

Original Article

Prevalence of Vertebral Compression Fracture Deformity by X-ray Absorptiometry of Lateral Thoracic and Lumbar Spines in a Population Referred for Bone Densitometry

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Abstract

The presence of a vertebral compression fracture has been demonstrated to be a predictor of future fracture independent of bone mineral density in prospective cohort studies. Fan-beam densitometers are now available that can image the thoracic and lumbar spines and detect deformities consistent with fracture. We report a pilot study of 342 patients referred for bone densitometry who had lateral vertebral imaging performed. Fifty patients (14.6%) of the entire cohort had one or more vertebral deformities identified on lateral vertebral imaging. Seventy-three patients (21.3%) of the entire cohort were 60 or more years of age and had osteopenia by World Health Organization (WHO) criteria (T-score: -1.0 to -2.4 at the spine, total hip, or femoral neck). Twenty of these patients (27.4%) had one or more vertebral deformities. Without identifying prevalent vertebral deformities, these individuals at high risk for fracture may not be offered pharmacologic therapy to reduce fracture risk. Therefore, it may be reasonable to obtain lateral vertebral imaging at least for individuals age ≥ 60 yr who have mild to moderate bone loss at the spine or hip.

Key Words: Lateral vertebral X-ray absorptiometry; vertebral compression fracture; vertebral deformity.

Introduction

Vertebral fractures are common in the general population, increasing in prevalence with advancing age. In an age-stratified random sample of postmenopausal white women, Melton and colleagues noted that the percentage of those with prevalent vertebral deformities consistent with fracture on standard radiographs rose from 10.1% of women age 50–54 to 55% of those age 80 and older (1).

Prior vertebral fractures are associated with a 4- to 5-fold increased risk of future spine fractures (2–4) and 1.5-fold increased risk of future hip fractures (4), independent of bone mineral density. Incident vertebral fractures, even ones that have not been recognized clinically, are associated with increased chronic back pain and functional limitation (5). Prevalent vertebral fracture is associated with an increased risk of hospitalization (6) and mortality (6,7). If a prior vertebral fracture has occurred with minor or no trauma, pharmacologic treatment may be indicated even if bone density is only mildly reduced.

Only 20–30% of vertebral fractures are recognized clinically (8), and the rest are discovered incidentally on radiographs. Until recently, identifying

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these prevalent fractures has required lateral thoracic and lumbar spine radiographs. Lateral spine images of near-radiographic quality can now be obtained with fan-beam X-ray absorptiometry. Studies have shown reasonably good agreement between assessment of vertebral fractures on lateral densitometry imaging and standard radiographs (9–12). Using standard radiography as a gold standard, Rea and colleagues found that lateral X-ray absorptiometry could identify vertebral deformities consistent with fracture with 68.4% sensitivity and the subset of moderate to severe deformities with 79% sensitivity (9). When the analysis was restricted to vertebral levels T7–L4, where the majority of vertebral compression fractures occur, the sensitivity of X-ray absorptiometry improved to 81.2%. The specificity of X-ray absorptiometry was 98.4% in analyzable vertebrae, the positive predictive value was 84.6%, and the negative predictive value was 97.5%.

In a second small study of 21 women, 10 of whom were considered normal and 11 of whom had known vertebral deformities, the agreement between standard radiographs evaluated by semiquantitative criteria and two sets of X-ray absorptiometry scans was very good, with kappa scores of 0.84 and 0.87, respectively (10). Although this study did show that the reproducibility of vertebral height measurement was poorer for X-ray absorptiometry than for standard radiographs, the precision error for X-ray absorptiometry was still much smaller than the 20% height reduction criterion often used to define incident vertebral deformities (11). Ferrar and Eastell found that short-term precision of vertebral height measurement was better with standard radiographs, but that long-term precision was equivalent between standard radiographs and X-ray absorptiometry (12).

