Analysis of Initial Injury Radiographs of Occult Femoral Neck Fractures in Elderly Patients: A Pilot Study

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Abstract

Diagnosis of occult hip fractures by initial radiographs remains challenging in the emergency department. Previously, the gold standard for accurate diagnosis of occult hip fractures was magnetic resonance imaging. This study used initial radiographs obtained in the emergency department to evaluate specific signs and measurements as diagnostic references for occult femoral neck fractures in elderly patients.

Initial negative radiographs were reviewed for 2 groups of patients: a group with occult femoral neck fractures (n=16) and a group without fractures (n=32). Reviews of initial radiographs and all imaging studies were performed by a senior orthopedist (C-C.C.) and a radiologist (H-T.W.). Diagnostic signs included lateral, medial, anterior, and posterior signs; measurements included elevation of the fat pad and external rotation of the femur. The prevalence of occult femoral neck fracture was 3.3%. Initial radiographs of occult femoral neck fractures were not routinely negative; 14 (87.5%) of 16 patients with fractures had at least 1 radiographic sign. Using the positive lateral or posterior sign as the diagnostic reference, the sensitivity was 0.875 and the specificity was 0.906. When elevation of the fat pad was ≥1.5 mm, the sensitivity was 0.867 and the specificity was 0.857 for the diagnosis of occult femoral neck fracture.

The lateral and posterior signs and elevation of the fat pad ≥1.5 mm on initial radiographs are recommended as diagnostic references for occult femoral neck fracture. These references are clearly defined and may offer important information for all clinicians and radiologists in the emergency department.

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Figure: Anteroposterior radiograph of an 81-year-old woman in the occult femoral neck fracture group showing a lateral sign (arrow) with a zigzag pattern of the lateral cortex at the subcapital femur.
Surgery is currently the treatment of choice for most osteoporotic hip fractures. Delays in hospitalization and surgical treatment of acute hip fractures may increase the length of hospital stay, morbidity, and mortality. Early and prompt diagnosis of hip fracture is mandatory before proper surgical repair is performed. However, diagnosis of occult hip fractures in elderly patients in the emergency department constitutes a considerable challenge for orthopedists and radiologists.

When initial radiographs yield negative or equivocal findings, other imaging approaches are recommended for early and accurate diagnosis of clinically suspected occult hip fractures in elderly patients. Helland et al. recommended further radiographic evaluation by viewing various internal rotations of the affected hip. Using sonography as a screening tool for occult hip fractures, Safran et al. reported a sensitivity of 100% and a specificity of 65%. By contrast, less evidence is available to support the use of computed tomography for early diagnosis. Currently, magnetic resonance imaging (MRI) is the imaging technique of choice for the detection of occult hip fractures. However, the cost and availability of MRI are major drawbacks to the use of this technique. Many community hospitals treating traumatic hip pain in elderly patients have limited access to MRI.

To date, studies that specifically address the diagnostic value of initial radiographs of occult femoral neck fractures in elderly patients have not been described. The purpose of the current study was to examine the hypothesis that thorough examination of initial radiographs of occult femoral neck fractures in elderly patients is capable of providing crucial early diagnostic information. In this pilot study to investigate and uncover subtle findings on radiographs of occult femoral neck fractures, a senior orthopedist (C-C.C.) and a radiologist (H-T.W.) reviewed all image studies to define possible radiographic signs and measurements.

