Vertebral Fracture Initiative

Part III

Densitometric Vertebral Fracture Assessment (VFA)

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Abstract

Vertebral fracture assessment (VFA) can be done seamlessly at the bone densitometry point of care. Such an approach enhances fracture risk assessment because bone mineral density (BMD) and prevalent vertebral fracture are independent predictors of incident fractures. Since two thirds to three quarters of vertebral fractures do not come to clinical attention at the time of their occurrence, spine imaging is required for their detection. Although densitometric lateral spine images do not have the spatial resolution of lateral spine radiographs, VFA detects moderate to severe radiographic vertebral fractures with a high level of accuracy. Prevalent vertebral fractures are particularly likely to be present in women 70 or older and men age 80 or older, those with significant height loss or history of prior fracture, and those on glucocorticoid therapy. VFA at the time of bone densitometry is warranted in these individuals if the results of the test would reasonably influence therapeutic choices to reduce their fracture risk.
Introduction

Since the advent of fan-beam dual-energy X-ray absorptiometry (DXA) systems, the technology has been developed and adapted to obtain near radiographic quality lateral images of the lumbar and thoracic spine. These images allow evaluation for prevalent and (if a prior image is available for comparison) incident vertebral fractures, a process called vertebral fracture assessment (VFA), using qualitative, semi-quantitative, or quantitative morphometric methods. Bone mineral density (BMD) and vertebral fracture assessment give complementary, independent information regarding a person’s fracture risk (see below). Densitometric imaging of the spine allows vertebral fracture assessment to be done efficiently at time of bone densitometry, improving overall assessment of an individual’s future fracture risk.

This section of the IOF vertebral fracture initiative reviews the advantages and disadvantages of densitometric lateral spine imaging compared to standard radiography, indications for VFA, acquisition and interpretation of VFA images, and incorporation of the results of VFA into overall fracture risk assessment.

Importance of Densitometric VFA

Vertebral fractures are a marker of bone fragility and indicate a higher risk of fractures. The presence of one or more prevalent vertebral fractures on lateral spine radiographs is a strong predictor of future incident vertebral fractures and a moderate predictor of non-vertebral fractures, independent of BMD.(1-4) Similarly, prevalent vertebral fractures on lateral VFA images are predictive of incident clinical non-vertebral fractures and specifically incident hip fractures independent of bone density in women age 75 and older.(5) Two-thirds to three quarters of vertebral fractures, however, are not clinically recognized (6, 7), and hence spine
imaging is required for their detection. Among women age 65 and older who do not have osteoporosis by BMD criteria, 10% to 28% have one or more prevalent vertebral fractures.(8-11) VFA combined with bone densitometry can alter an individual’s estimated fracture risk sufficiently to change therapeutic recommendations in over 10% of those referred for bone densitometry.(12)

Comparison of Densitometric VFA and Lateral Spine Radiography

Densitometric VFA has several advantages over lateral spine radiographs. First, the images can be obtained easily and quickly at the same time as a bone density scan at less cost than standard spine radiographs, facilitating estimation of the patient’s fracture risk by incorporating both bone density and vertebral fracture status. Second, the radiation exposure required to obtain a VFA image is low, approximately 3-40 microSieverts, whereas the radiation exposure associated with lateral thoracic and lumbar spine radiographs is upwards of 600 microSieverts. Third, standard lateral spine radiographs are obtained using cone-beam X-rays, which creates parallax distortion within vertebrae located above or below the central point of the beam. In contrast, densitometric VFA uses fan-beam methodology to image the spine. Hologic densitometers use a wide fan-beam of X-rays, which is oriented with the plane of the X-rays perpendicular to the spine, whereas Lunar-GE densitometers use a narrow fan-beam with the plane of the X-rays parallel to the spine. In both cases, parallax distortion causing oblique projections of vertebrae are much less common on VFA images than on lateral spine radiographs, which makes the detection of lumbar vertebral fractures potentially more challenging on the radiographs.
However, the images obtained with standard spine radiography are less noisy and have higher spatial resolution than VFA images, such that the cortical edges and endplates are better defined. As a result, more vertebrae are evaluable on conventional radiographs than on VFA images, especially in the upper thoracic spine. With VFA images 90% to 94% of T8 vertebrae, 60% to 80% of T6 vertebrae, and 30% to 63% of T4 vertebrae are evaluable in three separate studies.(9, 13, 14) Moreover, the inter-rater reliability for identification of patients with one or more prevalent vertebral fractures is slightly lower for VFA than for standard radiography, but still good (kappa scores 0.56 to 0.70 across 4 studies).(11, 14-16) When using the Genant semi-quantitative method for vertebral fracture assessment on standard lateral spine radiographs as the gold standard, the sensitivity and specificity of VFA for individuals with one or more moderate to severe (Genant SQ grade 2 or 3) vertebral fractures is 87% or higher and 85% or higher, respectively, but is substantially lower (~50%) for Genant grade 1 deformities (Table 1). (17-20) The inter-rater reliability for vertebral fracture detection is slightly lower on VFA than on conventional lateral spine radiographs. The accuracy of VFA, like conventional radiography, for identifying radiographic vertebral fractures appears to be better in the lumbar than in the lower thoracic spine,(13) may be compromised when there is adjacent degenerative disc disease, and is poorer in the presence of moderate to severe scoliosis.(20)