None of these studies, however, have evaluated the prevalence of vertebral deformity as determined by X-ray absorptiometry in a population representative of those referred for bone densitometry in clinical practice. This is pertinent, because using X-ray absorptiometry to detect these deformities is intended to be done at the time of a bone mineral density (BMD) test. The purpose of our pilot study was to determine the prevalence of vertebral deformities in a consecutive sample of individuals referred for bone densitometry, using lateral spine X-ray absorptiometry. We also wished to explore other factors associated with

prevalent vertebral fracture, specifically age and bone density, that may, in the future, allow us to perform lateral vertebral imaging more cost-effectively in a selected subgroup of those referred for bone densitometry.

Materials and Methods

The Park Nicollet Osteoporosis Center is the sole provider of bone densitometry services for a large, suburban multispecialty integrated health care system with 500 physicians, caring for 300,000 patients. Half of those referred have their bone density test done on a Hologic Delphi C densitometer (Hologic, Inc., Bedford, MA) that can obtain lateral spine images to detect vertebral deformities. The other half are tested on a Hologic 4500sl densitometer, which, at the time of this study, did not have this capability.

The Park Nicollet Institutional Review Board granted approval of the study.

Prior to the start of the study, the four participating physicians together evaluated lateral vertebral images obtained for 25 patients on the Hologic Delphi C densitometer, by a combination of the semiquantitative criteria of Genant (13) and quantitative morphometry. Through this process, we established that all four physicians were interpreting and applying the Genant criteria and measuring vertebral heights the same way.

We offered lateral vertebral imaging to 456 consecutive patients scheduled to have a bone density test on the Hologic Delphi C densitometer from February 6, 2001 through April 3, 2001. Three hundred forty-two (342) agreed to have this done and gave signed, informed consent; 114 refused the procedure. The lateral vertebral images were evaluated by one of four physicians assigned to read bone density tests for that day. Each of the vertebrae from T4 to L4 was first evaluated for image quality. We considered vertebrae whose superior and inferior end plates could be seen from the posterior to anterior borders of the vertebra to be evaluable. Those evaluable vertebrae were graded for deformity according to a combination of the semiquantitative method of Genant and quantitative morphometry. For vertebrae that appeared to be clearly or possibly deformed visually, the posterior, middle, and anterior heights were measured by hand. Vertebrae were judged to be

Table 1
Vertebral Deformities by Semiquantitative Criteria of Genant

Grade	Type	Criteria
1	Wedge	20–24% reduction of anterior height compared to posterior height
1	Biconcave	20–24% reduction of midvertebral compared to posterior height
1	Crush	20–24% reduction of posterior height compared to posterior heights of adjacent vertebrae above and below.
2	Wedge	25–39% reduction of anterior height compared to posterior height
2	Biconcave	25–39% reduction of midvertebral compared to posterior height
2	Crush	25–39% reduction of posterior height compared to posterior heights of adjacent vertebrae above and below.
3	Wedge	≥40% reduction of anterior height compared to posterior height
3	Biconcave	≥40% reduction of midvertebral compared to posterior height
3	Crush	≥40% reduction of posterior height compared to posterior heights of adjacent vertebrae above and below

normal or to have grade 1 (mild), grade 2 (moderate), or grade 3 (severe) deformity, according to the percent height loss of the posterior, middle, or anterior portions of the vertebrae (*see* Table 1). The deformity was also classified by type (wedge, biconcave, or crush). For posterior (crush) deformities, we required that the height reduction criteria compared to the posterior vertebral height of the adjacent vertebra both above and below the vertebra in question be satisfied. Interpreting lateral vertebral images required less than 1 min if the vertebrae all appeared normal, and up to 5 min if vertebra(e) were questionable or appeared deformed.

Frequencies for all categorical variables were calculated. These included the percentage of vertebra considered evaluable at each vertebral level, the number of deformed vertebrae broken down by type and severity, and the number of patients with no deformity, one deformity, or two or more deformities. The mean and standard deviation of continuous variables, specifically bone mineral density at the lumbar spine, total hip, and femoral neck, were also calculated. Finally, the percentage of patients with one or more deformed vertebrae was established for different age and bone density categories. Ninety-five percent confidence intervals for these percentages were calculated using a formula for binomial distributions valid for small sample sizes (14).