**Materials and Methods**

This study was approved by the Institutional Review Board. A database search for emergency department duties of a senior orthopedist (C-C.C.) between January 2000 and December 2010 was performed. A total of 527 patients older than 50 years who had visited the emergency department for a painful hip after a low-energy fall, and for whom initial radiographic findings were negative, were included. Hospital records of all patients were retrospectively reviewed, and telephone interviews were conducted if follow-up information was inadequate. Inclusion criteria for occult femoral neck fractures were negative injury radiographs of the hip as diagnosed by a clinician and follow-up imaging studies performed at an outpatient clinic revealing evident fractures of the femoral neck. Radiographic reports of injuries judged to be positive by radiologists were excluded. Among the 527 patients, 16 patients met the criteria of occult femoral neck fracture, 8 were judged to have other occult hip fractures, 3 were diagnosed solely by radiologists at the emergency department, 38 were lost to follow-up, and 462 were truly negative. After excluding the 38 lost to follow-up and the 3 diagnosed solely by radiologists at the emergency department, 486 patients had negative initial radiographs diagnosed by clinicians and radiologists with definitive follow-up results. The occult femoral neck fracture group comprised 16 patients. Patients in the no-fracture group, comprising 32 patients, were randomly selected from the remaining 462 negative patients.

The evaluators included the primary author (C-C.C.) and a radiologist (H-T.W.). Together, these evaluators reviewed the imaging studies of both groups in an unblinded fashion. Each of the evaluators had at least 15 years of experience as a specialist. For each patient in the occult femoral neck fracture group, follow-up radiographs and other available imaging studies showing evident fractures were initially evaluated for exact fracture line, pattern, and location. Anteroposterior (AP) and lateral radiographs then underwent several cycles of examination and comparison with follow-up imaging studies until consensus was reached regarding the findings from the initial injury radiographs. Close attention was paid to comparisons of the bilateral hips for all AP radiographs. All possible diagnostic signs and measurements of occult femoral neck fracture were proposed and defined. The absence or presence of these signs was recorded, and measurements were made for the occult femoral neck fracture group. Injury radiographs for the normal group were then examined for the absence or presence of these signs and measurements using identical procedures.

All radiographs and follow-up imaging studies involved digital images displayed on the Picture Archiving and Communication System (PACS) with adjustable brightness, contrast, and magnification to the best resolution for interpretation and measurement. All measurements performed on the radiographs were conducted with the built-in measuring tools of the PACS.

**Radiographic Signs**

*Lateral Sign.* This sign, defined as any disruption of the lateral cortex at the subcapital femur on AP radiographs, may present as a small stepping, cracking, zigzag irregularity or as a thin sclerotic line (Figure 1).

*Medial Sign.* This sign, defined as any disruption of the medial cortex at the subcapital femur on AP radiographs, may present as an irregularly broken line, rarefaction, or an unsMOOTH transition of the inferior border from the femoral neck to the head (Figure 2).

*Anterior Sign.* This sign was defined as any disruption of the anterior cortex at the subcapital femur on lateral radiographs. Presentation often involved the presence of double rims of the cortex above the greater trochanter (Figure 3).

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*Anterior Sign.* This sign was defined as any disruption of the anterior cortex at the subcapital femur on lateral radiographs. Presentation often involved the presence of double rims of the cortex above the greater trochanter (Figure 3).
Posterior Sign. This sign, defined as any disruption of the posterior cortex at the subcapital femur on lateral radiographs, may be seen as a small stepping, mild displacement, or loss of circularity of the femoral head (Figure 4).

Radiographic Measurements

Elevation of the Fat Pad. On AP radiographs, the fat pad outside the joint capsule of the hip could be identified as a low-density line from the supra-acetabular ilium (below the anteroinferior iliac spine) to the medial border of the greater trochanter. Capsular distension was defined as the length of the perpendicular line drawn from the outermost point of the femoral head to the line of the fat pad. Elevation of the fat pad was defined as capsular distension of the affected hip minus that of the normal hip (Figure 5).

External Rotation of the Femur. On AP radiographs, the dimension of the lesser trochanter increased as external rotation of the femur increased. External rotation of the femur was measured from the medial border of the lesser trochanter to the medial cortex of the femur at the middle of the lesser trochanter. Difference of external rotation was defined as external rotation of the affected hip minus that of the normal hip (Figure 5).

