertical center and the medial-most edge of each symphysial bony surface.

Finally, diameters of right-sided femoral heads were measured on initial portable pelvic radiographs and standardized pelvic radiographs acquired in radiographic suites (in 1 case, a left-sided femoral head was used as a control in a patient with a concomitant right femoral head fracture). Follow-up pelvic radiographs acquired in radiographic suites were obtained with standard AP pelvis techniques. A radiographic source was centered midline and halfway between the anterior superior iliac spine and the pubic symphysis in the sagittal plane. The radiographic source and an orthogonally aligned receptor were 40 inches apart. Portable pelvic radiographs included in this study were acquired with an FCR GO portable radiograph machine (FUJIFILM Medical Systems USA, Inc, Stamford, Connecticut), and standardized pelvic films were acquired with a Philips Optimus Diagnostic H BuckyDiagnost machine (Koninklijke Philips Electronics NV, Eindhoven, The Netherlands). The CT scans were obtained with a General Electric VCT 64 Slice Scanner (General Electric Healthcare, Port Washington, New York). The CT reconstructions were sliced between 0.98 mm and 5 mm and were assumed to be accurate within ±0.49 mm.
and ±1.25 mm, respectively.\textsuperscript{8} Measurements were made with iSite PACS version 3.6.134.0 (Philips Healthcare Informatics, Foster City, California). Statistical analysis was performed with paired Student’s \(t\) tests and least-squares linear modeling.

RESULTS

Independent measurements of diastasis on both radiographs and CT scans showed excellent intraobserver reliability (average correlation coefficient, 0.986) and interobserver reliability (average correlation coefficient, 0.979).

Average patient age was 47.6 years (range, 18-72 years). Of the patients, 21 were men and 6 were women. All patients had high-energy pelvic injuries, mostly as a result of motor vehicle accidents or falls from greater than 12 feet. Compared with reconstructed coronal images from spiral CT scans, portable pelvic radiographs overestimated diastasis by an average of 12.6 mm (\(P<.0001\); 95% confidence interval, 9.6-15.6). Scatter plots (Figure 2) were used to compare radiographic vs CT measurements of diastasis. A best-fit line with a zero intercept showed that portable radiographs exaggerated deformities by an average of 48.8%.

Of the 27 patients who did not receive a pelvic binder between radiographs and CT scan, 12 met the indications for surgery based on plain radiographs but not on CT. In this group, average radiographic diastasis was 31.5±5.2 mm, whereas average CT diastasis was 20.6±3.5 mm (\(P<.001\)). Of these 12 patients, 11 underwent subsequent ORIF; 6 underwent ORIF of the pubic symphysis and 5 underwent ORIF of both the pubic symphysis and the sacroiliac joint. The decision to provide additional sacroiliac fixation was based on the findings of intraoperative stress examination and imaging. In this small sample, the finding of sacroiliac instability did not significantly correlate with the magnitude of diastasis. One patient in this group was successfully treated nonoperatively in a removal binder for 8 weeks (Figure 3).

Right-sided femoral head controls measured an average of 57.5±6.8 mm (±1 SD) on initial portable radiographs (n=27) and measured an average of 58.8±6.0 mm (\(P=.034\)) on available follow-up standardized films (n=22). Average CT femoral head diameter was 48.0±4.3 mm. On initial radiographs, the ratio of diastasis to femoral head diameter was an average of 0.61±0.29; on CT scan, the ratio of diastasis to femoral head diameter was an average of 1.19±0.09 (\(P<.001\)).

Figure 4 shows a plot of femoral head diameter on initial portable radiographs of (y-axis) vs CT scans (x-axis) in red and femoral head diameter on standardized radiographs (y-axis) vs CT scans (x-axis) in blue. Standardized follow-up radiographs had a significantly greater coefficient of determination (\(R^2\)) than portable radiographs, 0.907 vs 0.736 (\(P=.048\)).

