VERTEBRAL FRACTURE INITIATIVE
Part III

Densitometric Vertebral Fracture Assessment (VFA)

By John T. Schousboe, Tamara Vokes, Neil Binkley, and Harry K. Genant
Topics to be covered

• What is vertebral fracture assessment?
• How does VFA compare to standard lateral spine radiography?
• Who should have VFA testing?
• How should VFA images be obtained?
• How should VFA images be interpreted?
Topics to be covered

- Incorporating VFA results into fracture risk assessment
- Characteristics of good VFA reports
- Illustrative cases
Vertebral Fracture Assessment (VFA)

Definition

- Use of fan beam densitometry to image the lateral and AP thoraco-lumbar spine for prevalent and incident vertebral fractures
Importance of vertebral fractures

- Prevalent radiographic vertebral fractures are an indicator of poor bone strength
  - Confer 4 fold risk of incident vertebral fractures independent of BMD
  - Confer 1.8 fold risk of incident hip fractures independent of BMD
  - Confer 1.6 fold increased risk of non-vertebral fractures independent of BMD

- Prevalent vertebral fracture without major trauma = diagnosis of osteoporosis
Only 25 to 33% of vertebral fractures are clinically recognized.

Diagnosing vertebral fractures requires spine imaging which is usually not performed when evaluating osteoporosis.

VFA can accurately detect moderate to severe radiographic vertebral fractures - it fills a clinical need.
Prevalence of vertebral fracture according to BMD classification

Classification by BMD alone misses many patients with prevalent vertebral fractures

- 482 patients screened for an osteoporosis study – no known history of vertebral fracture
- VFA found vertebral fractures in 18.3%

Adapted from Greenspan SL et al. (2001) J Clin Densit 4: 373
Estimated prevalence* of clinically silent vertebral deformity in women

<table>
<thead>
<tr>
<th>Age</th>
<th>Femoral Neck T-score (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1.0</td>
</tr>
<tr>
<td>60</td>
<td>8%</td>
</tr>
<tr>
<td>65</td>
<td>10%</td>
</tr>
<tr>
<td>70</td>
<td>13%</td>
</tr>
<tr>
<td>75</td>
<td>16%</td>
</tr>
<tr>
<td>80</td>
<td>20%</td>
</tr>
</tbody>
</table>

* Assuming 70% of prevalent vertebral fractures are clinically silent and an odds of 1.5 for one or more prevalent vertebral fractures being present per each Z-score decrease in BMD

Adapted from Melton LJ et al. (1993) Osteoporosis Int 3(3): 113
Incident vertebral fracture risk: effect of BMD and prevalent vertebral fractures

SQ score: worst grade of any fractured vertebra according to Genant semi-quantitative scale

Siris ES et al. (2007) Osteoporosis Int 18: 761
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Incident non-vertebral fracture risk: effect of BMD and prevalent vertebral fractures

SQ score: worst grade of any fractured vertebra according to Genant semi-quantitative scale

Siris ES et al. (2007) Osteoporosis Int 18: 761
With kind permission from Springer Science+Business Media
How does VFA compare to standard lateral spine radiography?
## Comparison of X-ray and VFA

<table>
<thead>
<tr>
<th></th>
<th>X-ray</th>
<th>VFA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiation dose</strong></td>
<td>600 $\mu$Sv</td>
<td>3 - 40 $\mu$Sv</td>
</tr>
<tr>
<td><strong>Access</strong></td>
<td>Separate visit</td>
<td>Point of service</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Higher ($92^*$)</td>
<td>Lower ($45^*$)</td>
</tr>
<tr>
<td><strong>Obliquity</strong></td>
<td>Common in LS</td>
<td>Less parallax effect</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Visualization</strong></td>
<td>Superior above T7</td>
<td>May be superior in LS</td>
</tr>
</tbody>
</table>

* Medicare reimbursement; Sv = Sievert, LS = Lumbar Spine

Adapted from the ISCD VFA Course 2009
Limitations of VFA

• **Lower resolution than X-ray**
  – Can be more difficult to differentiate etiologies for vertebral deformities other than fracture