Statistical Analysis

Data were analyzed with SAS version 9.2 software (SAS Institute, Cary, North Carolina). Findings were presented as mean±SD for continuous variables or as numbers with percentages for discrete variables with respect to the 2 groups. Fisher’s exact test was used to compare differences between the 2 groups for each discrete variable, and Student’s t test was used for each continuous variable. Sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratio for a positive test, likelihood ratio for a negative test, and accuracy were calculated to evaluate the radiographic signs. The cutoff value for elevation of the fat pad was determined by analysis of the receiver operating characteristic curve.

RESULTS

The prevalences of occult femoral neck fracture and total occult hip fracture on negative initial radiographs at the emergency department were 3.3% (16/46) and...
4.9% (24/486), respectively. Mean age of the occult femoral neck fracture group was 74.6 years (range, 52 to 93 years). Among the 16 patients in this group, 5 were men and 11 were women. All 16 patients had subcapital femoral neck fractures. Other imaging studies, except plain radiographs at follow-up, included MRI for 2 patients, computed tomography for 3 patients, and a bone scan for 3 patients. Mean age of the no-fracture group was 75.1 years (range, 55 to 94 years); 10 patients were men and 22 were women. No significant differences in age or sex were observed between the 2 groups.

Radiographic Signs

Positive Signs. The frequency of diagnostic signs is shown in Table 1. In the occult femoral neck fracture group, the lateral sign was positive for 10 (62.5%) patients and the posterior sign was positive for 9 (56.2%) patients. Lateral and/or posterior signs were positive for 14 (87.5%) patients. The prevalence of all radiographic signs was significantly higher in the occult femoral neck fracture group. The estimated sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratio for a positive test, likelihood ratio for a negative test, and accuracy of radiographic signs are shown in Table 2. When using a single positive lateral sign to diagnose occult femoral neck fracture, the sensitivity was 0.625, specificity was 0.969, positive predictive value was 0.331, negative predictive value was 0.987, likelihood ratio for a positive test was 19.38, likelihood ratio for a negative test was 0.387, and accuracy was 0.854. When using the positive lateral or the positive posterior sign, the sensitivity was 0.875, specificity was 0.906, positive predictive value was 0.239, negative predictive value was 0.995, likelihood ratio for a positive test was 9.24, likelihood ratio for a negative test was 0.138, and accuracy was 0.896.

False Positive Signs and Differential Diagnosis. One false positive lateral sign was observed on an AP radiograph in the no-fracture group. A sclerotic lazy-S-shape extension from the femoral head to the neck with no sharp zigzag appearance was observed, accompanied by mild osteophyte formation at a dysplastic acetabulum with bilateral involvement (Figure 6). This observation was related to a degenerative change at the hip joint.

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Occult Femoral Neck Fracture Group (n = 16)</th>
<th>No-fracture Group (n = 32)</th>
<th>Mean Difference (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>74.6 ± 11.3</td>
<td>75.1 ± 9.8</td>
<td>-0.50 (-6.83, 5.83)</td>
<td>.8740</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td>1.0000</td>
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<tr>
<td>Male</td>
<td>5 (31)</td>
<td>10 (31)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>11 (69)</td>
<td>22 (69)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiographic signs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>10 (62.5)</td>
<td>1 (3.1)</td>
<td>&lt;.0001&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>4 (25.0)</td>
<td>0 (0.0)</td>
<td>.0094&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>3 (18.7)</td>
<td>0 (0.0)</td>
<td>.0300&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>9 (56.2)</td>
<td>2 (6.3)</td>
<td>.0002&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>L/P</td>
<td>14 (87.5)</td>
<td>3 (19.4)</td>
<td>&lt;.0001&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>A/P/L/M</td>
<td>14 (87.5)</td>
<td>3 (19.4)</td>
<td>&lt;.0001&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Elevation of the fat pad, mm&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.0 ± 1.6</td>
<td>0.2 ± 1.0</td>
<td>2.83 (1.83, 3.82)</td>
<td>&lt;.0001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>External rotation of the femur, mm&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.2 ± 2.1</td>
<td>0.2 ± 1.6</td>
<td>1.97 (0.85, 3.10)</td>
<td>.0010&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Abbreviations: A/P/L/M, anterior/posterior/lateral/medial; CI, confidence interval; L/P, lateral/posterior.

