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ORIGINAL ARTICLE

Lateral vertebral assessment: a valuable technique to detect clinically significant vertebral fractures

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Abstract Although many vertebral fractures are clinically silent, they are associated with increased risk for subsequent osteoporotic fractures. A substantial number of these fractures are demonstrable using instant vertebral assessment with Hologic densitometers. Whether similar recognition is possible using dual-energy lateral vertebral assessment (LVA) with GE Lunar densitometers remains uncertain. Thus, we evaluated the ability of clinicians using LVA to detect prevalent vertebral fractures. Dual-energy LVA and conventional thoracic and lumbar spine radiographs were concurrently obtained in 80 postmenopausal women. Using an established visual semiquantitative system, vertebral fractures were identified individually by two non-radiologist clinicians on LVA images, and the results were compared with spinal radiograph evaluation by an expert radiologist. Using LVA, 95% of vertebral bodies from T7 through L4 were evaluable, but a majority (66%) of vertebrae from T4 to T6 were not adequately visualized. In the LVA-evaluable vertebrae, prevalent fractures were identified in 40 vertebral bodies by radiography. In this regard, the clinicians using LVA detected 17 of 18 radiographically evident vertebral fractures of grade 2 or 3, a false negative rate of 6%. They identified 50% (11/22) of grade 1 fractures. Additionally, the vast majority of evaluable non-fractured vertebrae, (764/794, 96.2%) were correctly classified as normal by LVA. Thus, clinicians utilizing LVA correctly identified the vast majority of grade 2 or 3 vertebral compression fractures and normal vertebral bodies, although detection of grade 1 fractures was less effective. In conclusion, the low-radiation, dual-energy LVA technique provides a rapid and convenient way for clinicians to identify patients with, and without, grade 2 or 3 vertebral fractures, thereby enhancing care of osteoporotic patients.

Keywords Instant vertebral assessment · Lateral vertebral assessment · Osteoporosis · Radiography · Vertebral fracture

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Introduction

Vertebral compression fractures due to osteoporosis are associated with pain, kyphosis, reduced quality of life and increased mortality [1–6]. Furthermore, people who have sustained such vertebral deformities are at increased risk for future fracture [7, 8] and should receive aggressive osteoporosis treatment. However, since many vertebral fractures are silent [9], often neither the patient nor clinician appreciates this increased risk. To better define fracture risk, therefore, bone mass measurement ideally should be combined with assessment of vertebral fracture status. Although coincidentally performed conventional radiography would permit such assessment, this would necessitate additional expense, inconvenience and radiation exposure. To minimize these concerns, lateral spine imaging using currently available bone densitometers may prove a viable option [10–13]. Whereas existing data suggest that this is feasible using Hologic densitometers [11], it is not established that clinicians utilizing GE Lunar instruments are able to detect fractures compared with radiologists using standard radiographs. Thus, in this study we evaluated the ability of clinical densitometrists utilizing lateral spine DXA imaging to detect vertebral fractures in comparison with an expert radiologist's interpretation of spine radiographs.

Methods

Subjects

Eighty Caucasian postmenopausal women participating in osteoporosis treatment studies or having clinical bone mass measurement performed were invited by the research study coordinator or densitometry technologist to participate in this study. This study was approved by the University of Wisconsin Health Sciences IRB.

Lateral vertebral assessment (LVA) and radiography

Dual-energy LVA imaging was performed in the lateral decubitus position (Fig. 1) utilizing GE Lunar Prodigy densitometers with software version 4.0 (GE Medical Systems Lunar, Madison, WI, USA). The LVA image was evaluated by two non-radiologist clinicians (N.B./M.K.D.) and consensus reached for any difference of interpretation. Immediately following acquisition of the LVA image, lateral thoracic and lumbar spine images were obtained in routine clinical manner. These images were analyzed by an expert skeletal radiologist (H.K.G.) utilizing a digital imaging system.