Recent VFA technological advancements may further improve performance compared to standard radiography. In this regard, Buehring and colleagues recently found 92% of all vertebrae to be evaluable on VFA images using a newest Lunar-GE densitometer (Figure 1), compared to 76% on VFA images obtained on an older generation densitometer (both manufactured by GE Healthcare Lunar, Madison, WI).(21) In this study, 43 vertebral fractures
were identified by consensus readings on the VFA images obtained with the newer technology, compared to 21 fractures found on images obtained with the older technology.

The most recently available Hologic VFA technology also yields better VFA images compared to older Hologic densitometers (Figure 2). The only study assessing the agreement between VFA images obtained with the newer Hologic technology reported less than 2% of vertebrae to be unevaluable. (22) Analyzed per vertebra, this study showed very high specificity of VFA using the newer Hologic technology (99%) and better sensitivity (83%) to detect those with any grade of fracture (Genant SQ 1, 2, or 3) compared to studies using older Hologic VFA technology (Table 1).

When VFA should be followed by radiography is controversial and depends on the individual patient clinical situation. (15, 23) However, additional imaging should be considered if there are two or more unevaluable vertebrae below T6, poor visualization due to moderate to severe scoliosis or a need to confirm possible grade 1 vertebrae. (20) For Genant SQ grade 2 or grade 3 prevalent vertebral fractures, VFA has close to 100% specificity in comparison to radiographs and at least 93% sensitivity, which is likely to be even higher for the technologies with the improved resolution mentioned above.

**Indications for VFA**

The International Society for Clinical Densitometry (ISCD) has published indications for performing VFA as part of bone densitometry, that were created by a task force for the ISCD Position Development Conference of 2007 and vetted by a panel of experts. (24) Populations considered appropriate for VFA are those in whom the pre-test probability of one or more prevalent vertebral fractures being present exceeds 10%, (25) and for whom documentation of
one or more vertebral fractures will alter patient management (Tables 2 and 3). The populations for whom documentation of a prevalent vertebral fracture is most likely to alter therapy are those who do not have osteoporosis by bone density criteria and/or in the absence of a prevalent vertebral fracture would not be judged to have a sufficiently high absolute 10-year fracture risk to warrant therapy. Among women with a femoral neck T-score of -1.5 to -2.4, VFA is indicated at the time of bone densitometry for those with one of the following risk factors; age 70 or older, height loss of more than 4 cm compared to recalled young adult height, more than 2 cm of height loss between two measurements with the same stadiometer, and self-reported prior vertebral fracture without prior documentation of that fracture (Table 2). VFA is also indicated for women with a femoral neck T-score of -1.5 to -2.4 and two of the following; age 60 to 69, historical height loss of 2 to 4 cm, self-reported prior non-vertebral fracture, or a chronic disease that is associated with a higher risk of vertebral fracture (such as rheumatoid arthritis, moderate to severe COPD, or Crohn’s disease).

