Canal-to-Diaphysis Ratio as an Osteoporosis-Related Risk Factor for Hip Fractures

NOVAK ROSTISLAV, MD, PHD; ROSENBERG NAHUM, MD; NIKOMAROV DAVID, MD; BERKOVICH YARON, MD; MAZIN SERGEY, PHD; NORMAN DORON, MD; KEREN YANIV, MD

abstract

Prevention of osteoporosis is essential to health, quality of life, and independence in the elderly. The accepted diagnostic method for evaluation of fracture risk after osteopenia and osteoporosis is the measurement of bone mineral density with dual-energy x-ray absorptiometry (DEXA). This method is limited because of its low accessibility, high capital costs, and low sensitivity. This study evaluated whether canal diameter is a reliable indicator as a major risk factor for hip fracture in the elderly. The canal-to-diaphysis ratio was measured on plain radiographs in 38 patients with trochanteric hip fracture and compared with this ratio in 39 age-matched patients with no hip fracture. Comparison was done with the Shapiro-Wilk test and the likelihood ratio test. Measurements were taken twice with an interval of 1 week apart by the same investigator and then validated by 2 orthopedic consultants from the authors’ institution to ensure inter- and intraobserver reliability. The canal-to-diaphysis ratio was significantly increased (P<.001) in patients with trochanteric hip fracture compared with control subjects without fracture. An index of 0.62 represents a risk of intertrochanteric hip fracture of 85.8%. Inter- and intraobserver reliability analysis showed very high reproducibility of the test. An inexpensive and widely accessible tool, such as evaluation of the radiographic canal-to-diaphysis ratio, can be considered as a simple method for the stratification of risk factors for hip fracture in the elderly. A cutoff is suggested to classify patients with a canal-to-diaphysis ratio of more than 0.62 who are at high risk for hip fracture. [Orthopedics. 2015;38(6):e457-e461.]
Osteoporosis is characterized by an absolute decrease in the amount of bone to a level below that required for mechanical support of normal activity and by structural deterioration of bone tissue that causes increased bone fragility and a consequent increase in nontraumatic skeletal fracture risk.\(^1\) As the elderly population increases, the number of adults with osteoporosis is expected to increase as well. Age-related bone loss is asymptomatic, and the morbidity of osteoporosis is secondary to fracture. Common sites of fracture include the spine, hip, forearm, and proximal humerus. Fractures of the hip incur the greatest morbidity and mortality and lead to the highest direct costs for health services. The incidence of fractures increases exponentially with age.\(^1\)

Osteoporosis is an established and well-defined disease that affects more than 75 million people in the United States, Europe, and Japan.\(^2\) Osteoporosis causes more than 8.9 million fractures annually worldwide, and more than 4.5 million of these occur in the Americas and Europe. Osteoporosis is not only a major cause of fractures but also ranks high among diseases that cause patients to become bedridden with serious complications. These complications may be life-threatening in elderly people. In the Americas and Europe, osteoporotic fractures account for 2.8 million disability-adjusted life years annually, somewhat more than the number associated with hypertension and rheumatoid arthritis, but less than the number associated with diabetes mellitus or chronic obstructive pulmonary disease. Collectively, osteoporotic fractures account for approximately 1% of the disability-adjusted life years attributable to noncommunicable diseases.\(^3\)

Because of the morbid consequences of osteoporosis, prevention of this disease and associated fractures is considered essential to health, quality of life, and independence in the elderly population. Several studies have shown that bone mass and density correlate with the risk of osteoporotic fracture.\(^4,7\) Therefore, measurement of bone mineral density with dual-energy x-ray absorptiometry (DEXA) is considered the main diagnostic method for evaluation of fracture risk.