On average, CT scans followed initial radiographic evaluation by 48±26 minutes (n=19); however, 8 patients did not undergo initial radiographs and thus injuries were diagnosed on CT chest-abdomen-pelvis imaging. Subsequent pelvic portable radiographs were acquired in these cases.

DISCUSSION

According to Advanced Trauma Life Support guidelines from the American College of Surgeons, AP pelvic radiography is a recommended adjunct to the primary survey when pelvic injury is suspected.\textsuperscript{5,9} In the acute setting, portable pelvic radiographs may alert health care providers to severe pelvic injuries and allow early intervention for life- or limb-
threatening injuries, such as pubic diastasis or hip dislocation.\textsuperscript{10} Recent findings, however, challenged the sensitivity of plain radiographs in detecting fractures, citing elevated rates of false-negative interpretation or underassessment of the true extent of injuries.\textsuperscript{1,11} At their level I trauma center, the authors found that portable pelvic radiographs acquired during the primary trauma survey did not underassess but rather exaggerated the severity of anterior pubic diastasis injuries. Portable radiographs overestimated diastasis by an average of 49\% compared with CT imaging. To the best of the authors’ knowledge, few studies have attempted to quantify the magnitude of radiographic magnification in pelvic trauma. One exception is a study by Suzuki et al\textsuperscript{1} that compared dynamic stress radiographs with static imaging to evaluate pubic diastasis injuries. On average, pelvic diastasis was 29\% greater on pelvic radiographs than on CT scans.\textsuperscript{1} The clinical relevance of these findings is limited, however, because results were neither statically quantified nor qualified. Additionally, the authors did not indicate whether the pelvic images were portable or standardized radiographs.

Magnification distortion of pelvic radiographs is a well-recognized phenomenon, perhaps most commonly encountered by orthopedic surgeons in the preoperative templating process for hip arthroplasty. Many current techniques assume a magnification factor of approximately 115\%, or 15\% larger than reality, for the femoral head and acetabulum. One study reported as much as 127\% magnification.\textsuperscript{12}

As a relatively anterior structure, the pubic symphysis is subject to even greater magnification on AP-oriented radiographs. By taking the ratio of femoral head diameter to pubic diastasis distance on portable radiographs and comparing it with the unchanged femoral head-to-diastasis ratio from CT scans, the authors determined that the difference in diastasis is as much as 35\% greater, even when accounting for a standard amount of magnification \textit{(P<.001)}. Therefore, all measured structures were magnified on plain radiographs and those located more anteriorly were especially exaggerated in size.

In addition to potential magnification errors, portable radiographs were less precise than standardized pelvic radiographs in measuring constant control structures such as femoral heads. Femoral head diameter was chosen as a control because its central location in the sagittal plane is less prone to magnification error and because its spheric shape remains essentially constant despite inconsistencies in thigh position and rotation. Figure 4 shows the plot of measurements of femoral head diameter on portable radiographs (red) vs standard films (blue) vs actual coronal CT scan measurements. Significantly greater variation was noted in portable radiographs compared with standard pelvic radiographs. This variation likely occurs because portable films are often acquired with inconsistent distances and alignment among the source, plate, and patient. Although several studies reported the insensitivity and inaccuracy of plain radiographs in diagnosing pelvic injuries, the authors are unaware of previous reports that formally compared both portable pelvic radiographs and standard pelvic radiographs with CT scans. This study is unique in qualifying and quantifying the differences between portable trauma radiographs and standardized pelvic radiographs acquired in radiographic suites.