Fig. 1 Positioning for lateral vertebral assessment: Participants were positioned in the decubitus position as per manufacturer's recommendations

Vertebral fracture assessment

Initially, we reviewed all LVA images and excluded non-evaluable vertebrae from the study. Subsequently, all adequately visualized vertebrae were evaluated for deformity using an established semiquantitative visual scoring system (Fig. 2) [14, 15]. Using this system, a grade 1 (mild) fracture is defined as an approximate 20–25% reduction in either anterior or middle or posterior height relative to the adjacent vertebral bodies; a grade 2 (moderate) fracture is an estimated 25–40% reduction in any height and a grade 3 (severe) fracture is a reduction of greater than approximately 40% in any height. Two non-radiologist physicians (N.B./M.K.D.) visually evaluated the LVA images independently then mutually agreed upon a consensus interpretation. Radiographic fractures were detected by an expert radiologist (H.K.G.).

Data analysis

The expert radiologist's assessment was utilized as the gold standard. The correct assessment of fracture status by the clinicians utilizing LVA is reported as percentages and either false-positive or false-negative rate. The overall agreement, beyond that expected by chance alone, between LVA and radiograph interpretation (both fracture and non-fracture) was evaluated using the kappa score. For this calculation, vertebral bodies were classified as normal or fractured. Only those vertebral bodies that could be adequately visualized on LVA were included in the kappa score calculation.

Results

Subjects

One of the 80 subjects recruited for this study was excluded due to a non-evaluable LVA image that precluded adequate visual assessment of vertebral structure. Subject age ranged from 61–84 years, mean 72.8 ± 0.5 (SEM). Applying the World Health Organization (WHO) criteria, T -scores of the L1–L4 spine, total proximal femur, femoral neck and/or trochanteric region established that 27 of these women were osteoporotic, 38 osteopenic and 15 normal. The group mean lumbar spine T -score was -1.7.

Evaluation of vertebral bodies by LVA

Of 1,027 potentially evaluable vertebrae from T4 through L4, 834 (81%) were adequately visualized on LVA imaging to permit assessment for the presence of

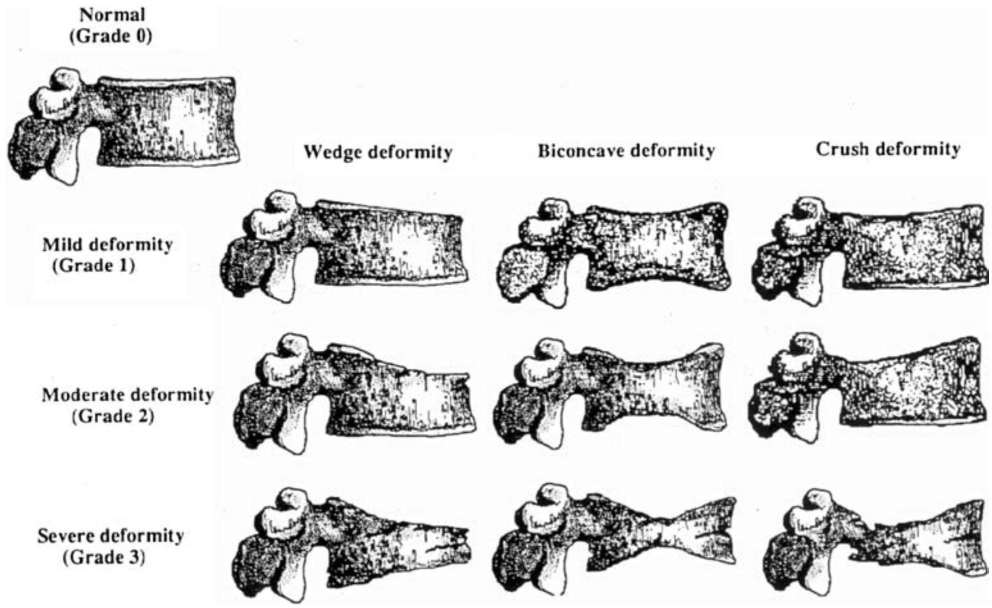

Fig. 2 Visual semiquantitative system utilized to evaluate vertebral deformities: Reproduced from Genant et al. [14]

fracture. Most, 81% (156/193), of the non-evaluable vertebral bodies were located from T4 through T6. Conversely, 95% (753/790) of vertebral bodies from T7 through L4 were adequately visualized.