Osteoporosis has been operationally defined on the basis of bone mineral density. According to the World Health Organization criteria, osteoporosis is defined as bone mineral density that is 2.5 standard deviations (SDs) or more below the average value for young, healthy women (T-score less than -2.5 SDs).\(^2,8\) This criterion has been widely accepted, and in many World Health Organization member states it provides both a diagnostic and an intervention threshold. The most widely validated technique to measure bone mineral density is DEXA, and diagnostic criteria based on the T-score for bone mineral density provide a recommended entry point for pharmaceutical intervention.\(^9-11\)

There are, however, several problems with the use of bone mineral density tests alone. In many areas of the world, bone mineral density measurement with DEXA is not widely available or is used predominantly for research, in part because of the high capital costs of DEXA. In other areas, bone mineral density testing is not reimbursed, despite the availability and approval of effective drug treatments. For this reason, many other techniques for measuring bone mineral density have been developed, and these methods have lower costs and are more portable. Experience with several of these methods is limited, however, and there is no clear guidance for their use, with or without DEXA, for either the diagnosis of osteoporosis or the assessment of fracture risk.

A second major problem with bone mineral density measurement is that these tests alone are not optimal for the detection of individuals at high risk for fracture. Over most reasonable assumptions, the tests have high specificity but low sensitivity.\(^2\) In other words, the risk of fracture is very high when osteoporosis is present, but it is by no means negligible when bone mineral density is normal. Most hip fractures occur in individuals with a normal test result. Thus, the potential effect of widespread testing of bone mineral density on the burden of fractures is less than optimal, and for this reason, many agencies do not recommend population screening of bone mineral density.\(^2,12,13\)

In the past decade, a great deal of research has been conducted to identify factors other than bone mineral density that contribute to fracture risk. Examples include age, sex, degree of bone turnover, history of fracture, family history of fracture, and lifestyle risk factors, such as physical inactivity and smoking.\(^14\) Some of these risk factors are partially or wholly independent of bone mineral density. Therefore, independent risk factors used with bone mineral density could enhance the information provided by bone mineral density alone. Conversely, in principle, some factors that are strongly dependent on bone mineral density can be used to assess fracture risk in the absence of bone mineral density tests. Consideration of well-validated risk factors, with or without bone mineral density, is likely to help in identifying individuals who are at high risk for fracture.\(^14\)

The World Health Organization has recommended bone mineral density as the sole criterion to initiate drug therapy.\(^14\) According to the previously mentioned limitations of this test, however, a simpler and more accessible test is needed. Anteroposterior pelvic or hip joint radiographs, usually obtained for the assessment of conditions other than osteoporosis, such as osteoarthritis, are routinely taken in the community and hospital environments. Conventional plain radiographs are versatile because they can visualize localized processes, such as osteoarthritis, and can also reflect systemic changes, such as osteoporosis.\(^15,16\) The coexistence of osteoporosis and osteoarthritis of the hip, as described in a series of postmenopausal white women,\(^17,18\) emphasizes the
usefulness of such radiographs. Sah et al\textsuperscript{19} showed that femurs with a low radiographic thickness index had lower T-scores on DEXA tests. They suggested that a radiographic hip cortical thickness index of 0.40 or less should prompt referral for osteoporosis evaluation and bone mineral density testing.\textsuperscript{19}

The authors postulated that the proximal femur thickness index, discussed here as the canal-to-diaphysis ratio, could be directly related to fracture risk. Furthermore, the authors were seeking a quantitative method that would yield a cutoff that would indicate a high risk of hip fracture.

**Materials and Methods**

Data were collected retrospectively from September 2011 to December 2012.

**Patients**

The study group included patients admitted for trochanteric hip fracture (AO classification 31-A1 to 31-A3). The study group included 38 patients, with 28 women and 10 men. Mean age was 81 years, with a range of 65 to 97 years.

Additional anteroposterior hip radiographs of 39 patients without bone fracture were examined as a control group. This group included 24 women and 15 men, with a mean age of 78.7 years (range, 65-90 years). Radiographs showed no evidence of current or past fracture.

**Radiographs**

All radiographs were taken in the imaging room of the emergency department at the authors’ institution, which uses a standardized approach.

The radiographs were obtained from the picture archiving and communication system film library of the hospital. In the study group, the contralateral intact side was used for measurement to avoid errors resulting from comminution of the fractured femur.