The age categories were chosen based on the smoothed prevalence data of Melton et al. (1) and the expected reduction of sensitivity of X-ray absorp-

tiometry for vertebral deformity (9). We expected the percentage of individuals with one or more vertebral deformities to be less than 10% for those under age 60, but over 20% for individuals over age 70.

Results

The demographic characteristics of patients who accepted lateral vertebral imaging compared to those who refused the procedure are shown in Table 2. No statistically significant differences were noted in age, weight, or bone mineral density of the lumbar spine, total hip, or femoral neck ($p > 0.1$ for each, by two-tailed t -test). Only 12 of those who had the procedure (3.5%) and 1 of those who refused were male.

Sixty-six vertebral deformities consistent with fracture were seen in 50 patients (14.6% of the total population). Thirty-nine patients had 1 deformity, and 11 had 2 or more. For each vertebral level, the percentage of evaluable vertebrae is shown in Table 3. The percentage of evaluable vertebrae that had a deformity is also shown for each vertebral level. Of a total of 4446 vertebrae, 4096 (92.1%) were considered evaluable. Deformities consistent with fractures were mostly seen from T8 through L1, and 94–99% of the vertebrae were evaluable at each of these levels. As has been reported by others, vertebrae from T4 to T6 were less likely to be evaluable (9).

Table 4 classifies the 66 deformities by type and severity. Most were anterior wedge deformities, and most were grade 1. Twenty-two patients had 1 grade

Table 2
Demographic Characteristics of Study Population

Category	Accepted lateral spine imaging	Refused lateral spine imaging
Total number	342	114
Age ^a (yr) (range)	58.7 ± 10.9 (28–93)	59.8 ± 11.2 (26–91)
Mean weight (lbs)	156	153
Mean bone mineral density (g/cm ²) (± standard deviation)		
Lumbar spine	0.971 ± 0.152	0.953 ± 0.169
Total hip	0.883 ± 0.138	0.865 ± 0.156
Femoral neck	0.740 ± 0.118	0.728 ± 0.144
Sex (female/male)	330/12	113/1
Race		
White/Hispanic	336	112
Asian	4	2
African-American	2	0

^a Data are presented as mean ± standard deviation with the range in parentheses.

Table 3
Percentages of Evaluable and Deformed Vertebrae by Level

Vertebral level	No. evaluable vertebrae (% total)	No. deformed vertebrae (% of evaluable vertebrae)
T4	215(63)	0
T5	270(79)	0
T6	299(87)	2 (0.7)
T7	308 (90)	7 (2.3)
T8	322 (94)	10 (3.1)
T9	328 (96)	6 (1.8)
T10	327 (96)	2 (0.6)
T11	332 (97)	11 (3.3)
T12	336 (98)	12 (3.6)
L1	337 (99)	10 (3.0)
L2	342 (100)	1 (0.3)
L3	342 (100)	2 (0.6)
L4	338 (99)	3 (0.9)

1 deformity only, and 28 had 1 grade 2 or 3 deformity and/or 2 or more deformities.

Table 5 shows the percentages of patients in categories of age and bone density that were judged to have one or more vertebral deformities. Unexpectedly, 9.3% of individuals younger than age 60 with normal

bone density had one or more deformities, but the confidence interval around this percentage is large (4.3–16.8%). Otherwise, as expected, deformities were more prevalent with advancing age and greater degrees of bone loss. Of the entire cohort, 14.6% had one or more deformities, with a 95% confidence inter-

Table 4
Classification of Vertebral Deformities by Type and Grade of Severity

Type of deformity	Severity grade of deformity			Totals
	1	2	3	
Wedge	30	16	7	53
Biconcave	8	0	0	8
Crush	3	0	2	5
Totals	41	16	9	66

Table 5
Numbers and Percentages of Patients with One or More Vertebral Deformities, According to Age and Bone Mineral Density at the Spine, Total Hip, and Femoral Neck (95% Confidence Interval)

