Original Research

**Bone Mineral Content of the Spine and Proximal Femur in Female Patients With Hip Fracture**

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**Abstract**

Measurement of bone density in the spine and hip by quantitative computed tomography (QCT) and dual photon absorptiometry (DPA) was performed in 36 women with hip fracture. Hip density by DPA was determined at three anatomic subregions of the hip. Comparison to normals revealed an average decrease in hip bone density by 15% below controls. Spine density measurements were not significantly different from that of controls. Correlations of hip and spine densities varied by hip subregion. This study demonstrated that bone density measurement methods and measurement at one axial site may not accurately reflect bone density at appendicular subregions.

The noninvasive measurement of bone density remains limited in its ability to clearly separate osteoporotic from normal patients, and the utilization of measurements at one skeletal site to predict fracture risk at other sites is also in question. The latter limitation is often attributed in part to controversy over the correlation of axial and appendicular bone density measurements. Previous studies have attempted to compare axial and appendicular bone density and have yielded variable results. Although some studies have shown that decreased appendicular bone mineral density (BMD) is not accompanied by similar changes in the lumbar spine, a few have found a more significant association in BMD at these two sites. The variation in results from bone densitometry studies is not surprising, as the outcome of any such investigation is significantly influenced by several variables including the population studied, the measurement technique utilized, and the anatomic sites chosen for sampling.

The purpose of this investigation was to further examine axial and appendicular regional patterns of bone loss in patients with hip fracture. In addition, because the proximal femur is composed of variable ratios of cortical and trabecular bone, we analyzed the bone density of three subregions of the hip and compared them to axial measurements.

**Methods and Materials**

The study population consisted of 36 consecutive female hip fracture volunteers with a mean age of 73 years (range: 49 to 88). Nineteen had suffered intertrochanteric fracture and 17 femoral neck fracture. Within the first 10 days after admission, informed consent was obtained from all patients, and each completed a risk factor survey and underwent several bone density measurements as described below.

Determination of lumbar spine vertebral tra-
Table 1

<table>
<thead>
<tr>
<th>Site</th>
<th>Percent of Mean Values for Age/Sex-Matched Controls*</th>
<th>All Patients</th>
<th>Intertoch. Fx†</th>
<th>Neck Fx†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QCT</td>
<td>120 ± 51</td>
<td>109 ± 47</td>
<td>132 ± 55</td>
<td></td>
</tr>
<tr>
<td>DPA</td>
<td>107 ± 18</td>
<td>103 ± 24</td>
<td>110 ± 14</td>
<td></td>
</tr>
<tr>
<td>Hip‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>90 ± 13</td>
<td>86 ± 13</td>
<td>94 ± 14</td>
<td></td>
</tr>
<tr>
<td>Troch.</td>
<td>82 ± 17</td>
<td>77 ± 15</td>
<td>87 ± 17</td>
<td></td>
</tr>
<tr>
<td>Ward’s</td>
<td>83 ± 17</td>
<td>79 ± 15</td>
<td>88 ± 17</td>
<td></td>
</tr>
</tbody>
</table>

*Values expressed as mean ± SEM.
†Differences between neck and intertrochanteric fracture subgroups not statistically significantly different.
‡All hip values were statistically significantly different from controls.

Table 2

<table>
<thead>
<tr>
<th>Age at:</th>
<th>Spine</th>
<th>Hip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>QCT</td>
<td>DPA</td>
</tr>
<tr>
<td>Int Fx</td>
<td>.63/.01</td>
<td>.20/.53</td>
</tr>
<tr>
<td>FN Fx</td>
<td>.09/.75</td>
<td>.10/.71</td>
</tr>
<tr>
<td>All patients</td>
<td>.51/.01</td>
<td>.10/.60</td>
</tr>
</tbody>
</table>

Int Fx = Intertrochanteric fracture
FN Fx = Femoral neck fracture

Becquerel bone mineral density (BMD, in mg/cm²) was made using a GE CT/T 9800 scanner (General Electric, Milwaukuee, WI). Using a technique previously described, scan slices were taken through the middle portion of each lumbar vertebra (L2-L5) parallel to the endplates and BMD was calculated using paraspinal muscle and fat as internal reference standards.5 Integral bone mineral content (BMC, in mg/cm²) of the lumbar spine and of the unfactured hip was determined using a Lunar DP3 Dual Photon Absorptiometer (DPA) with an external source of Gd-153.6 BMC measurements of the unfactured hip were determined at three anatomic subregions: Ward's triangle, femoral neck, and greater trochanter, and an average value was also calculated.

Mean values of the DPA and QCT measurements of the lumbar spine were calculated for each patient and also expressed as the percent of the mean value for age/sex-matched normal controls. The normative data for QCT was from Genant et al7 and for the DPA was supplied by Lunar Radiation Corp. Both of these large, normative databases were first validated by comparison with a smaller group of normal controls scanned at our institution showing a variance of less than 3%.