All radiographs were copied to PowerPoint software (Microsoft, Redmond, Washington) and were numbered in a sequential fashion, without identifying data, such as age, name, or identity number. The study group file was designated as group 1. The control group file was designated as group 2. All radiographs were printed twice with a single printer to avoid measurement errors resulting from different computer screen sizes. The investigators did not know in advance which file belonged to which group. Measurement was performed manually on the printed radiographs with a plain ruler.

**Canal-to-Diaphysis Ratio Index**

Measurements were obtained at a point that was 5 cm distal to the mid-lesser trochanter on anteroposterior views (Figure 1). This index was calculated as the ratio of femoral canal width divided by diaphysis width. The higher the ratio, the wider the canal, and hence the thinner the cortex. The canal-to-diaphysis ratio of the intact hip of patients in the study group was compared with that of patients in the control group. Measurements were taken twice, 1 week apart, by 3 experienced orthopedic surgeons to assess inter- and intraobserver reliability of the screening tool.

The canal-to-diaphysis ratios of the fractured hips were not included in the study because external rotation of the fractured limb could have affected the measurements.

**Statistical Analysis**

The Shapiro-Wilk test was used to assess whether a sample came from a specified distribution (in this case, normal distribution). The confidence interval was 95% (alpha=0.05).

A likelihood ratio test was performed to show the likelihood of manifestation of the target problem (study group) vs the likelihood that the same result would be expected in a patient without the target disorder (control group).

Using calculated parameters $\mu$ and $\sigma$, theoretical normal distributions were built for the study and contusion samples.

**RESULTS**

Adequate contralateral (intact) anteroposterior hip radiographs were available.
for 38 patients in the study group. In the control group, adequate hip radiographs were obtained for 39 patients.

1. The canal-to-diaphysis ratio for the study group (contralateral, intact side) was 0.54 SD and 0.475 SD for the control group. This difference was statistically significant ($P < .001$) (Figure 2).

2. The likelihood ratio test for the unaffected contralateral side (study group) showed that a patient with an index of 0.51 had a likelihood of hip fracture of 50% (Figure 3, first dashed line). However, with increasing index values, the likelihood of having an intertrochanteric fracture grows exponentially. With an index of 0.62 (Figure 3, second dashed line), the likelihood of hip fracture was 6.02 times greater than that for a patient in the control group. In other words, with an index of 0.62, the probability of intertrochanteric fracture was 85.8%. Therefore, patients with an index of more than 0.62 were considered to be at high risk for intertrochanteric fracture.

3. Results of inter- and intraobserver reliability are summarized in Table 2. The interclass correlation coefficient for both measurements (study and control indexes) showed excellent agreement (0.81 and 0.86, respectively) between all observers. Intraobserver reliability (Pearson’s correlation coefficient) showed strong positive relationships for all observers for both the study and control groups.

**DISCUSSION**

The rationale for performing this study was the recognition that orthopedic surgeons often find great differences between young and elderly patients in ease of inserting intramedullary devices to the femur shaft to treat fractures of the hip. In young patients, it is almost always necessary to ream and enlarge the proximal diaphysis to make room for the metal nail. In elderly patients, the diaphysis is usually wide enough and does not need to be enlarged. Hip fractures are much more common in the elderly, which made the authors consider the width of the proximal femur as a reliable risk factor for hip fracture in this age group. Therefore, the authors chose the ratio between the medullary canal and the diaphysis as a simple method to assess this hypothesis.

The results showed that a simple method, such as measuring an uncomplicated ratio of the diameters of the proximal femurs on plain radiographs, can provide a

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pearson’s Correlation Coefficient for Interpreting Strength of Correlations</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strength of Association</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak</td>
<td>0.1 to 0.3</td>
<td>-0.1 to -0.3</td>
</tr>
<tr>
<td>Medium</td>
<td>0.3 to 0.5</td>
<td>-0.3 to -0.5</td>
</tr>
<tr>
<td>Strong</td>
<td>0.5 to 1.0</td>
<td>-0.5 to -1.0</td>
</tr>
</tbody>
</table>