Bone mineral density	Age < 60	Age 60–69	Age ≥ 70	Totals
Normal ^a	9/97 (9.3%) (CI 4.3–16.8%)	2/30 (6.7%) (CI 0.8–22.1%)	1/7 (14.3) (CI 0.4–57.9%)	12/134 (8.9%) (CI 4.7–15.1%)
Osteopenia ^b	3/89 (3.4%) (CI 0.7–9.5%)	7/44 (15.9%) (CI 6.6–30.1%)	13/29 (44.9%) (CI 26.4–64.3%)	23/162 (14.2%) (CI 9.2–20.4%)
Osteoporosis ^c	2/15 (13.3%) (CI 1.7–40.5%)	3/12 (25.0%) (CI 5.5–57.2%)	10/19 (52.6%) (CI 28.9–75.6%)	15/46 (32.6%) (CI 19.5–48.0%)
Totals	14/201 (7.0%) (CI 3.9–11.4%)	12/86 (14.0%) (CI 7.4–23.1%)	24/55 (43.6%) (CI 30.3–57.7%)	50/342 (14.6%) (CI 11.0–18.8%)

^a Normal: T-score >–1.0 at the lumbar spine, total hip, and femoral neck.

^b Osteopenia: T-score between –1.0 and –2.4 at the lumbar spine, total hip, or femoral neck, but >–2.5 at all three.

^c Osteoporosis: T-score ≤–2.5 at the lumbar spine, total hip, or femoral neck.

val of 11.0–18.8%. The confidence intervals for the percentages of patients with one or more deformities in the smaller subsets defined by age and bone density are quite wide (*see* Table 5).

Among the 73 patients age 60 and older with osteopenia, 20 had 1 or more vertebral deformities (27.4%, 95% confidence interval 17.6–39.1%).

All of these results are unchanged when the data are analyzed for women only.

Discussion

In this study, lateral vertebral imaging by X-ray absorptiometry appeared to be successful in identifying vertebral deformities consistent with fracture in a significant percentage of patients referred for bone densitometry.

We believe that identifying these deformities may be particularly important in patients who do not have osteoporosis by bone mineral density criteria. These individuals are at high risk of future vertebral fracture, and, yet, if their vertebral deformities are undetected, they may not be offered pharmacologic therapy to reduce their fracture risk. Although bisphosphonates are Food and Drug Administration (FDA) approved for treatment of those with osteopenia by World Health Organization (WHO) criteria, current treatment guidelines from the National Osteoporosis Foundation recommend treatment for those with T-scores <–2.0 if they do not have other recognized risk factors for fracture (15). Other recognized experts in the field of osteoporosis have published even more conservative guidelines, suggesting pharmacologic therapy only for those with T-

score <-2.5 (16). A recent post hoc analysis of data from the Fracture Intervention Trial suggests that bisphosphonate therapy can reduce the incidence of clinical vertebral fracture by 66% in those with one or more prevalent vertebral fractures and femoral neck T-score >-2.5 (17).

Our data suggest that performing lateral vertebral X-ray absorptiometry at the time of bone densitometry to assess for fracture may be particularly appropriate for individuals age 60 and older who have osteopenia by WHO criteria. We are not confident that the prevalence of detectable deformities by X-ray absorptiometry in younger individuals would justify use of the procedure. The age cutoff, if any, over which this procedure is reasonable will need to be established with larger studies.

We are also not certain that pharmacologic therapy in those with one or more vertebral deformities and *normal* bone density at the spine, total hip, and femoral neck cost-effectively reduces the risk of future fractures. The role of lateral X-ray absorptiometry to detect vertebral deformity and its cost-effectiveness in those with normal bone density also need further study.

Clearly, those with osteoporosis and vertebral deformity have a particularly high risk of future fracture. At this time, we are not routinely doing this procedure in those who have osteoporosis by bone density criteria, as pharmacologic therapy is indicated in these individuals even if they do not have any vertebral deformities. If incident deformities occur while on therapy in those with osteoporosis, however, additional therapy may be appropriate to consider because 20% of those with an incident deformity will have a subsequent vertebral fracture within 1 yr (18). This may be particularly relevant once parathyroid hormone is available. Outcome studies of the documentation of vertebral deformities in those with T-scores <-2.5 on clinical management are needed.