In addition to bone density measurement, each patient completed a survey of positive and negative factors known to affect bone metabolism. From this questionnaire a net risk factor score was calculated as previously described.8 This score was then compared to the patients' bone mineral measurements and Singh index grade.

The Singh bone density classification (grade I-VI) was determined for each patient using plain radiographs of the uninvolved hip. Each of the radiographs was read and graded on two different occasions by the originator of the index, and the average score of the readings was compared to the bone mineral of the hip and spine as determined by DPA and QCT.

Statistical analysis of the data was performed using Apple Staturworks on an Apple Iic computer. Spearman correlation coefficients were calculated for the two measurement techniques (DPA, QCT), the Singh index, risk factor scores, and the various anatomic sites. The data were analyzed for the group as a whole and according to fracture type (intertrochanteric/femoral neck). The significance of differences between fracture patients and control mean values, as well as the difference between anatomic sites and methods, was determined using a two-tailed, paired t-test. Regression analysis of subject age, type of fracture, and bone mineral measurements was also performed. Statistical significance was reached when P<.05.

RESULTS

In this cohort of hip fracture patients, bone mineral content in the three hip subregions was significantly less than that of age/sex-matched controls. The largest BMC decreases from expected (control) values were observed at the greater trochanter (18%, P<.001) and Ward's triangle (17%, P<.001), and the decrease was less in the femoral neck (10%, P<.001). There was a trend for BMC to be lower in patients with intertrochanteric fracture than in those with neck fractures, but this difference was not statistically significant. In the lumbar spine, bone density was not significantly different from normal control values as measured by DPA or QCT (Table 1); however, the two techniques correlated strongly with each other (r = .69, P<.001).

Regression analysis demonstrated variable correlations of age with bone mineral in the spine and hip (Table 2). BMC of the hip in all three subregions showed a significant negative correlation with age which was stronger at the trochanteric subregion (r = −.67, P<.011) than...
at Ward's triangle ($r = -0.50, P<0.006$) or the femoral neck ($r = -0.39, P<0.041$). When the data were separated by fracture type, the relative strength of the correlation at each site remained the same, but for all three subregions the patients having suffered femoral neck fracture had greater negative correlation of density with age than those with intertrochanteric fracture (Table 2). Spinal BMC by QCT showed a moderate negative correlation with age ($r = -0.51, P<0.001$), and although spinal BMD by DPA showed a negative trend with age, it was not statistically significant.

The risk factor score generated for each patient from their questionnaire did not significantly correlate with any of the bone mineral measurements at the spine or hip. There was also no significant correlation of risk factor score with the Singh index grades.

The Singh index grade was determined for all of the patients who had radiographs with adequate technique and no pre-existing hardware in the unfractured hip. Singh index grade did not correlate significantly with age ($r = -0.31, P<0.31$). Singh index grade did correlate strongly with lumbar spine BMD by QCT ($r = 0.76, P<0.01$) and less strongly with spine BMC by DPA ($r = 0.58, P<0.10$). Singh index grade was weakly related to overall hip BMC ($r = 0.48, P<0.11$), but this was due to poor correlation to BMC at the femoral neck ($r = 0.33, P<0.29$) and a much stronger correlation to BMC at the trochanter ($r = 0.67, P<0.017$). Interestingly, Singh index grade correlated strongly with overall BMC of the hip in patients who had suffered intertrochanteric fracture ($r = 0.85, P<0.03$), but not in those with femoral neck fracture ($r = 0.36, P<0.48$) (Fig 1).

DPA measurements of bone mineral in the spine were variably related to BMC in the three hip subregions. Spine BMC by DPA was only moderately correlated to BMC of the femoral neck ($r = 0.48, P<0.02$), but was more strongly correlated to BMC of the greater trochanter ($r = 0.60, P<0.003$) and Ward's triangle ($r = 0.56, P<0.007$). These correlations were not significantly different when analyzed by fracture type, except in the Ward's triangle subregion in patients who had intertrochanteric fracture. In these patients, BMC of the spine was much more strongly related to BMC of Ward's triangle ($r = 0.72, P<0.02$) than in patients who had femoral neck fracture ($r = 0.29, P<0.35$) (Fig 2).

BMD of the spine by QCT was more strongly related to BMC at all hip subregions than was BMC by DPA. The most significant correlation was again seen at the trochanter ($r = 0.64, P<0.001$) and Ward's triangle ($r = 0.63, P<0.001$). At the neck and trochanter subregions there was moderate correlation between spine BMD and hip BMC in patients with intertrochanteric or femoral neck fracture, but at Ward's triangle the correlation was strong for patients with intertrochanteric fracture ($r = 0.76, P<0.005$) and poor in those with femoral neck fracture (Fig 3).