• **Poor visualization above T7**
  – T7 and below - 97% visualized\(^1\)
  – T6 - 70%\(^2\)
  – T5 - 60%\(^2\)
  – T4 - 43%\(^2\)

\(^1\)Rea JA et al. (1998) Osteoporos Int 8(2):177
T12 Fracture

X-ray

VFA
Grade 1 fractures: more difficult to identify

Of 22 grade 1 compression fractures present in evaluable vertebral bodies, 11 (50%) were detected by LVA (VFA)

Adapted from Binkley N et al. (2005) Osteoporos Int 16:1513
Accuracy of VFA vs. standard radiography (per vertebra analyses)

<table>
<thead>
<tr>
<th>Fracture Grades 1-3</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>53% - 70%</td>
<td>94% - 99%</td>
</tr>
<tr>
<td>Fracture Grades 2-3</td>
<td>57% - 95%</td>
<td>96% - 99%</td>
</tr>
</tbody>
</table>

- Those patients with unevaluable vertebrae on VFA or moderate to severe scoliosis excluded

Rea JA et al. (2000) Osteoporos Int 11: 660
Schousboe JT et al. (2006) Osteoporos Int 17: 281
Chapurlat RD et al. (2006) Osteoporosis Int 17:1189
VFA technology has improved

- These studies may underestimate the performance of VFA with the latest technologies compared to standard.

- Manufacturers of densitometers have changed their technologies to improve image quality.
Improved VFA technology

All but one of the studies comparing VFA and standard radiography used older technology
Hospers, IC et al. (2009) Radiology 251(3): 822-828

- Agreement between VFA vs Genant SQ radiography (grades 1-3): kappa = 0.83
- Agreement between VFA vs qualitative radiography (grades 1-3): kappa = 0.82
Improved VFA technology: newer (a) vs. older (b)

Better visualization of thoracic spine

Changes in VFA technology: newer (A) vs. older (B)
Indications for VFA
Indications for VFA: criteria used for 2007 ISCD official positions

- Reasonable pre-test probability of VFA being positive (e.g., >10%)

- Result will influence therapy
## Association of prevalent vertebral fractures with clinical risk factors

### Vertebral fracture prevalence by level of PVFI*

<table>
<thead>
<tr>
<th>PVFI value</th>
<th>Prevalence of PVFI</th>
<th>Vertebral fracture prevalence</th>
<th>Sensitivity (%) (95% CI)</th>
<th>Specificity (%) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.4</td>
<td>3.8</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>1</td>
<td>14.2</td>
<td>7.9</td>
<td>99.4 (99.1-99.7)</td>
<td>4.2 (3.4-5.0)</td>
</tr>
<tr>
<td>2</td>
<td>22.1</td>
<td>11.3</td>
<td>93.9 (93.0-94.9)</td>
<td>20.7 (19.1-22.3)</td>
</tr>
<tr>
<td>3</td>
<td>21.8</td>
<td>15.6</td>
<td>82.0 (80.4-83.5)</td>
<td>45.4 (43.4-47.4)</td>
</tr>
<tr>
<td>4</td>
<td>18.6</td>
<td>21.6</td>
<td>65.5 (63.6-67.4)</td>
<td>68.7 (66.8-70.5)</td>
</tr>
<tr>
<td>5</td>
<td>9.4</td>
<td>32.7</td>
<td>46.2 (44.2-48.2)</td>
<td>87.0 (85.7-88.4)</td>
</tr>
<tr>
<td>6+</td>
<td>10.4</td>
<td>62.3</td>
<td>31.4 (29.5-33.2)</td>
<td>95.0 (94.2-95.9)</td>
</tr>
</tbody>
</table>

* **Prevalent Vertebral Fracture Index.**
  Calculation: age>70 (2pts), age 60-69 (1pt); history non-vertebral fracture (1pt); self-reported vertebral fracture (6pts); self-reported osteoporosis (1pt); historical height loss >4cm (2pts), 2-4cm (1pt)

Appropriate indications for VFA

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 inches)
- Self-reported history of vertebral fracture*

* If the documentation of a vertebral fracture would influence choice of therapy.
Appropriate indications for VFA

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

And

• 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)

* If the documentation of a vertebral fracture would influence choice of therapy.