Identification of vertebral fractures

Eighteen grade 2 or grade 3 fractures were identified on the spine radiographs. Five fractures were present at L2, four at L1, two each at L3, T9 and T8, and one each at T6, T7 and T12. All of these fractures occurred in vertebral bodies adequately visualized on LVA. All but one fracture was correctly detected as being grade 2 or grade 3 by the clinicians; this vertebral body was incorrectly interpreted as normal, resulting in a false negative rate of 6% (Table 1). The single fracture missed on LVA was a T7 grade 2 fracture. A single vertebral body was incorrectly identified as a grade 2 fracture on LVA, when, in fact, it was normal on the radiologist's reading.

Twenty-nine grade 1 fractures were identified radiographically, nine at T7, four at T8, three each at T6 and L1, two each at T4, T9, T12, and L4, and one each at T5 and L3. Of these 29 fractures, 22 were in vertebral bodies evaluable on LVA images. Of these evaluable vertebrae, 11 were classified as fractures on the LVA image, and 11 had no detectable abnormalities, a false negative rate of 50% (Table 1). Conversely, 29 vertebrae were classified as having grade 1 fracture on LVA where no fracture was detected on radiographs. Examples of correct, false-negative and false-positive evaluation of grade 1 fractures on LVA are shown in Fig. 3.

Table 1 Radiography versus LVA fracture interpretation

	LVA			
Radiography	Grade 2/3	Grade 1	Normal	Total
Grade 2/3	17	0	1	18
Grade 1	0	11	11	22
Normal	1	29	764	794
Total	18	40	776	-

Identification of normal vertebrae

In the 834 vertebral bodies adequately visualized on LVA, there were 794 that were non-fractured per radiograph. Of these, 764 (96.2%) were correctly classified as normal on the LVA. However, 30 were incorrectly classified as fractured when no fractures were detected by radiograph, a false positive rate of about 3.8% (Table 1). All but one of these 30 false positives were felt to be grade 1 fractures by the clinicians utilizing LVA.

Agreement between LVA and radiography

The kappa statistic was utilized to evaluate overall agreement between LVA and radiography for evaluable vertebrae. All LVA evaluable vertebral bodies were utilized and classified as either fractured or not fractured. Overall, there was fair agreement (95%) with the kappa statistic =0.545.

Discussion

DXA-based vertebral fracture assessment using LVA is an excellent technique to detect grade 2 and grade 3 vertebral compression fractures. Using this technology, clinicians correctly identified 94% of radiographically

