Asymptomatic Vertebral Deformity as a Major Risk Factor for Subsequent Fractures and Mortality: A Long-Term Prospective Study

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ABSTRACT: In elderly men and women, asymptomatic vertebral deformity was found to be associated with subsequent risk of symptomatic fractures, particularly vertebral fracture, and increased risk of mortality after a fracture.

Introduction: Vertebral deformity is associated with an increased risk of fracture and mortality. However, it is unclear whether the three events of vertebral deformity, fracture, and mortality are linked with each other and what role BMD plays in these linkages.

Materials and Methods: Vertebral deformity was determined from quantitative analysis of thoracolumbar spine X-rays in 300 randomly individuals (114 men and 186 women) aged 60 years of age (as of mid-1989), who were randomly selected from the prospective Dubbo Osteoporosis Epidemiology Study. Incidence of atraumatic fractures and subsequent mortality were ascertained from 1989 to 2003. Cox’s proportional hazards model was used to determine the association between asymptomatic vertebral deformities, osteoporotic fractures, and risk of mortality.

Results: The prevalence of asymptomatic vertebral deformity was 31% in men and 17% in women. During the follow-up period, subjects with vertebral deformity had a significantly higher risk of any fracture than those without vertebral deformity (44% versus 29%; hazards ratio [HR], 2.2; 95% CI, 1.4–3.7), particularly symptomatic vertebral fracture (relative risk [RR], 7.4; 95% CI, 3.2–17.0). Mortality rate was highest after a symptomatic fracture among those with vertebral deformity (HR, 9.0; 95% CI, 3.1–26.0). These associations were independent of age, sex, and BMD.

Conclusion: Vertebral deformity was a strong predictor of subsequent risk of fractures, particularly symptomatic vertebral fracture, and may modify fracture-associated mortality in both elderly men and women.

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Key words: vertebral deformity, vertebral fracture, mortality, BMD, elderly, women, men

INTRODUCTION

Vertebral deformity, a hallmark of osteoporosis, affects at least 20% of the elderly population,1-3 but only 30–40% of all these cases come to clinical attention.4,5 Vertebral deformity is associated with an increased risk of subsequent fractures, including vertebral6-9 and hip fractures.8-13 Recent studies have further suggested that vertebral deformity could be associated with increased risk of mortality in men10 and women.8,10,14,15

Fracture is associated with increased risk of mortality.16,17 Low BMD is a primary predictor of fracture risk18,19 and is suggested to be a risk factor for mortality as is fracture per se.20 However, it is not known whether the three events (e.g., vertebral deformity, fracture, and mortality) are linked with each other or are independent of each other and of BMD. This study was designed to examine the interrelationship between asymptomatic vertebral deformity, subsequent symptomatic fractures, and fracture-associated mortality in relation to BMD in a group of elderly men and women.

MATERIALS AND METHODS

Study design

This study was part of the larger on-going Dubbo Osteoporosis Epidemiology Study (DOES); of which the study design and protocol have been described elsewhere.22 Briefly, DOES is a longitudinal, population-based study of risk factors for fracture and mortality. The sampling frame is the city of Dubbo, New South Wales (Australia), a locality of ~32,000 people, 98.6% white, of which 1581 men and...
2095 women were ≥60 years of age in 1989. It is relatively isolated in terms of medical care, allowing virtually complete ascertainment of all fractures.

**Study participants**

This study consisted of 300 subjects (114 men and 186 women) who were randomly selected from a database of DOES participants. All subjects were ≥60 years of age as of June 1989 and were free of any illness deemed likely to affect bone metabolism.

**Measurements**

Radiographs were performed by a standardized procedure with a target-to-film distance of 105 cm. The presence or absence of vertebral deformity was assessed separately by one investigator and read in a masked fashion to BMD. Vertebral deformity was defined as a reduction of at least 3 SD from same-sex normals, according to Eastell et al.,(22) except that posterior deformities were defined by comparison with same-sex normals rather than by comparison with levels above and below, because this may lead to practical difficulties especially in subjects with multiple deformities. Normal values were derived from a subsample of 50 women (mean age, 67.9 years) and 30 men (mean age, 68.2) who were clinically assessed by two experienced clinicians to be free of deformity.