There are several limitations to this study. We did not obtain standard spine radiographs to compare to lateral X-ray absorptiometry images or to confirm deformities detected on X-ray absorptiometry. It is probable that a minority of the apparent deformities, especially those that were grade 1, would not have appeared deformed on standard radiography. Although we tried to standardize our image-reading

technique before embarking on the study, we did not formally measure agreement among the four physicians in this study. The sample size of this pilot study is relatively small, and the confidence intervals around our estimates of percentages of patients with vertebral deformities are wide in the subsets defined by age and bone density.

The main strength of this study is that the study population was a sample of patients consecutively referred for bone densitometry to the sole densitometry unit used by 500 physicians caring for a patient population of 300,000. We believe this is the first study to show how lateral spine X-ray absorptiometry to detect vertebral deformities might perform in clinical practice at the time of a bone density test. Although the study population is small, the percentages of patients identified as having deformities appears to be consistent with prevalence studies in the general population (1). Similarly, the percentage of vertebrae considered evaluable was consistent with other studies (9,19). The majority of detected deformities were in the lower thoracic and upper lumbar spine, again consistent with other studies (20,21).

Our estimates of the prevalence of vertebral deformities may be conservative, because we required that a vertebra look visually deformed *and* meet height-loss criteria morphometrically to be considered deformed, rather than relying solely on a visual reading, as did Rea et al. (9). We chose these criteria because the vertebral end plates on X-ray absorptiometry are not as clear and distinct as on standard radiographs.

A reasonable question is whether or not these individuals should have standard lateral spine radiographs to look for vertebral deformities. Standard radiographs are more accurate in differentiating normal from deformed vertebrae than X-ray absorptiometry (11,15), particularly in the upper thoracic vertebrae. Lateral X-ray absorptiometry is not an appropriate substitute for radiography in clinical practice in the workup of symptomatic back pain or in other situations in which the presence or absence of a vertebral fracture needs to be firmly established.

Lateral X-ray absorptiometry at the time of bone densitometry, however, requires little additional technician time to acquire the image and physician time to interpret it. Therefore, the direct medical cost of lateral X-ray absorptiometry to detect vertebral

deformity as an additional risk factor for future fracture is likely to be much less than standard radiography. The radiation exposure with lateral X-ray absorptiometry is also far less than with standard radiographs.

Practically, obtaining lateral images of the thoracic and lumbar spines at the time of the bone density study is also more desirable for the patient, as they do not have to have a separate X-ray done. The reader of the study also benefits because the lateral spine view can be evaluated at the time of BMD interpretation. As a result, this information can be incorporated into a final set of recommendations for the physician who requested the BMD test more efficiently.

Rea and colleagues suggest that X-ray absorptiometry may be most accurate in ruling out vertebral deformity and that standard radiography then be used to further evaluate deformed or questionable vertebrae (9). We believe that most of the deformities noted in our study were unequivocal. In general, we believe that using standard radiographs in clinical practice to evaluate equivocal vertebrae is the best approach, particularly if documentation of vertebral deformity will alter therapeutic management.

We conclude that X-ray absorptiometry can be appropriately utilized in clinical bone densitometry units to detect vertebral deformities and further define the risk of future fracture in these individuals, provided they do not have other clinical indications for standard spine radiographs. Further research is needed to better define the subset(s) of individuals who may benefit from the procedure, the role of standard radiography in confirming possible deformities, and the effect of the procedure on clinical therapeutic decisions.