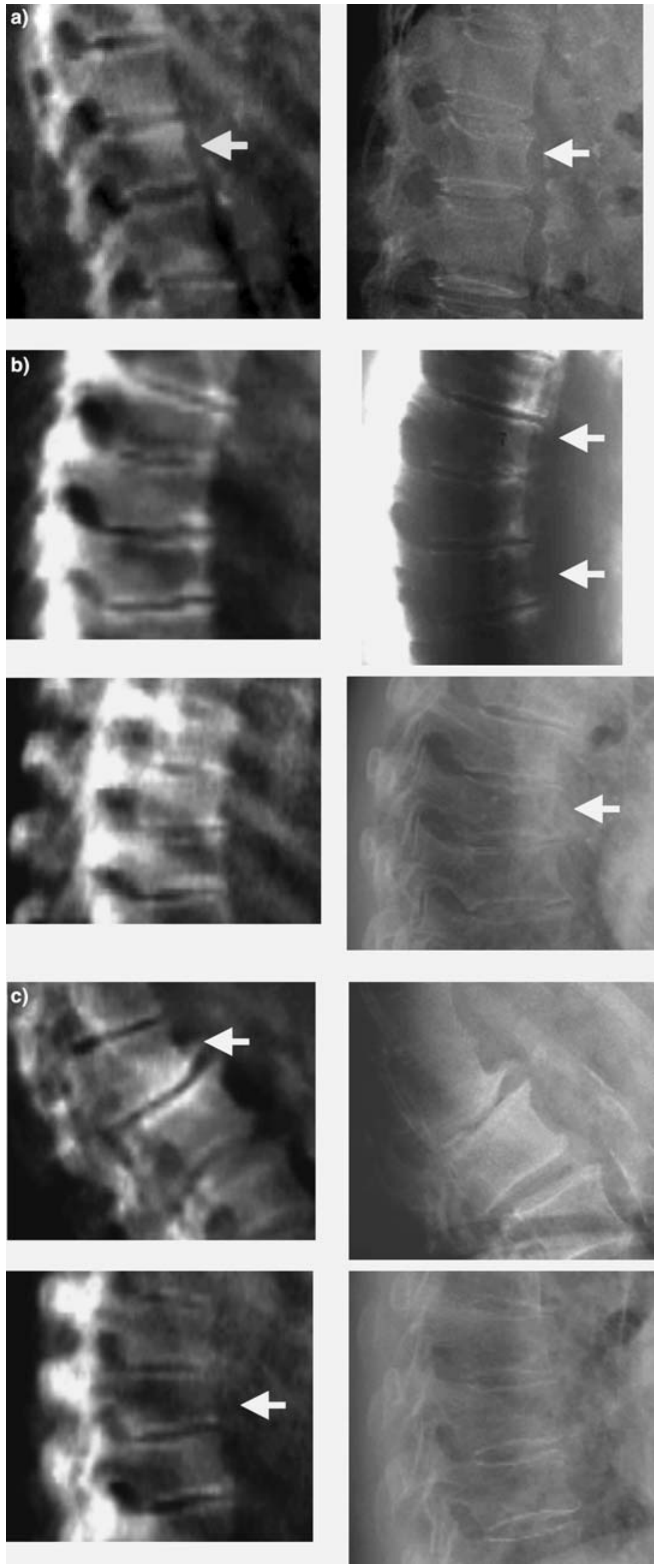

Fig. 3 a–c Examples of difficulty in correctly identifying grade 1 fractures: (LVA images on *left*, radiographs on *right*). **a** Concordant, i.e., correct interpretation of a grade 1, L1 vertebral-compression fracture (*arrow*) on LVA. **b** False negative LVA. The fractures identified on radiograph (*arrows*) were not detected by the clinicians utilizing LVA. **c** False positive LVA; the clinicians interpreted these vertebral bodies (*arrows*) as fractured when no fracture was present

defined grade 2 and grade 3 vertebral compression fractures. However, using LVA the clinicians correctly identified only 50% of radiographically detected grade 1 vertebral compression fractures. Finally, 96% of non-fractured vertebrae were correctly identified as normal on LVA. Thus, clinician identification of grade

2/3 vertebral fractures, or classification of vertebral bodies as normal, is almost entirely correct using LVA.

These results are very similar to those reported utilizing other densitometric equipment [11]. However, clinicians who consider using densitometric vertebral-fracture assessment must recognize that there is no universally agreed-upon gold standard for the diagnosis of vertebral fracture, and they should remain cognizant of the difficulties involved in detecting mild, i.e., grade 1 deformities [16, 17]. It is crucial to be aware that vertebral deformities are not always due to osteoporotic vertebral fracture. Specifically, other than osteoporotic and prior traumatic vertebral fracture, the differential diagnosis of vertebral deformity includes Paget's disease, Scheuermann's disease, congenital malformations, inflammatory diseases, and, importantly, degenerative spine diseases [17, 18]. In this regard, spinal osteoarthritis can be associated with anterior "wedging," which may be confused with vertebral fracture [19]. In fact, many incident vertebral deformities are not associated with corresponding areas of increased uptake on radionuclide bone scans, [20] suggesting that these "fractures" are not osteoporotic in origin. Finally, it is important for clinicians to appreciate that the mid-thoracic region is particularly problematic, as deformities in this area are often not associated with osteopenia [21]. As a result, some authors have suggested that, to define a grade 1 fracture, a greater decrease in vertebral height be required from T6 to T9 [22]. Given the above, it is not surprising that some of the false positive fractures reported by these clinicians in their evaluation of LVA images are likely due to osteoarthritis or degenerative remodeling. Consequently, we suggest that clinicians utilize caution in the diagnosis of grade 1 fractures with DXA-based techniques. The impact of this shortcoming is significantly reduced, however, by recent studies that suggest that mild (grade 1) fractures have less clinical importance, as they have a weaker association with future fracture and cause less height loss or back pain. Specifically, incident grade 1 vertebral fractures cause a height reduction of about 4 mm and back pain in 34% of patients, compared with 11 mm and 63% among women with grade 2 fractures [23]. Furthermore, postmenopausal women with severe vertebral-compression fracture are at highest risk of subsequent vertebral, and nonvertebral, fracture. In fact, fracture severity was found to better predict future nonvertebral fracture risk than BMD did [24].