**Discussion**

Many investigations have attempted to determine if hip fracture patients are more osteoporotic than controls of the same age and gender. Some authors have shown that patients with hip fracture are more osteoporotic. Others believe that body habitus and propensity for falls, rather than bone density, are more predominant risk factors for hip fracture. In the present study, patients with hip fracture had an overall hip bone mineral content that was 15% less on average than that of normal controls. However, we did not observe any decrease...
in spinal bone density. In fact, both the QCT and the DPA measurements in the spine showed that the hip fracture population had a mean spinal BMD 10% to 20% higher than control values (although this was not statistically significant) (Table 1). If the trend of higher than normal spine BMD were true, we might postulate that spinal bone density had been relatively preserved and that there was a greater than normal loss of bone from the hips. Alternatively, the patients with enough bone loss to result in hip fracture may also have had subclinical vertebral compression fractures increasing the effective concentration of bone/unit volume.

Different methods of bone mineral quantitation may yield variable results. While QCT and DPA have both been shown to be accurate and reproducible, there remains a fundamental difference in what is being measured by the two techniques. DPA measures integral bone density, which is a combination of cortical and trabecular bone, while QCT is more specific and is capable of measuring purely trabecular bone. The Singh index is based on the pattern of trabecular bone loss in the proximal femur and can be used as a non-invasive method of quantification of osteopenia in this region.¹³

Precision of bone density determinations should also be considered when choosing a specific technique for a given study or clinical application. Dual energy x-ray absorptiometry is a relatively new technique similar to DPA, but it utilizes an x-ray tube instead of a radioisotopic source. Like DPA, it measures integral bone density and exposes the patients to a much lower radiation dose than does QCT (<10mR vs 100-1000mR). However, DEXA is faster than DPA and more importantly has a higher resolution allowing for greater precision than DPA (1% vs 2% to 3%), making it as precise as QCT (1.3%).¹⁴ Because DEXA precision approaches 1%, it is more useful than DPA for longitudinal studies and yearly clinical evaluations. DEXA's increased resolution also may allow more precise measurements of subregional bone density.

The inherent differences in bone density measurement techniques should be considered when comparing the outcome of various studies, when analyzing bone density at different sites, or when attempting to correlate measurements by QCT and DPA to each other or to other measurement techniques such as the Singh index.

Singh index reflects trabecular (cancellous) bone density in the proximal femur; therefore, we would expect it to best correlate with other measurements of predominantly trabecular (rather than cortical) bone. Accordingly, the Singh index grades should correlate better with DPA bone mineral measurements in anatomic sites with a higher trabecular-to-cortical bone ratio. The femoral neck is 25% trabecular and 75% cortical, while the intertrochanteric area is 50% trabecular.¹⁵ The relatively higher content of trabecular bone in the trochanteric subregion of the proximal femur is likely to explain our finding of the strongest correlation of the Singh index with DPA bone content in this region. Similarly, because QCT is capable of measuring exclusively trabecular bone, it is not surprising that the Singh index grades in our study patients demonstrated a stronger correlation with QCT than with DPA measurements of the spine. Although patterns of bone loss in the spine and hip may be different, the majority of previous studies that failed to show a strong correlation of Singh index and spine bone content may have been hampered by the use of DPA, rather than QCT, as in the present study.¹²,¹⁶,¹⁷

Our net risk factor score did not significantly correlate with any of the bone density findings. This is in contrast to data from a study of young hip fracture patients where a similar questionnaire was used.⁸ In that study a significant correlation was observed between bone density and risk factor score.

It is unclear whether the mechanics of a fall or the relative pre-existing subregional bone losses determine the location (trochanteric vs neck) of a hip fracture. Density measurements of the hip in patients with intertrochanteric fracture tended to be lower than in those with femoral neck fracture. If the patients with intertrochanteric fracture had lost relatively more trabecular bone than the patients with femoral neck fracture, we would expect the measurements that reflect primarily trabecular bone to better correlate in these patients. In our study, those patients with intertrochanteric hip fracture did show a much stronger correlation between Singh index and
QCT density of the spine, and between Singh index and DPA mineral content of the hip at the trochanteric area, than did the patients who had suffered femoral neck fracture.

As mentioned earlier, the ability to correlate axial and appendicular bone density measurements remains controversial, and some of the discrepancies may be technique and site dependent. Because the spine is predominantly trabecular, we would expect its vertebral density measurements to correlate better with those appendicular sites that have greater relative amounts of trabecular bone. In our study of hip fracture patients, QCT and DPA bone density measurements of the spine correlated well with each other, but showed variable correlation with bone content in the hip. The BMC of the spine, as measured by DPA, showed some correlation with the average BMC of the entire hip, but showed a stronger correlation with the trochanteric subregion. Measurements of the spine by QCT were more strongly correlated to overall and subregional hip BMC than was DPA of the spine. These observations demonstrate the importance of analysis of bone density in anatomic subregions of the hip in addition to the average density of the entire hip region, especially when attempting to discern differences in bone loss patterns in patients with different metabolic bone disorders. For example, this type of subregional densitometric analysis may aid in distinguishing Type I (post-menopausal) from Type II (senile) osteoporosis based on differences in the relative loss of cortical vs trabecular bone.14

REFERENCES