2007 ISCD Official Positions
Appropriate indications for VFA

**Men** with a T-score of -1.5 to -2.4

And

- Age 80 or older*
- Historical height loss > 6 cm*
- Prospective height loss > 3 cm*
- A self-reported history of vertebral fracture*

* If the documentation of a vertebral fracture would influence choice of therapy.
Appropriate indications for VFA

**Men** with a T-score of -1.5 to -2.4

And

- 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
  - On pharmacologic androgen deprivation therapy or following orchiectomy

* If the documentation of a vertebral fracture would influence choice of therapy.
Appropriate indications for VFA

- **Osteoporosis by bone density criteria**
  
  **IF** documentation of a prevalent vertebral fracture will influence:
  
  - Choice of therapy (e.g. an anabolic agent instead of an anti-resorptive agent).
  
  - How long to continue drug therapy

  **spine, total hip, or femoral neck T-score less than or equal to -2.5**

- **Chronic glucocorticoid therapy**
VFA “contraindications”

- “Recent” imaging of spine that can be reviewed for incident fractures
  - e.g. CXR, CT or MRI of spine or nuclear medicine bone scans
- Pregnancy
- When results would not alter therapy
How are VFA images obtained?
Positioning

- **Supine lateral position vs. lateral decubitus**
  - Supine lateral position requires densitometer with a rotating C-arm
  - Lateral decubitus positioning requires triangular pillow between patient’s side and table
    - Prevent functional scoliotic curve in side lying posture

- **Reverse lateral decubitus:** vertebrae not evaluable with lateral decubitus on one side, may be with lateral decubitus opposite side
Proper decubitus positioning

Buttocks and shoulders firmly against backrest

Ribcage support
Reverse lateral positioning:

T11 fracture missed lying on one side (a) but visible lying on opposite side (b)

AP spine image

- Not essential for vertebral fracture assessment

**BUT**

- Can aid identification and labeling of vertebra
- Can aid evaluation of scoliosis severity if present
- Can aid detection of lateral cortex / endplate compression fractures
Modality for image viewing

- **Paper**
  - Can be printed with different contrasts, and with standard (bones white in color) or inverse image (bones black in color)

- **Electronic**
  - Requires monitor with appropriate viewing software
  - Can allow changes in magnification, contrast, brightness to make evaluation of vertebral shape and morphology easier
How are VFA images interpreted?
Genant semi-quantitative criteria for vertebral fracture

Grade 0: normal, unfractured vertebra.

Grade 0.5: uncertain or questionable fracture with borderline 20% reduction in anterior, middle or posterior heights relative to the same or adjacent vertebrae.

Grade 1: mild fracture with approximately 20-25% reduction in anterior, middle or posterior heights relative to the same or adjacent vertebrae.

Grade 2: moderate fracture with approximately 25-40% reduction in anterior, middle or posterior heights relative to the same or adjacent vertebrae.

Grade 3: severe fracture with approximately >40% reduction in anterior, middle or posterior relative to the same or adjacent vertebrae.

Combines both visual inspection and selected measurement of vertebral heights.

Note, borderline grade is not used in practice.
Advantages of Genant semi-quantitative criteria

- Excellent *inter-rater and intra-rater reliability*
- *Concurrent validity* (SQ vertebral fractures are associated with low BMD)
- *Predictive validity* (SQ vertebral fractures predict incident fractures independent of BMD)
- Easy to implement in clinical practice
- May be more accurate than clinical morphometry

Identifying vertebral deformities with the Genant SQ criteria

Ultimately the question is: “Are the vertebral bodies normal or abnormal?”

- Normal
- Abnormal
  - Definite vertebral fracture
  - Equivocal vertebral fracture
  - Other vertebral abnormalities
Identification of vertebral fracture

SQ analysis of Genant
- Identify abnormal vertebrae visually
- Visual determination of vertebral morphological change:
  - Lack of parallelism of end plates (horizontal edges)
  - End plate depression
  - Buckling of cortices (vertical edges)
  - Loss of vertical continuity with adjacent vertebrae
- Severity grading of fracture deformity

<table>
<thead>
<tr>
<th>Normal (Grade 0)</th>
<th>Wedge Deformity</th>
<th>Biconcave Deformity</th>
<th>Crush Deformity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild (Grade 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate (Grade 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe (Grade 3)</td>
<td></td>
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</tbody>
</table>

~20-25%
~25-40%
>40%
Isolated mild anterior height reduction may not be associated with incident vertebral fracture.