<sup>a</sup>Data presented as mean ± SD.

<sup>b</sup>Student’s t test.

<sup>c</sup>Data presented as No. (%).

<sup>d</sup>Fisher’s exact test.

Figure 5: T1-weighted magnetic resonance image of the patient described in Figure 2 showing the fat pad of the hip (arrows) and a subcapital fracture in the right hip with distension of the joint capsule as compared with the left hip. Fat pad lines are indicated by arrows (A). Anteroposterior radiograph. Capsular distension was measured by the length of the dashed double arrow. Elevation of the fat pad was defined as capsular distension of the right hip minus that of left hip. The difference of external rotation of the femur (solid double arrow) was defined as the external rotation of the right femur minus that of the left femur (B).
Two false positive posterior signs were seen on lateral radiographs in the no-fracture group. They displayed as smooth and overlapping curves at the head–neck junction with intact circularity of the head and were thought to be related to normal superimposition of the head on the neck at the subcapital femur (Figure 7).

### Radiographic Measurements

**Elevation of the Fat Pad.** Elevation of the fat pad was 3.0±1.6 mm (range, 1 to 6.2 mm) in the occult femoral neck fracture group and 0.2±1.0 mm (range, −1.8 to 2.2 mm) in the no-fracture group. The difference between the 2 groups was statistically significant (P<.0001, Student’s t test). When the cutoff value for elevation of the fat pad was set at ≥1.5 mm, the sensitivity was 0.867 and the specificity was 0.857 by receiver operating characteristic curve analyses. Usually, fat pad lines were easily identified in the hips, but these lines could not be clearly defined for 2 patients in the occult femoral neck fracture group and 2 patients in the normal group.

**External Rotation of the Femur.** The difference of external rotation of the femur was 2.2±2.1 mm (range, −1.6 to 5.4 mm) in the occult femoral neck fracture group and 0.2±1.6 mm (range, −2.8 to 3.8 mm) in the no-fracture group. The difference between the 2 groups was statistically significant (P=.0010, Student’s t test).

### Discussion

In the current study, the prevalences of occult femoral neck fracture and occult hip fracture in patients with negative initial radiographs in the emergency department were 3.3% and 4.9%, respectively. Of the cases of occult hip fracture, 66.7% were identified as occult femoral neck fractures. Some radiographic signs were present in the injury radiographs of occult femoral neck fractures; 14 (87.5%) of 16 patients in the occult femoral neck fracture group had at least 1 of the 4 diagnostic signs.

Based on a retrospective analysis of 764 emergency department patients,
Dominguez et al. reported a 4.4% incidence of occult hip fracture in patients with negative initial radiographs. Cannon et al. reported a 3% to 4% prevalence of occult hip fracture in such patients. In a retrospective cohort study by Beloosesky et al., 75.9% of occult hip fracture cases involved subcapital femoral neck fractures. If left unrecognized, minimally displaced occult femoral neck fracture may progress to significant displacement; in such cases, internal fixation is likely to be inadequate, and more extensive reconstructive surgery, such as arthroplasty, with its attendant higher risks, may be required. Missed orthopedic injury is among the most frequent causes for lawsuits against emergency physicians.