Older men have a lower age-specific prevalence of vertebral fracture than women of comparable age (26) and hence the indications for VFA among men are slightly more stringent compared to those for women (Table 3). Among men with a femoral neck T-score of -1.5 to -2.4, VFA is indicated for those with one of the following risks factors; age 80 and older, height loss of more than 6 cm compared to recalled young adult height, more than 3 cm of height loss between two measurements with the same stadiometer, and self-reported prior vertebral fracture without prior documentation of that fracture.(24) VFA is also indicated for men with a femoral neck T-score of -1.5 to -2.4 and two of the following; age 70 to 79, historical height loss of 2 to 4 cm, self-reported prior non-vertebral fracture, or a chronic disease that is associated with a higher risk of vertebral fracture.(24)
Among those for whom pharmacologic fracture risk reducing therapy is indicated, regardless of the presence or absence of a prevalent vertebral fracture (such as osteoporosis by bone density criteria or a high absolute 10-year fracture risk), VFA might nonetheless be appropriate if documentation of a prevalent vertebral fracture would influence the choice of therapeutic agent or the duration of drug therapy. For example, a reasonable choice for some individuals with osteoporosis by bone density criteria and prevalent vertebral fracture may be an initial one to two year treatment period with an anabolic agent followed by an anti-resorptive agent which may yield superior improvements in BMD (and potentially lower fracture risk to a greater degree) than anti-resorptive drug therapy alone.(27) Similarly, there remains controversy over how long anti-resorptive therapy should be continued, particularly in the case of bisphosphonates. Because of their long-term skeletal retention, some anti-resorptive effect may persist for years after their discontinuation. This question was explored by the FLEX study that randomly assigned women treated with alendronate for 5 years to continue that drug for an additional 5 years or switch to placebo. Among the subset with a prevalent vertebral fracture, those switched to placebo had a higher risk of subsequent clinical vertebral fracture compared to those who continued alendronate.(28) At this time, there are no data to specifically guide how long anti-resorptive therapy should be continued in either those with or without prevalent vertebral fracture. In the absence of such data, clinicians nonetheless have to make decisions in individual patients. These decisions should be influenced by that individual’s current fracture risk. The individual’s risk of fractures after several years of anti-resorptive drug use clearly will be influenced by whether or not there are any prevalent vertebral fractures. In patients with a prevalent fracture it may be appropriate to consider a longer treatment period.
The future fracture risk associated with a prevalent vertebral fracture is higher in those who have sustained their fracture more recently. It may therefore be reasonable to obtain a baseline VFA at the time that osteoporosis is diagnosed, such that follow-up VFA’s can determine whether or not incident vertebral fractures have occurred since the baseline study. Incident fractures remain common even in those on pharmacological treatment; in randomized controlled trials of oral bisphosphonates, incident vertebral fractures occurred in 5 to 18% of those on anti-resorptive drug therapy over a three year period.(29-32). It would therefore be useful to obtain a baseline VFA when drug therapy is initiated even in patients that have a very high risk of fracture even without knowing their prevalent fracture status. Hence follow-up VFA a few to several years later would determine incident fractures and influence further treatment options.

Finally, those who are on chronic systemic glucocorticoid therapy have a much higher incidence of vertebral fractures at all ages (33-36) and hence even younger individuals who have been on long-term glucocorticoid therapy have a high prevalence of vertebral fractures. VFA at the time of bone densitometry, for those requiring ongoing systemic glucocorticoid therapy, is appropriate if documentation of prevalent and/or incident vertebral fracture will influence choice or duration of therapeutic fracture prevention therapy.

Obtaining VFA Images

Patient positioning

Obtaining lateral spine images for vertebral fracture assessment can be done quickly and easily at the time of bone densitometry. Patient positioning is particularly easy when using a densitometer with a rotating C-arm.(37) In this instance, the patient is kept in the same position
used to obtain AP lumbar spine bone density; supine with a bolster under the distal lower extremities such that the hips are flexed at 90 degrees, and arms held above the head.

Without a rotating C-arm, lateral spine images for VFA are obtained in the lateral decubitus position. With this approach, proper positioning by the technologist produces VFA image quality comparable to supine lateral VFA images. The patient needs to be lying on the side without trunk rotation such that the coronal plane of the body is perpendicular to the plane of the densitometer table. If the body is rotated forward or backward from this position, the vertebral body outlines can be obscured. An indication that this has occurred is prominent appearance of the rib angles of one side of the rib cage posterior to the spinal column (Figure 3). Additionally, in the lateral decubitus position, most individuals will have a smaller body circumference at the level of the mid-abdomen compared to the level of the hips, such that they will naturally have a functional scoliosis convex downward when lying on their side. For these individuals, a triangular pillow needs to be place under their side at the level of the mid-abdomen such that the spine is parallel to the table without a curve (Figure 4).