BMD at the lumbar spine and femoral neck was measured by DXA using Lunar DPX densitometer (GE Lunar, Madison, WI, USA). The CV of BMD at our institution for normal subjects is 1.5% for the lumbar spine and 1.3% for the femoral neck.(23) As part of the estimation of the risk of fracture caused by low BMD and vertebral deformity, individuals were classified as “osteoporotic” if the femoral neck BMD was ≥2.5 SD below the young normal level; otherwise, a “normal” classification was made.

**Incidence of fractures and mortality**

The primary outcomes in this study were the incidence of symptomatic fractures and of death. During the follow-up period (from mid-1989 to June 2003), the incidence of symptomatic atraumatic fractures was ascertained. Low-trauma symptomatic fractures were identified for residents of the Dubbo local government area through radiologists’ reports from the only two centers providing X-ray services as previously described.(21) They were defined as fractures with minor or no trauma (e.g., fall from a standing height or less). The fractures were grouped within the following categories: (1) any type of fracture, (2) hip fracture, (3) vertebral fracture, (4) Colles’ fracture, and (5) major upper or lower limb or multiple rib fractures but excluding hip fracture. Subsequent symptomatic vertebral fractures were confirmed by comparison with the baseline radiographs.

Death was also recorded during the study period. They were subgrouped into those after a symptomatic fracture event and those with no intervening fracture event.

**Statistical analysis**

The association between symptomatic fracture and mortality (outcome) and vertebral deformity (risk factor) was analyzed by the Cox’s proportional hazards model, in which the hazards ratio (HR) and 95% CI of fracture and mortality associated with a vertebral deformity were estimated. Further analyses taking into account age, sex, BMD, and body weight were also performed. Because each HR is subjected to sampling variability (as represented by the CI), it was also of interest to estimate the probability that an association with an HR being ≥2. The HR of 2 was selected as a cut-point for defining “effect,” because it is equivalent to the probability of 0.67 that a vertebral deformity individual has a fracture first compared with a nonvertebral deformity individual. All analyses were conducted within the SAS software version 9.(24)

**RESULTS**

A total of 300 subjects (114 men and 186 women) were included in this analysis. The median length of follow-up was 10.2 ± 4 (SD) years. There was no significant difference in the follow-up duration between men (10.5 years) and women (10 years).

At baseline, men had a higher body weight, height, and body mass index (BMI) than women (p < 0.05). As expected, lumbar spine and femoral neck BMD were significantly higher in men than in women (p < 0.001) Using the 3 SD criteria, 35 men (30.7%) and 31 women (16.7%) had at least one vertebral deformity. The prevalence of deformity only increased moderately with age in both men and women, such that by the age of 75 years or above, 38.5% of men and 23.9% of women had a vertebral deformity. Seventeen men (14.9%) and 15 women (8.1%) had a single vertebral deformity, whereas 18 men (15.8%) and 16 women (8.6%) had two or more vertebral deformities. There was no significant difference in age, body weight, height, and BMI between subjects with and without vertebral deformity among either men or women, but femoral neck BMD in men and women and lumbar spine BMD in men with baseline vertebral deformity were significantly lower than those without vertebral deformity (Table 1).

**Incidence of symptomatic fractures**

During the follow-up period, 26 men (22.8%) and 67 women (36%) sustained at least one symptomatic atraumatic fracture. Among those, 67 had one fracture and 26 had two or more fractures. The incidence of subsequent fractures among subjects with baseline vertebral deformity was 44% (n = 29/66), significantly higher than those without baseline vertebral deformity (27%; n = 64/234; p = 0.01), making the relative hazard of fracture at 2.2 (95% CI, 1.4–3.4). The probability that a vertebral deformity incurred an HR of >2 was estimated to be 66%. However, the probability that a vertebral deformity incurred an HR of >1 was 99% (data not shown). The difference was most pronounced for symptomatic vertebral fracture, with a 5-fold (95% CI, 1.3–20.0) increase in the relative hazard of fracture in men and almost an 11-fold (95% CI, 3.9–30.9) increase in women being observed. In both sexes, the effect of vertebral deformity on symptomatic vertebral fracture was virtually confirmatory, with the probability of an HR of >2
being 91% (for men) and 100% (for women). However, there was no significant effect of vertebral deformity on nonvertebral fractures (Table 2).