References

- Melton LJ, Lane AW, Cooper C, Eastell R, O'Fallon WM, Riggs BL. 1993 Prevalence and incidence of vertebral deformities. *Osteoporos Int* 3:113–119.
- Ross PD, Davis JW, Epstein RS, Wasnich RD. 1991 Pre-existing fractures and bone mass predict vertebral fracture incidence in women. *Ann Intern Med* 114:919–923.
- Ross PD, Genant HK, Davis JW, Miller PD, Wasnich RD. 1993 Predicting vertebral fracture incidence from prevalent fractures and bone density among non-black, osteoporotic women. *Osteoporosis Int* 3:120–126.
- Black DM, Arden NK, Palermo L, Pearson J, Cummings SR. 1999 Prevalent vertebral deformities predict hip fractures and new vertebral deformities but not wrist fractures. *J Bone Miner Res* 14:821–828.
- Nevitt MC, Ettinger B, Black DM, et al. 1998 The association of radiographically detected vertebral fractures with back pain and function: a prospective study. *Ann Intern Med* 128:793–800.
- Ensrud KE, Thompson DE, Cauley JA, et al. 2000 Prevalent vertebral deformities predict mortality and hospitalization in older women with low bone mass. *J Am Geriatr Soc* 48:241–249.
- Center JR, Nguyen TV, Schneider D, Sambrook PN, Eisman JA. 1999 Mortality after all major types of osteoporotic fracture in men and women: an observational study. *Lancet* 353:878–882.
- Ensrud KE, Nevitt MC, Palermo L, et al. 1999 What proportion of incident morphometric vertebral fractures are clinically diagnosed and vice versa? *J Bone Miner Res* 14(Suppl):S138.
- Rea JA, Li J, Blake GM, Steiger P, Genant HK, Fogelman I. 2000 Visual assessment of vertebral deformity by X-ray absorptiometry: a highly predictive method to exclude vertebral deformity. *Osteoporos Int* 8:660–668.
- Rea JA, Li J, Blake GM, Steiger P, Genant HK, Fogelman I. 2000 Reproducibility of visual vertebral deformity assessment on lateral X-ray absorptiometry scans and conventional radiographs of the spine. *J Bone Miner Res* 15(Suppl):S285 (abstract).
- Rea JA, Chen MB, Li J, et al. 2001 Vertebral morphometry: a comparison of long-term precision of morphometric X-ray absorptiometry and morphometric radiographs in normal and osteoporotic patients. *Osteoporosis Int* 12:158–166.
- Ferrar L, Eastell R. 1998 Short and long-term precision of vertebral heights and height ratios measured by morphometric radiography (MR) and morphometric X-ray Absorptiometry (MXA). *Bone* 23(Suppl 5):S605 (abstract).
- Genant HK, Wu CY, van Kujik C, Nevitt MC. 1993 Vertebral fracture assessment using a semiquantitative technique. *J Bone Miner Res* 8:1137–1148.
- Brown LP, Cai TT, Das Gupta A. 2001 Interval estimation for a binomial proportion. *Statis Sci* 16:101–117.
- National Osteoporosis Foundation, 1999 Physician's Guide to Prevention and Treatment of Osteoporosis. Washington DC: National Osteoporosis Foundation.
- Meunier PJ, Delmas PD, Eastell R, et al. 1999 Diagnosis and management of osteoporosis in postmenopausal women: clinical guidelines. *Clin Ther* 21:1025–1044.
- Quaid SA, Thompson DE, Schneider D, Nevitt M, Musliner T. 2001 Alendronate reduces the risk of clinical vertebral fracture in osteopenic women: data from FIT. *Bone* 28(Suppl 5):P575 (abstract).
- Lindsay R, Silverman SL, Cooper C, et al. 2001 Risk of new vertebral fracture in the year following a fracture. *JAMA* 285:320–323.
- Ferrar L, Eastell R. 1999 Identification of vertebral deformities in men: comparison of morphometric radiography and morphometric X-ray absorptiometry. *Osteoporosis Int* 10:167–174.

20. Hasserijs R, Redlund-Johnell I, Mellstrom D, Johansson C, Nilsson BE, Johnell O. 2001 Vertebral deformation in urban Swedish men and women: prevalence based on 397 subjects. *Acta Orthop Scand* 72:273–278.
21. Jackson SA, Tenenhouse A, Robertson L. 2000 Vertebral fracture definition from population-based data: preliminary results from the Canadian Multicenter Osteoporosis Study (CaMos). *Osteoporosis Int* 11:680–687.