Even with the best positioning possible, as noted previously, upper thoracic vertebrae are more likely to be unevaluable than lower thoracic and lumbar vertebrae. Vallarta-Ast and colleagues have shown that in some patients obtaining a second VFA image with the patient lying on their opposite side (reverse lateral decubitus position) will often yield images on which additional vertebrae are evaluable (Figure 5).

**Dual-energy versus single-energy images**

VFA images obtained with X-rays of only one level of energy (single-energy) yield images that include prominent soft tissue features. In contrast, dual-energy X-rays can use a second level of X-ray beam energy to account for the X-ray absorption by soft tissues, producing
images that are noisier but with higher contrast for bone and greatly diminished soft tissue shadows. Advantages of single-energy imaging are that the images can be obtained faster, and the endplates and cortices are slightly sharper than on dual-energy images. However, single-energy images are disadvantaged in that the shadows created by soft tissues can obscure visualization of the vertebrae, especially in areas where the contrast between adjacent soft tissues is considerable, such as the diaphragm (Figure 6). Hologic densitometers are optimized to provide high quality single-energy X-ray images, whereas Lunar densitometers are optimized to provide high quality dual-energy X-ray images.

*AP Image*

AP VFA images can aid both labeling of vertebrae and assessing the severity of scoliosis, which influences how well VFA images can be interpreted. Nonetheless, AP imaging of the thoraco-lumbar spine is generally not necessary to successfully interpret VFA images with high quality, and hence is not routinely done.

**Interpreting VFA Images**

VFA interpretation starts with an evaluation of image quality. The superior portion of the sacrum should be visualized at the bottom of the image, and none of the rib angles of the rib cage should be prominent posterior to the spinal column (Figure 3). The next step is to label the vertebrae correctly, starting with identification of the fourth lumbar vertebra. Ninety-one percent of individuals have five lumbar vertebrae, and labeling the vertebral immediately superior to the sacrum as L5 will lead to appropriate vertebral labeling. Seven to eight percent of individuals have only four lumbar vertebrae, and 2% have six lumbar vertebrae.(39) Correctly identifying and labeling vertebrae in such individuals is a challenge. There is no easy method of doing so
that is always accurate, and there is the possibility that vertebrae considered to be T4 to L4 may actually be T3 to L3 or T5 to L5. As long as vertebrae are consistently labeled the same way on repeat VFA’s, this is of little consequence given that fracture ascertainment within each evaluable vertebra is accurate.

The next step is to determine what vertebrae are evaluable. This is important as the Genant semi-quantitative method depends on recognizing differences in vertebral shape compared to what is expected as normal in order to determine whether or not an individual vertebra is deformed.(40) Hence, for a vertebra to be fully evaluable the anterior and posterior cortices and the endplates need to be fully visible. If parts of one of the endplates or cortices cannot be seen, it may nonetheless be possible to identify a vertebra as deformed if, based on that portion of the vertebra that is visible, it is clear that its shape deviates from what is normal for that vertebral level. However, one cannot state that a vertebra has no deformity or abnormality without the full outlines of the vertebra being visible. Generally, the default score is 0 for reasonably but not completely visible vertebrae.

For each evaluable vertebra, the next step is to determine whether or not the vertebra is deformed. According to the Genant semi-quantitative criteria, this is done primarily by comparing the shape of each vertebra to its neighbours; this method is described in much more detail in Part II. Briefly, normal vertebrae will be roughly in the shape of a rectangle, with the inferior and superior endplates being parallel to each other. Wedge deformities are recognized by a reduction in the anterior and to a lesser extent middle height of the vertebra, such that the superior and inferior endplates are no longer parallel, but rather would converge if extended along their planes anterior to the vertebra. With biconcave deformities, the anterior and posterior heights of the vertebrae are maintained, but the middle heights are reduced. Typically, one or
both endplates are bowed in (convex) toward the middle of the vertebral body. With *crush deformities*, all three vertebral heights are reduced such that the superior and inferior endplates may remain parallel to each other, but the overall height of the vertebra is reduced compared to its immediate neighbours. The distinction between these types of deformities is often confounded by the variable combination of deformities, but fortunately this classification is less important than the severity score for fracture risk prediction. For questionable cases where it is not obvious that the apparent height reduction(s) are sufficient to consider the vertebra deformed, it may be helpful to measure vertebral heights using VFA imaging software: six points are placed on the borders of the vertebra (as described in part II) and the software reports the vertebral heights, their ratios and the degree (percent) of deformation. For borderline wedge deformities, the interpretation of a true fracture is supported by associated endplate deformities or cortical breaks consistent with fracture.(40,16)