In the Cox’s proportional hazards regression model taking into account the effect of age, sex, and BMD, the relative hazard of any subsequent fracture associated with a vertebral deformity was 2.3 (95% CI, 1.4–3.4). The strength of association was stronger for symptomatic vertebral fractures (HR, 6.5; 95% CI, 2.7–15.7). The association was more pronounced after adjusting for age, sex, and weight (instead of BMD), although the magnitude of relative risk did not significantly increase. In both analyses, the strength of associations for symptomatic vertebral fractures was stronger in women than in men (Table 3).

The effect of vertebral deformity on fracture risk was most pronounced in those with BMD T scores ≤ −2.5 SD (i.e., osteoporotic), among whom, the relative hazard for any fracture was 3.2 (95% CI, 1.2–8.7) and 6.7 (95% CI, 1.5–29.1) for vertebral fracture. Among those with osteopenia and normal BMD, the effect of vertebral deformity was significant only for the risk of symptomatic vertebral fracture (HR, 7.0; 95% CI, 2.3–18.1; Fig. 1).

Mortality

During the follow-up period, 20 men and 25 women died; of those, 17 (7 men and 10 women) had had symptomatic fractures. The unadjusted relative hazard of death associated with a baseline vertebral deformity was 2.7-fold higher (95% CI, 1.5–4.9) than in those without a baseline vertebral deformity (Table 4), and this effect seemed to be more pronounced with time (Fig. 2). There was an 83% chance that the relative hazard [of mortality associated with a vertebral deformity] was ≥2 (Table 4). Moreover, the risk of death was highest in those with a vertebral deformity who had had a subsequent symptomatic fracture (HR, 9.0; 95% CI, 3.1–26.0). On the other hand, in those without a subsequent fracture, the risk of death was not significantly different between those with and without a vertebral deformity (HR, 1.0; 95% CI, 0.3–3.2). Adjustment for age and BMD did not significantly change the associations (Table 4).

The association between vertebral deformity and mortality was independent of femoral neck BMD. For example, individuals with vertebral deformity and an osteoporotic BMD (8% of the sample) had the highest risk of mortality compared with individuals with vertebral deformity only or low BMD only who, in turn, had higher risk of death than those without vertebral deformity and normal BMD (Fig. 3).

DISCUSSION

Vertebral deformity is one of the classic hallmarks of osteoporosis and is an important public health problem, because it is associated with increased morbidity (back pain and disability) and mortality. In this study, baseline vertebral deformity was associated with an increased risk of subsequent symptomatic fractures, particularly vertebral fracture. Moreover, vertebral deformity individuals—regardless of age, sex, and BMD—also had a substantially higher risk of death, particularly after sustaining a fracture.

The strength of association between vertebral deformity and subsequent symptomatic fractures observed in this study is comparable with previous reports. That is, the presence of a vertebral deformity increased the risk of any subsequent fracture by between 2.0- and 2.8-fold. However, in contrast to previous studies, which found no significant association between vertebral deformity and future fractures in men, this study suggested that the relationship of vertebral deformity with subsequent fracture was equivalent between men and women.