We recognize that the over-interpretation of a number of vertebral bodies as having fractures (false positives) could be of concern. However, the fact that false positives (and false negatives) occur when clinicians utilize LVA does not negate the usefulness of this technology, since similar results occur when radiologists interpret standard radiographs. For example, a recent osteoporosis treatment study found that 43% of vertebral fractures identified upon review by an expert radiologist, using the same visual, semiquantitative methodology applied in this study, were not detected by local radiologists. Furthermore, the local radiologists fairly frequently (9%) misdiagnosed fractures in vertebral bodies subsequently determined to be normal [25]. Thus, the false negative rate of 30% and false positive rate of about 4% demonstrated in this study by clinicians using LVA are similar to those obtained by community radiologists utilizing conventional radiographs. Though the study noted above has not yet been published in final form, it seems likely that many of the false negatives and false positives reflect the inherent difficulty in determining what is a minimal deformity, i.e., a grade 1 fracture. Additionally, discordance is likely between radiologists in the clinical setting. In one report, inter-rater agreement for diagnosis of thoracic spine fracture was 84.5%, and fracture prevalence was 16% vs 29% by radiologists utilizing the same radiographs [26].

The above-noted difficulties with the recognition of radiographic vertebral fracture highlight the importance of training and a standardized approach to this process. In this regard, substantially better interobserver agreement regarding fracture detection has been reported when careful training and standardization of radiographic fracture detection is emphasized [14, 15, 17]. It is imperative that, if/when LVA/IVA becomes routine clinical practice, a similar training and standardization program be developed.

It might be assumed that the quantitation features available on software for assessing densitometric fractures would obviate the problem of vertebral fracture noted above. Unfortunately, this is not the case, as with all of the morphometric approaches, the choice of point placement for height measurement, and importantly, the threshold of height reduction to define a fracture, leads to substantial differences in fracture diagnosis [27–30]. For example, application of four different quantitative approaches led to fracture prevalence ranging from 33% to 85% in the same population [31]. In fact, what are thought to be fractured vertebrae may prove to be unfractured on follow-up if morphometry is used alone. Clearly, use of quantitative morphometric approaches is not the sole answer for DXA-based vertebral fracture assessment [17]. Furthermore, we felt it unlikely that clinicians would routinely utilize a more time-consuming morphometric approach and would prefer a visual, semiquantitative method.

The visual semiquantitative system utilized in this study has the advantages of allowing visual assessment of height, endplate deformities including lack of parallelism, and overall altered appearance in comparison with adjacent vertebrae. Using this system, the interpreting clinician should not only evaluate vertebral height, but also shape, and compare them with neighboring vertebrae. It is acknowledged that this approach adds some subjectivity to the interpretation, [17] which again emphasizes the need for standardized training.

It is important that users of this technology recognize the limitation of inadequate upper-thoracic vertebral body visualization. As such, fractures in the T4–T6 region may often not be detected. Fortunately, vertebral compression fractures are less common in this region, particularly at T4 and T5 [32]. Additionally, even with conventional radiography this area is difficult to image successfully [33].

In conclusion, LVA is an effective tool to correctly identify grade 2 and grade 3 vertebral fractures. Detection of grade 1 fractures is less effective; as such, clinicians who utilize densitometric vertebral-fracture assessment technology are advised to exercise caution when diagnosing these mild deformities. More accurate DXA-based vertebral-fracture assessment will require establishing standards and instructional programs that optimize identification of grade 1 fracture and facilitate recognition of normal variants and/or artifacts. It seems probable that vertebral fracture assessment can serve a valuable function by quickly establishing need for appropriate therapy in patients with unappreciated vertebral fracture and, additionally, may be an efficient screening tool for osteoporosis clinical trials.

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