*Non-Fracture Deformities*

For vertebrae that do appear to be deformed, it is important to assess whether or not non-osteoporotic pathology could account for the deformity. Several conditions can change vertebral shape in ways that can mimic vertebral fracture. Disc degeneration can produce osteoarthritic remodeling that results in some loss of vertebra height and elongation of the vertebra in the sagittal plane, creating a wedged appearance (anterior height shorter relative to the posterior height *(Figure 7).* (41) Sometimes in these instances, the anterior aspect of the endplates are convex away from the center of the vertebra. *Schuermann’s disease* is also often characterized by wedged vertebrae, especially in the mid-thoracic spine *(Figure 8).* These anomalies can often
be recognized by the undulating, wavy nature of the endplates. *Congenital fusion of two adjacent vertebrae* can also create a wedged structure, with the posterior height of the fused vertebrae significantly greater than the anterior height (Figure 9). *Schmorl’s nodes* are sharply marginated invaginations of only a portion of the superior or inferior endplate with the bulk of the endplates intact (Figure 10). Similarly, *Cupid’s bow* can be recognized as bowing of the posterior aspect of the inferior endplate toward the middle of the vertebra, more commonly in the lower lumbar spine.(42) In contrast, biconcave vertebral fractures typically involve the superior endplate to a greater degree, with the greatest degree of endplate bowing typically in the mid-sagittal plane. *Malignancy* within a vertebra may result in destruction of a portion of the cortex, expansion of the cortex, or areas of radiodensity or lucency in the middle of the vertebra atypical for osteoporotic fracture (Figure 11).(43, 44)

*Indications for follow-up imaging*

Follow-up spine radiographs can be very helpful if there are vertebrae that are unevaluable on VFA between T7 and L3. Similarly, because VFA does not detect Genant grade 1 deformities accurately, follow-up radiography would be appropriate if confirmation of grade 1 vertebral deformities, consistent with fracture, would alter patient management. Follow-up lateral spine radiography may be advisable for any patient with a vertebral deformity and a history of malignancy with potential to metastasize to the spine, or with any abnormalities on VFA that cannot be comfortably ascribed to benign causes.

**Incorporating VFA into fracture risk assessment**

Both the number and severity of prevalent vertebral fractures substantially influence the risk of subsequent vertebral and non-vertebral fractures independent of BMD.(1, 4) Moreover,
current available pharmacologic fracture prevention therapies have fracture reduction efficacy in those with prevalent vertebral fracture with T-scores below -1.0,(45, 46) and hence VFA largely identifies those for whom fracture prevention therapy is indicated virtually regardless of other risk factors.

The World Health Organization FRAX® model estimating absolute fracture risk gives an assessment of major osteoporotic (hip, clinical vertebral, humerus, and wrist) fracture and specifically of hip fracture. The FRAX® algorithm is based on clinical risk factors, one of which is prior fracture.(47, 48) It may be reasonable to count the presence of one or more prevalent vertebral fracture as “prior fracture” in the algorithm when estimating absolute fracture risk in those who have had one or more vertebral fractures documented on VFA. This may underestimate the risk of subsequent vertebral fractures especially in those with high grade and/or more than one vertebral fracture,(49) but the extent to which future versions of FRAX® should be altered to predict skeletal site specific fracture risk is quite controversial.(50) Nonetheless, VFA may aid calculation of absolute fracture risk by detecting that subset with prior vertebral fracture(s) that have not come to clinical attention.

**Characteristics of good VFA reports**

VFA reports at a minimum should state the vertebra(e) within the range of T4 to L4 that are evaluable for deformity, those that are deformed, and whether or not the deformity is consistent with a vertebral fracture or is more likely due to non-osteoporotic causes. The presence of osteoarthritic or degenerative changes should be noted if present in the lumbar spine, because its presence often results in overestimation of spine bone density to some degree.
Potential clinically-significant extra-spinal pathology, evident on the VFA images, should be noted. A common extra-spinal pathology that may be noted is abdominal aortic calcification (AAC). AAC detected on lateral spine radiographs is an independent predictor of incident cardiovascular disease, specifically myocardial infarction and stroke, independent of other clinical cardiovascular disease risk factors.(51-53) Similarly, two recent studies, one with single-energy VFA images (54) and the other with dual-energy VFA images,(55) have shown that AAC on densitometric VFA images is a significant predictor of incident myocardial infarction or stroke, and as significant or more so than the presence of peripheral vascular disease.(53) This may represent an indication for more aggressive management of modifiable cardiovascular disease risk factors such as LDL cholesterol.(56) VFA should not be used to regularly screen for AAC, at this time is the sole indication for VFA is the detection of vertebral fractures.
Conclusion