The effect of vertebral deformity on incidence of symptomatic vertebral fracture observed in this study was high in both sexes (HR, 6.5; 95% CI, 2.7–16), but was well within the range of relative risk previously reported (between 4.7-
and 12.6-fold). The mechanism of the relationship between vertebral deformity and subsequent low-trauma fracture risk is unknown, but it is perhaps equally not surprising, because individuals with vertebral deformity have reduced BMD as observed in this study. However, this study further showed that the effect of vertebral deformity on subsequent fracture risk was independent of BMD and age. Thus, it is possible that vertebral deformity is a marker of poor bone health such as height loss and increased bone loss. Furthermore, the fact that the presence of a vertebral deformity increased the risk of subsequent symptomatic vertebral fracture implies the roles of reduced mobility and mechanical factors in the relationship. In contrast to previous studies, in this study, there

| Table 2. New Fractures in Subjects With and Without Baseline Vertebral Deformity |
|---------------------------------|-------------------------------|-----------------|-----------------|-----------------|
| Fractures site                  | Vertebral deformity (%)       | No vertebral deformity (%) | HR (95% CI)    | p    | Posterior probability of HR > 2 |
| All                             | N (%)                        | N (%)                        |                 |      |                              |
| Number of subjects              | 66                           | 234                          |                 |      |                              |
| Any fracture                    | 29 (43.9)                    | 64 (27.4)                    | 2.2 (1.4–3.4)   | 0.01 | 0.66                          |
| Hip fracture                    | 3 (4.5)                      | 7 (3.0)                      | 1.7 (0.4–6.4)   | 0.54 | 0.41                          |
| Vertebral fracture              | 15 (22.7)                    | 9 (3.8)                      | 7.4 (3.2–17.0)  | <0.001 | 0.99                          |
| Colles’ fracture                | 4 (6.1)                      | 16 (6.8)                     | 1.0 (0.3–2.9)   | 0.82 | 0.12                          |
| Major fractures*                | 14 (21.2)                    | 33 (14.1)                    | 1.8 (0.6–5.7)   | 0.16 | 0.43                          |

**Table 3. Relative Hazard of Various Fractures According to Baseline Vertebral Deformity After Adjusted for Age, Sex, BMD, or Weight**

<table>
<thead>
<tr>
<th>Outcome (vs. baseline)</th>
<th>Adjusted for age, sex, and BMD*</th>
<th>Adjusted for age, sex, and weight*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any fracture</td>
<td>2.3 (1.4–3.7)</td>
<td>2.5 (1.5–3.9)</td>
</tr>
<tr>
<td>Hip fracture</td>
<td>1.3 (0.5–2.5)</td>
<td>1.4 (0.3–5.4)</td>
</tr>
<tr>
<td>Vertebral fracture</td>
<td>6.5 (2.7–15.7)</td>
<td>7.5 (3.2–17.8)</td>
</tr>
<tr>
<td>Colles’ fracture</td>
<td>1.5 (0.5–4.6)</td>
<td>1.6 (0.5–5.0)</td>
</tr>
<tr>
<td>Major fractures*</td>
<td>1.6 (0.8–3.2)</td>
<td>1.9 (1.0–3.6)</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any fracture</td>
<td>1.5 (0.6–3.5)</td>
<td>1.9 (0.8–4.5)</td>
</tr>
<tr>
<td>Hip fracture</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Vertebral fracture</td>
<td>4.0 (1.0–16.3)</td>
<td>5.5 (1.3–22.4)</td>
</tr>
<tr>
<td>Colles’ fracture</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Major fractures*</td>
<td>1.3 (0.4–4.3)</td>
<td>1.9 (0.6–5.9)</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any fracture</td>
<td>2.9 (1.7–5.1)</td>
<td>3.0 (1.7–5.2)</td>
</tr>
<tr>
<td>Hip fracture</td>
<td>1.8 (0.4–8.8)</td>
<td>2.8 (0.6–11.7)</td>
</tr>
<tr>
<td>Vertebral fracture</td>
<td>10.3 (3.5–30.6)</td>
<td>11.1 (3.8–32.3)</td>
</tr>
<tr>
<td>Colles’ fracture</td>
<td>1.7 (0.5–5.3)</td>
<td>1.7 (0.5–5.2)</td>
</tr>
<tr>
<td>Major fractures*</td>
<td>1.8 (0.8–3.9)</td>
<td>1.9 (0.9–4.0)</td>
</tr>
</tbody>
</table>

* Includes major upper or lower limb and/or multiple rib fractures.

* Values are HR (95% CI).