The clinical significance of recognizing the discrepancy between the magnitude of diastasis on radiographs vs CT scans relates to the relationship between diastasis and true pelvic instability. In 1980, Pennal et al\textsuperscript{13} attributed diastasis of 25 mm or greater on either plain AP or inlet-outlet radiographs to a “significant degree of separation at 1 or both sacroiliac joints.” The Tile and Young-Burgess classifications of pelvic injuries more commonly used today are based on the same plain radiograph-based para-

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**Figure 5:** Preliminary trauma anteroposterior pelvic radiograph of a 20-year-old man with pubic diastasis measuring 29.6 mm (A). Coronal computed tomography reconstruction of the same patient measuring 14.8 mm (B). Axial reconstruction of the injury (C). Anteroposterior scout computed tomography scan reconstruction showing a nonmagnified, nondistorted anteroposterior view of the pelvis (D). Computed tomography images were obtained within 1 hour of the initial radiograph. Note that the patient has yet to have pelvic binding applied in all of these images.
meters. Recently, however, the association between stable and unstable AP compressive injuries and 25 mm pubic diastasis has been disputed. Little evidence supports the idea that 25 mm diastasis differentiates Young-Burgess AP compressive type I injuries from AP compressive type II injuries (ie, intact vs disrupted anterior sacroiliac elements). Cadaver-based studies suggest that true posterior ligamentous disruption is more likely to occur with 45 mm diastasis, as measured by 3-dimensional motion capture devices and standardized marker-calibrated radiographs. Although the correlation between diastasis and posterior sacroiliac injury is beyond the scope of this study, the theoretical basis for operative pelvic intervention hinges almost exclusively on the notion that 25 mm diastasis itself is an indication for ORIF. Almost half of the patients in this study met the surgical criteria on plain radiograph, but not on CT scan (12 of 27). In this group, average diastasis on portable radiograph was 31.5 mm, whereas average diastasis on CT scan was 20.6 mm (P<.001). Despite this dilemma, 11 of 12 patients underwent operative fixation: 6 underwent ORIF of the pubic symphysis and 5 underwent ORIF of both the pubic symphysis and sacroiliac joint. Intraoperative fluoroscopic evaluation of posterior pelvic stability was used as the primary factor determining adjunctive iliosacral fixation. Figures 5A-C shows an example of “conflicted” indications in a 20-year-old man who had a motorcycle collision. Pubic diastasis measures 29.6 mm on portable AP radiograph (Figure 5A), but only 14.8 mm on coronal, axial, and scout CT reconstructions (Figures 5B-D). Ultimately, the patient underwent ORIF of the pubic symphysis alone (Figure 5C); the sacroiliac joints were stable on intraoperative stress testing.

Appreciating the potential discrepancies between pubic diastasis measured on portable plain radiographs vs CT scans poses new challenges for patient management. Although CT imaging is considerably more accurate in gauging distances, the original studies and standard-of-practice recommendations were developed with plain radiographic techniques similar to those challenged in this article. Further, emerging evidence questions the indications for operative vs nonoperative treatment. Given the increased availability and use of pelvic CT scanning in acute trauma, there is a need to clarify the role of CT in the classification and management of pelvic ring injuries.

Limitations

Limitations of this study include the fact that patients were compiled from a database of patients treated by the orthopedic service at a single level I trauma center. Patients who died during resuscitation efforts were not followed by the service and thus were not included in this study. Additionally, the CT scanner used in the study had a slightly concave bed that has been suggested to influence diastasis on CT scan vs radiographs, which are typically obtained when the patient is on a flat surface. Although this factor may play a minor confounding role, the authors noted that many patients underwent CT scan obtained on a flat backboard, thus minimizing the effect.

Conclusion

As adjuncts to the Advanced Trauma Life Support primary trauma survey, portable pelvic radiographs allow for early identification of potentially life-threatening injuries. Although essential in guiding early interventions such as pelvic binding, the fast and provisional nature of portable trauma radiographs may lead to imaging inconsistencies that may exaggerate the magnitude of pubic diastasis injuries compared with CT scan. The findings suggest that portable pelvic radiographs in the trauma setting are significantly less precise in measuring constant structures, such as femoral heads, than standardized pelvic radiographs acquired under controlled conditions in radiographic suites. Given the increased availability and use of pelvic CT scanning in acute trauma, the role of CT scans in the classification and management of pelvic ring injuries should be more clearly defined.

References