Densitometric lateral spine imaging to detect vertebral fractures (VFA) substantially improves the utility of bone densitometry to improve fracture risk assessment. VFA detects moderate and severe radiographic vertebral fractures with a high level of accuracy, and this accuracy may improve further with technologic advances. VFA is indicated in a substantial proportion of older women and men having bone densitometry. Non-osteoporotic deformities need to be distinguished from those due to osteoporotic bone fragility. The presence of one or more vertebral deformities due to bone fragility constitutes, with unusual exceptions, an indication for pharmacologic fracture prevention therapy. Follow-up plain radiograph imaging is advisable if substantial numbers of vertebrae are unevaluable, if the presence of deformity is uncertain, if abnormalities cannot be ascribed to benign causes, or if deformities are noted in a person with a history of malignancy with potential to metastasize to the spine.
<table>
<thead>
<tr>
<th>Citation / Year / Vert Fx Definition</th>
<th>Population (number) &amp; Setting</th>
<th>Proportion Vertebrae Evaluable</th>
<th>VFA Sensitivity / Specificity</th>
<th>Agreement (Kappa) VFA -Rad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binkley, 2005 (17) Genant SQ</td>
<td>80, mean age 72.8 years; Academic bone densitometry center, U.S.</td>
<td>81% per vertebra</td>
<td>70.0%-96.2%</td>
<td>per vertebra 0.545</td>
</tr>
<tr>
<td>Chapurlat, 2006 (13) Genant SQ</td>
<td>85, mean age 71 years; Academic bone densitometry center, France</td>
<td>Reported by vertebral level; &lt;80% &amp; T7 and above</td>
<td>per vertebra T11-L4: Sens. 44%-83%, Spec. 80%-99%</td>
<td>T12-L4: 0.69-0.87 T10, T11: 0.36-0.37 T9 above: 0.34-0.85</td>
</tr>
<tr>
<td>Damiano, 2006 (15) Genant SQ</td>
<td>136, mean age 69.1 years; Academic rheumatology dept, France</td>
<td>89% without difficulty, 11% w/ difficulty, 1% unreadable</td>
<td>Per vertebra 82.8% / 98.3% Per person 94%/ 83%</td>
<td>Not reported</td>
</tr>
<tr>
<td>Ferrar, 2003 (57) Qualitative Visual X-ray; Qual visual VFA and Quant morphometric VFA</td>
<td>70, mean age 70; academic bone metabolism center, U.K.</td>
<td>88% (Qual. reading) 85% (Quant. morphometry)</td>
<td>Qual. VFA vs Qual. X-ray 85%-92% / 95-98% Quant. VFA vs Qual. X-ray 82% / 94%</td>
<td>Qual. VFA vs Qual. X-ray: 0.85 – 0.87 Quant. VFA vs Qual X-ray 0.77</td>
</tr>
<tr>
<td>Ferrar, 2008 (18) ABQ</td>
<td>Low risk=459 mean age 68 yrs), High risk=298 mean age 68 yrs</td>
<td>Not reported</td>
<td>Low risk 71.2%/97.4% High risk 84.3% /96.8%</td>
<td>Low risk: 0.62 High risk: 0.81</td>
</tr>
<tr>
<td>Fuerst, 2009 (14) Genant SQ</td>
<td>203, mean age 67.5 years; three bone densitometry centers U.S.</td>
<td>42% (T4) 91% (T8)</td>
<td>Per vertebra 70-73% / 99%</td>
<td>Per vertebra 0.64-0.78 per person 0.55-0.73</td>
</tr>
<tr>
<td>Hosapers, 2009 (22) Genant SQ &amp; Qualitative Visual of radiographs</td>
<td>250, mean age 62years; Bone densitometry center in Netherlands</td>
<td>98.7% VFA 94.3% visual radiography 88.2% SQ radiography</td>
<td>Per vertebra 83.6% / 99.8%</td>
<td>0.82</td>
</tr>
<tr>
<td>Rea, 2000 (19) Genant SQ</td>
<td>161, mean age 64 years; metabolic bone disease unit, U.K.</td>
<td>94.9% VFA 99.9% X-ray</td>
<td>Per vertebra 68%/94% Per person 77%/89%</td>
<td>Per vertebra 0.79 Per person 0.68</td>
</tr>
<tr>
<td>Schousboe, 2006 (20)</td>
<td>203, mean age 74.2 years. Community bone densitometry unit</td>
<td>70.7% of persons had all vertebrae on VFA evaluable</td>
<td>Per vertebra 47% - 57% / 98.5% Per person 52%-63%/ 85%-89%</td>
<td>Not reported</td>
</tr>
<tr>
<td>Vokes, 2003 (23) Genant SQ</td>
<td>66, mean age not reported</td>
<td>89% of persons had all vertebrae between T6 and L4 evaluable</td>
<td>Per person (grade 2-3 only) 95%/92%</td>
<td>Per person 0.73</td>
</tr>
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Abbreviations: Qual. Qualitative; Quant. Quantitative; Sens. Sensitivity; Spec. Specificity
Table 2 – Indications for VFA in Women*