† Statistically significant at p < 0.001.
was no significant association between vertebral deformity and hip fracture risk in either men or women. However, the absolute incidence of hip fracture in our study was small (two cases in men and eight cases in women). Although the relative hazard of hip fracture associated with a vertebral deformity was not statistically significant, the probability that an HR is >1 and 2 was estimated to be 0.77 and 0.41, respectively.

Past studies have taken into account the effect of BMD on fracture risk and vertebral deformity. In this study, we found that the effect of vertebral deformity on fracture risk was independent of age and BMD. The relative hazard of fracture associated with a vertebral deformity (around 2) is equivalent to the relative hazard associated with 1 SD lower femoral neck BMD. Interestingly, the association between vertebral deformity and fracture risk was dependent on BMD levels. For example, the relative hazard of fracture associated with a vertebral deformity was highest in those with osteoporotic BMD levels (T score \( \leq -2.5 \)), although in those with osteopenia, the risk of fracture was also increased with the presence of a vertebral deformity. This suggests that a combination of vertebral deformity and low BMD predicts subsequent fracture more accurately than either alone.

It is known that vertebral deformity and fracture are associated with increased mortality risk. However, it is not clear whether the vertebral deformity–mortality association is mediated through the vertebral deformity–fracture association. In this study, the risk of death was found to be highest in men and women who had a baseline vertebral deformity and then sustained a subsequent symptomatic fracture. It is important to note that this association was independent of BMD and age. It is not possible in this study to pinpoint the mechanism of the excess of mortality.

### Table 4. Vertebral Deformity and Mortality in Men and Women

<table>
<thead>
<tr>
<th>Mortality, N (%)</th>
<th>Vertebral deformity</th>
<th>No vertebral deformity</th>
<th>( HR^* ) (95% CI)</th>
<th>( HR^† ) (95% CI)</th>
<th>( HR^‡ ) (95% CI)</th>
<th>Posterior probability that the HR &gt; 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>All N = 66 N = 234</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total deaths</td>
<td>20 (30.3)</td>
<td>25 (10.7)</td>
<td>2.7 (1.5–4.9) (^b)</td>
<td>2.7 (1.5–5.1) (^b)</td>
<td>2.9 (1.6–5.2) (^b)</td>
<td>0.83</td>
</tr>
<tr>
<td>Death after fracture</td>
<td>12 (18.2)</td>
<td>5 (2.1)</td>
<td>9.0 (3.1–26.0) (^b)</td>
<td>8.1 (2.7–24.6) (^b)</td>
<td>8.6 (2.9–24.9) (^b)</td>
<td>1.00</td>
</tr>
<tr>
<td>Death without fracture</td>
<td>8 (12.1)</td>
<td>20 (8.5)</td>
<td>1.2 (0.3–3.2)</td>
<td>1.4 (0.6–3.3)</td>
<td>1.5 (0.6–3.4)</td>
<td>0.20</td>
</tr>
<tr>
<td>Men N = 35 N = 79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total deaths</td>
<td>8 (22.9)</td>
<td>13 (16.5)</td>
<td>1.6 (0.7–3.9)</td>
<td>1.4 (0.6–3.5)</td>
<td>1.7 (0.7–4.1)</td>
<td>0.31</td>
</tr>
<tr>
<td>Death after fracture</td>
<td>4 (11.4)</td>
<td>3 (3.8)</td>
<td>5.3 (1.0–28.1)</td>
<td>3.0 (0.6–16.2)</td>
<td>5.4 (1.0–28.6)</td>
<td>0.87</td>
</tr>
<tr>
<td>Death without fracture</td>
<td>4 (11.4)</td>
<td>10 (12.7)</td>
<td>1.8 (0.9–3.3)</td>
<td>1.1 (0.3–3.5)</td>
<td>1.1 (0.3–3.7)</td>
<td>0.38</td>
</tr>
<tr>
<td>Women N = 31 N = 155</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total deaths</td>
<td>12 (38.7)</td>
<td>12 (7.7)</td>
<td>5.0 (2.2–11.2) (^b)</td>
<td>5.6 (2.4–13.1) (^b)</td>
<td>5.4 (2.3–12.7) (^b)</td>
<td>1.00</td>
</tr>
<tr>
<td>Death after fracture</td>
<td>8 (25.8)</td>
<td>2 (1.3)</td>
<td>27.7 (5.7–134.1) (^b)</td>
<td>29.5 (5.9–147.5) (^b)</td>
<td>30.5 (6.1–151.5) (^b)</td>
<td>1.00</td>
</tr>
<tr>
<td>Death without fracture</td>
<td>4 (12.9)</td>
<td>10 (6.5)</td>
<td>1.7 (0.5–5.5)</td>
<td>1.9 (0.6–6.7)</td>
<td>1.7 (0.6–5.1)</td>
<td>0.40</td>
</tr>
</tbody>
</table>