Adapted from Lunt M et al. (2003) Bone 33: 505
Algorithm-Based Qualitative (ABQ) method

- Endplate depression is central to definition of a vertebral fracture
- ABQ is a qualitative method developed to avoid labeling vertebral bodies with short vertebral height as fractured
- Reliable, reproducible on both standard radiographs and VFA images
- Predictive validity (e.g., prospective fracture prediction) has yet to be demonstrated and compared to the SQ method
Algorithm-based Qualitative (ABQ) Assessment

Start

Depression of endplate?

- Yes → Close to centre of endplate?
  - Yes → Concave depression?
    - Yes → Whole endplate depressed within ring?
      - Yes → Trauma, tumour, metabolic disease?
        - Yes → Osteoporotic fracture
        - No → Non-fracture deformity, developmental variant, non-osteoporotic fracture, other disease / condition
      - No → Short vertebral height?
        - Yes → Scheuermann’s, childhood fracture, scoliosis, variants
        - No → Variants: anterior: step-like endplate in thoracic vertebrae, posterior: Cupid’s bow or balloon disc in lumbar vertebrae
    - No → Focused area: Schmorl’s node
  - No → Short vertebral height?
    - Yes → Variants: anterior: step-like endplate in thoracic vertebrae, posterior: Cupid’s bow or balloon disc in lumbar vertebrae
    - No → Check for oblique projection or scoliosis

Normal
Prevalence of vertebral fractures on VFA and spine radiographs

Adapted from Hospers IC et al. (2009) Radiology 251(3): 822-828
Incident T4 to T6 fractures are not common

Incident fractures: 6.3 years, Rotterdam study
240 new fractures in 176 of 3469 persons

Adapted from van der Klift M et al. (2002) J Bone Miner Res 6: 1051
Diagnosing vertebral fractures requires visual assessment, recognizing normal anatomic variants.

Normal vertebral morphology:
- Thoracic slightly “wedged”
- Lumbar slightly “biconcave”

Courtesy of ISCD VFA Course
Vertebral deformities that are not osteoporotic fractures

- Normal anatomic variants
- Congenital anomaly
- Degenerative disease – disc space narrowing
- Infection – TB, osteomyelitis
- Paget’s disease
- Scheuermann’s disease (+/- Schmorl’s Nodes)
- Malignancy
- Short vertebral height without any endplate depression or cortical break?
Degenerative remodeling and hypertrophy causing elongation and wedging of vertebra – mimics fracture
Non-fracture abnormality

Schmorl’s nodes
Here associated with vertebral fractures

Schmorl’s nodes are herniations of the intervertebral disc through the vertebral end-plate
Not all vertebral fractures are due to osteoporosis

Metastatic prostate carcinoma
Indications for follow-up imaging to rule out malignancy

- Vertebral deformities in a patient with a known history of a relevant malignancy
- Normal BMD
- Diffuse sclerosis of vertebral body
- Expansion or destruction of cortex
- “Pancaked” vertebra (vertebral plana)
Indications for following VFA with another imaging modality

- Lesions in vertebrae that cannot be attributed to benign causes
- Two or more mild (grade 1) deformities without any moderate or severe (grade 2 or 3) deformities
  - Two *genuine* grade 1 fractures confer as much subsequent fracture risk as one grade 2 fracture
Important inclusions in a VFA report

- Vertebral bodies that were visualized (example: from T3 to L4)
- Unevaluable vertebrae within range T4 through L4
- Deformed vertebrae, and whether or not the deformities are consistent with vertebral fracture; location and grade of fractures
- Unexplained vertebral and extra-vertebral pathology of potential clinical significance
VFA summary

- VFA is the use of bone densitometers to image the lateral thoraco-lumbar spine at the point of service of a bone density test
- VFA accurately detects moderate to severe vertebral fractures, two thirds of which are not recognized clinically
- Prevalent vertebral fractures predict subsequent fractures independent of BMD