Post-menopausal women with a T-score of -1.5 to -2.4, and
- Age 70 or older
- Historical height loss > 4 cm (1.5 inches)
- Prospective height loss of >2 cm (0.75 in)
- Self-reported history of vertebral fracture*
- Two or more of the following*:
  - Age 60 to 69
  - Historical height loss of 2-4 cm
  - Self-reported prior non-vertebral fracture
  - Chronic systemic diseases associated with increased risk of vertebral fractures
    (for example, moderate to severe COPD, rheumatoid arthritis, Crohn’s disease

Post-menopausal women with a T-score of ≤ -2.5 if documentation of a prevalent vertebral
fracture would influence choice of or duration of therapy

Women of any age on chronic systemic glucocorticoid therapy (dose equivalent to more than 5
mg of prednisone per day)

* If the documentation of a vertebral fracture would influence choice of therapy.
Table 3 – Indications for VFA in Men*

Post-menopausal women with a T-score of -1.5 to -2.4, and

- Age 80 or older
- Historical height loss > 6 cm (2.4 inches)
- Prospective height loss of >3 cm (1.2 inches)
- Self-reported history of vertebral fracture*
- Two or more of the following*:
  - Age 70 to 79
  - Historical height loss of 3-6 cm
  - Self-reported prior non-vertebral fracture
  - Chronic systemic diseases associated with increased risk of vertebral fractures
    (for example, moderate to severe COPD, rheumatoid arthritis, Crohn’s disease
  - Androgen deprivation therapy or following orchiectomy

Men with a T-score of ≤ -2.5 if documentation of a prevalent vertebral fracture would influence choice of or duration of therapy

Men of any age on chronic systemic glucocorticoid therapy (dose equivalent to more than 5 mg of prednisone per day)

* If the documentation of a vertebral fracture would influence choice of therapy.
Figure 1 – Improved VFA imaging with GE Lunar iDXA (right) vs Prodigy (left)
Figure 2 - Improved VFA imaging with Hologic Discovery (panel A) vs. Hologic Delphi/QDR (panel B)

Acquisition Time 10 seconds          Acquisition Time 15 seconds

Panel A                                Panel B
Figure 3 – Lateral decubitus VFA with poor positioning (left) and good positioning (right)*

*Poor thoracic alignment from shoulder rotation can be recognized by the prominent rib angles posterior to the spine
Figure 4 – Use of triangular pillow to avoid functional scoliosis in side-lying posture
Figure 5 – Improvement in number of evaluable vertebrae on reverse decubitus image
Figure 6 – Dual-energy on Prodigy (panel A) and single-energy on Hologic QDR (panel B)
VFA images
Figure 7 – Non-osteoporotic deformity in thoracic spine caused by degenerative spondylosis
Figure 8 – Non-osteoporotic deformity on VFA due to Schuermann’s disease
Figure 9 – Non-osteoporotic deformity due to lack of vertebral segmentation (congenital vertebral fusion)
Figure 10 – Non-osteoporotic deformity due to Schmorl’s nodes, note also the calcified disc, a relatively uncommon occurrence.
Figure 11 – Metastatic prostate carcinoma at T12 and grade 3 vertebral fracture at T7 on VFA (left panel) and lateral spine radiograph (right panel)
References