The positive signs proposed in the current study were the subtle findings of impaction of the femoral head in occult femoral neck fractures. Disruption of the lateral cortex and posterior cortex in occult femoral neck fractures represented an early stage of nondisplaced fracture. Lateral and posterior signs were the results of valgus and retroversion forces at the impact of low-energy falls. As the valgus impact occurred at the hip, a compression force was generated at the lateral neck and a tension force at the medial neck. As an impacted type of fracture, the lateral neck would break before the medial neck. However, a retroversion force led to compression at the posterior neck and tension at the anterior neck. Therefore, the posterior neck would fail before the anterior neck. Consequently, different mechanisms of injury caused different presentations of radiographic signs. The lateral and posterior signs were of the compressive type with zigzag shortening, sclerosis, and loss of circularity of the head, whereas the medial and anterior signs were of the tensile type with rarefied disruption and double-rimmed displacement. In the occult femoral neck fracture group, the incidences of lateral (62.5%) and posterior (56.2%) signs were significantly higher than those of medial (25%) and anterior (18.7%) signs. Using positive lateral or positive posterior signs as diagnostic tools, the sensitivity was 0.875, specificity was 0.906, and accuracy was 0.896.

With respect to the 2 radiographic measurements, the presence of intracapsular femoral neck fractures could be more directly inferred from elevation of the fat pad. Analogous to the fat pad signs of elbow fractures, elevation of the fat pad implied capsular displacement by an intracapsular hematoma and mild shortening of the lateral femoral neck in femoral neck fractures. In contrast, the difference of external rotation of the femurs constituted indirect evidence for the presence of such fractures. In this regard, the difference of external rotation of the femurs can result from a painful hip of multiple origins, such as bony and soft tissue lesions surrounding the injured hip. Therefore, if more external rotation of the injured hip is encountered in the absence of other radiographic signs, further investigation is required to exclude all possible etiologies.

The current study is the first to define positive signs and measurements of occult femoral neck fractures in initial injury radiographs. These signs and measurements are often ignored during routine radiograph screening at the emergency department. Identification of these signs and measurements should enable clinicians and radiologists to diagnose occult femoral neck fractures at earlier stages, thereby decreasing the need for further imaging studies and resulting in more rapid treatment of affected patients. In addition, careful screening of radiographs at the emergency department should prove highly valuable at clinical sites where additional imaging techniques, such as MRI, are not available. The current study was performed by a specialist team comprising a senior orthopedist (C.-C.C.) and a radiologist (H.-T.W.). Team review of questionable radiographs is recommended to avoid misdiagnoses in clinical settings.

The current study had limitations. This was a pilot study to investigate radiographic signs and measurements that have not been studied before. Therefore, it was conducted in an unblinded manner by 2 dependent specialists to define the diagnostic criteria for occult femoral neck fracture. It does not imitate the clinical scenario where inexperienced residents might be the first to review the radiographs. Consequently, the intra- and interobserver reliability of the findings could not be verified. In addition, 2 (12.5%) patients in the occult femoral neck fracture group remained negative for all proposed signs. Except for external rotation of the femur, radiographic signs and measurements used in this study were exclusive for occult femoral neck fracture, which accounts for three-quarters of occult hip fracture cases. Absence of these signs does not exclude the possibility of occult hip fracture. Furthermore, the variable quality of radiographs obtained in the emergency department is another concern for objective interpretation and measurement of these signs. Currently, MRI is considered the most accurate imaging technique for diagnosis of all painful hip conditions. In a study by Verbeeten et al., senior radiologists using MRI identified occult hip fracture with 100% accuracy and were in complete agreement. Additional imaging approaches, such as MRI, cannot be avoided if patient symptoms persist and diagnostic uncertainty remains regarding a painful hip. Further prospective studies with more patients and with direct comparison with MRI are needed to establish the value of our results.

**Conclusion**

Initial injury radiographs of occult femoral neck fractures are not always negative. Furthermore, the use of initial radiographs to identify the signs and measurements of occult femoral neck fracture as described in this pilot study is feasible and cost-effective for clinicians and radiologists who encounter elderly patients with
painful hips in the emergency department. The lateral and posterior signs and elevation of the fat pad $\geq 1.5$ mm in initial injury radiographs are recommended as diagnostic references for occult femoral neck fracture. Future research is necessary to verify the inter- and intraobserver reliabilities concerning the radiographic signs and measurements described in the current study.

REFERENCES