**Figure 2:** Histogram showing canal-to-diaphysis ratios between the study and control groups.

**Figure 3:** Normal distribution curves were built on the basis of the calculated means±SD of the study and control groups. The meeting point of these curves at a canal-to-diaphysis ratio of 0.51 represents equal probability (1:1 or 50%) of fracture or contusion.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interobserver and Intraobserver Reproducibility of Study and Control Group Indexes Based on Interclass Correlation Coefficient and Pearson’s Correlation Coefficient</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Interclass Correlation Coefficient (95% Confidence Interval)</th>
<th>Observer 1</th>
<th>Observer 2</th>
<th>Observer 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study group index</td>
<td>0.81 (0.66-0.89)</td>
<td>0.79</td>
<td>0.54</td>
<td>0.53</td>
</tr>
<tr>
<td>Control group Index</td>
<td>0.86 (0.76-0.92)</td>
<td>0.79</td>
<td>0.76</td>
<td>0.80</td>
</tr>
</tbody>
</table>

and for the control group showed that a patient with an index of 0.51 had a likelihood of hip fracture of 50% (Figure 3, first dashed line). However, with increasing index values, the likelihood of having an intertrochanteric fracture grows exponentially. With an index of 0.62 (Figure 3, second dashed line), the likelihood of hip fracture was 6.02 times greater than that for a patient in the control group. In other words, with an index of 0.62, the probability of intertrochanteric fracture was 85.8%. Therefore, patients with an index of more than 0.62 were considered to be at high risk for intertrochanteric fracture.

3. Results of inter- and intraobserver reliability are summarized in Table 2. The interclass correlation coefficient for both measurements (study and control indexes) showed excellent agreement (0.81 and 0.86, respectively) between all observers. Intraobserver reliability (Pearson’s correlation coefficient) showed strong positive relationships for all observers for both the study and control groups.

**DISCUSSION**

The rationale for performing this study was the recognition that orthopedic surgeons often find great differences between young and elderly patients in ease of inserting intramedullary devices to the femur shaft to treat fractures of the hip. In young patients, it is almost always necessary to ream and enlarge the proximal diaphysis to make room for the metal nail. In elderly patients, the diaphysis is usually wide enough and does not need to be enlarged. Hip fractures are much more common in the elderly, which made the authors consider the width of the proximal femur as a reliable risk factor for hip fracture in this age group. Therefore, the authors chose the ratio between the medullary canal and the diaphysis as a simple method to assess this hypothesis.

The results showed that a simple method, such as measuring an uncomplicated ratio of the diameters of the proximal femurs on plain radiographs, can provide a
screening tool for elderly patients who are at high risk for hip fracture. The results had respectable inter- and intraobserver reliability, which makes this method reproducible for wide use.

Although previous studies reported on certain types of proximal femur geometry as risk factors for hip fractures, the current results showed a direct relationship between a simple ratio that can be calculated immediately and the risk for hip fracture.

Furthermore, measurements used in the past to correlate hip index with osteoporosis were cumbersome and complicated to use. For example, suggested a ratio of femoral diaphysis width minus medullary canal width divided by diaphysis width as follows:

Cortical index=(Diaphysis width-Medullary canal width)/Diaphysis width

The authors believe that the ratio described in this article is as accurate as that used by Dorr et al and that it accurately reflects the relationship between the width of the cortex and the width of the medullary canal.

Further studies are needed to correlate canal-to-diaphysis ratio with DEXA score in patients with osteoporosis and the healthy population to further establish this hypothesis.

CONCLUSION

Inexpensive and widely accessible tools, such as evaluation of the radiographic canal-to-diaphysis ratio, can be used to stratify risk factors for hip fracture in the elderly. This tool can be used easily by orthopedic surgeons and general practitioners. Patients who are at risk, especially those with a canal-to-diaphysis ratio greater than 0.62, should be warned to use walking aids or to wear hip protectors to minimize the risk of hip fracture. Furthermore, because radiographs are inexpensive and easily accessible, they can be used as a follow-up tool in the treatment of osteoporosis and to monitor the risk of hip fracture.

REFERENCES