\(^{a}\) Adjusted for age and sex.  
\(^{b}\) Adjusted for age, sex, and femoral neck BMD.  
\(^{c}\) Adjusted for age, sex, and body weight.  
\(^{§}\) Statistically significant at \( p < 0.001 \).
associated with vertebral deformity; however, the effects of lifestyle factors and other concomitant diseases cannot be ruled out.

Because of the relatively small number of deaths and fractures, no subgroup analysis was done. Nevertheless, among the 17 deaths after fracture, 7 had symptomatic vertebral fracture, 2 had hip fractures, 5 had major fractures, and 3 had Colles’ fracture. These fractures have been previously reported to be associated with increased mortality. It could be argued that the vertebral deformity–mortality relationship was mainly attributable to the fracture associated with a vertebral deformity.

The cause of death in this study was not ascertained. However, previous studies have suggested that low BMD and co-morbidity/disability was each associated with increased risk of death. In this study, the effect of difference in mortality rate between vertebral and nonvertebral deformity groups was only evident after 6 years. This suggests that short time studies are less likely to observe the effect of vertebral deformity on mortality, and the median of time of fracture to the time of death was 1.9 years. It also suggests that the time after fracture presents a window of opportunity for intervention to save lives.

The prevalence of vertebral deformity in this population was between 17% and 30%, which is comparable with the prevalence of low BMD (10% in men and 25% in women). The prevalence of vertebral deformity or low BMD was 38%, and given their independent effects on fracture risk, this high prevalence suggests that up to 40% of elderly were at high but unrecognized risk of fracture, because only about one-third of vertebral deformities have been reported to come to clinical attention. The data presented here have important clinical implications, in that individuals who had vertebral deformity combined with low BMD (two risk factors) had the highest risk of fracture (83%) and death (70%) compared with individuals with normal BMD and without prior vertebral deformity (28% for fracture and 23% for death). On the other hand, for individuals with either a baseline vertebral deformity or low BMD, the risk of fracture and death was intermediate and only modestly, 1.6- and 2-fold, above those without either risk factor in both men and women. This finding supports that early identification and targeting of interventions in elderly men and women with a vertebral deformity with or without low BMD may reduce subsequent fractures as well as the burden of morbidity and mortality.

Despite a prospective and long duration of follow-up, the study has some potential limitations. Vertebral deformity was defined using a morphometric approach that does not completely exclude deformities because of congenital changes and Scheuermann’s disease; therefore, some misclassification could have occurred. However, the effect of this type of misclassification on the result would decrease the association observed. For the mortality data, we did not collect the cause of death; therefore, it was difficult to make inference regarding the link between fracture and death. However, this study used a fracture ascertainment system that completely documented all fractures and objectively verified the fracture type.

In conclusion, a vertebral deformity predicts subsequent fracture risk particularly symptomatic vertebral fracture, and is associated with increased fracture-associated mortality in elderly men and women. Vertebral deformity should be considered a primary risk factor for fracture and mortality, particularly in combination with low BMD. Intervention in this subgroup may be cost effective and beneficial to the community.

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REFERENCES

VERTEBRAL DEFORMITY AS A RISK FACTOR FOR FRACTURES AND MORTALITY


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