Assessment of Vertebral Fracture

Tuan Van Nguyen and Nguyen Dinh Nguyen
Bone and Mineral Research Program
Garvan Institute of Medical Research
Sydney, Australia
Vertebral fracture

- The most common osteoporotic fracture
- Patient’s and public health problem:
  - Increased risk of subsequent fractures
  - Quality of life: pain, disability
  - Increased morbidity and mortality risk
  - Costs
750,000 Spine Fractures each year

- Most common fragility fx
- 5-10% increase in all-cause mortality*
- Acute or chronic back pain
  ~2/3 of the fractures are clinically silent
- Height loss
- Gastrointestinal / respiratory difficulties
- Depression, loss of self-esteem
- Impact on activities of daily living


Vietnam Osteoporosis Workshop, HCMC 2006
Prevalence of Vertebral fracture

-Critically dependent on the criterion used. Irrespective of the criterion used, prevalence of VD higher in men than in women:
  -25% vs 20% (3SD)
  -17% vs 12% (4SD)
  -27% vs 25% (25%)

(Source: Jones G, Nguyen TV et al., Osteoporos Int. 1996;6:233-39)
Incidence (per 10,000 person-years) of vertebral fracture (using McCloskey-Kanis method), stratified by age and gender
(Source: The EPOS Group, 2002)
Association between prevalent vertebral fracture and subsequent fractures

![Graph showing the association between prevalent vertebral fracture and subsequent fractures. The graph illustrates the percentage of subsequent fractures (%/3y) for different levels of vertebral fracture severity: Normal, Mild, Moderate, and Severe. The x-axis represents the severity of prevalent vertebral fracture, while the y-axis represents the subsequent fracture percentage. The data is sourced from Delmas et al. BONE, 2003; 33:522-32.]

(Source: Delmas et al. BONE, 2003; 33:522-32.)
Terminology

Vertebral deformity/
Vertebral fracture

- Asymptomatic
  - $\Delta = \text{imaging}$

Clinical
vertebral fracture

- Symptomatic
  - $\Delta = \text{imaging}$
  - Symptom

Imaging diagnosis: X-ray, DXA, CT, MRI

IOF recommends to report as “Vertebral fracture”
Endpoint for clinical trials

• Trials of treatment of patients with existing vertebral fractures:
  – morphometric evidence of at least one baseline vertebral deformity
  – or the presence of at least one “definite” fracture according to SQ method.

• Trials of primary or secondary prevention of vertebral fracture: may use QM or SQ or a combination.
Types of vertebral fracture

- Normal
- End-plate
- Concave
- Bi-concave
- Wedge fracture
- Compression fracture (crush)
Assessment of vertebral fracture

Prevalent vertebral fracture
- Semi-quantitative
- Quantitative morphometry
- Algorithm-based qualitative

Incident vertebral fracture
- Quantitative morphometry
- Semi-quantitative
Approaches to the identification of vertebral fracture

- Semi-quantitative method (SQ) or visual method
- Quantitative vertebral morphometry (QM)
  - X-Ray
  - Lateral vertebral assessment (LVA): DXA
- Algorithm-based qualitative assessment (ABQ)
Semi-quantitative grading (Genant et al 1993)

Grade 0

Anterior Normal

Grade 1 (~20-25%)

Anterior Mild fracture

Grade 2 (~25-40%)

Anterior Moderate fracture

Grade 3 (~40%)

Anterior Severe fracture

(Source: Genant HK et al, JBMR 1993; 8:1137-1148)
SQ: visual normal spine
Morphometric measurements

• Typically based on placement of 6 points that define:
  – the anterior height (H_a)
  – the middle height (H_m)
  – the central height (H_c)
  – and the posterior height (H_p)
  of the Vertebral body
MQ: types of measurement

X-Ray
(Standard but not “Gold standard”)

Lateral Vertebral Assessment (LVA): DXA
Electronic Cursor for Morphometry
MQ: Placement of six digitizing points for different projections of the vertebrae
QM with Six-Point Placements
Defining vertebral fracture

Parameters:
- $H_a/H_p$
- $H_c/H_p$
- $H_{pi}/H_{pi+1}$; $H_{pi}/H_{pi-1}$

Types of fracture:
- Wedge: $\downarrow H_a$, $\downarrow H_a/H_p$
- Biconcave (end-plate): $\downarrow H_c$, $\downarrow H_c/H_p$
- Crush: $\downarrow H_{pi}/H_{pi+1}$ or $\downarrow H_{pi}/H_{pi-1}$
<table>
<thead>
<tr>
<th>Reference</th>
<th>Measurement</th>
<th>Parameters calculated</th>
<th>Fracture definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Minne et al., 1988)</td>
<td>$H_a, H_m, H_p$</td>
<td>Spine Deformity Index</td>
<td>Below lower limit of normative values. Values are adjusted to the dimensions of the T4&gt; 2SD from mean.</td>
</tr>
<tr>
<td>(Kleerekoper et al., 1984)</td>
<td>$H_a, H_m, H_p$</td>
<td>Wedge ratio, biconcave ratio, compress ratio.</td>
<td>Any ratio ≤ 0.85. Vertebral dimensions adjusted for specific level.</td>
</tr>
<tr>
<td>(Gallagher et al., 1988; Hedlund and Gallagher, 1988; Hedlund et al., 1989)</td>
<td>$H_p$, Width</td>
<td>Wedge angle, PRH, PDAH, area</td>
<td>Below lower limit of normative values. Values are adjusted to the dimensions of the T4&gt; 2SD from mean.</td>
</tr>
<tr>
<td>(Davies et al., 1989; Davies et al., 1993)</td>
<td>$H_a, H_p$</td>
<td>Wedge variable ($\approx$PRH), relative posterior height.</td>
<td>Below 1st decile above 10th decile of normative value (Minne et al., 1988); cutoff values adjusted to visual interpretation (Davies et al., 1993).</td>
</tr>
<tr>
<td>(Harrison et al., 1990)</td>
<td>$H_a, H_m, H_p$</td>
<td>Wedge ratio, biconcave ratio, compress ratio.</td>
<td>Any ratio ≤ 0.75, mean height 15% less than adjacent vertebrae.</td>
</tr>
<tr>
<td>(Raymakers et al., 1990)</td>
<td>$H_a, H_m, H_p$</td>
<td>Spine Fracture Index</td>
<td>15% difference from expected value</td>
</tr>
<tr>
<td>(Eastell et al., 1991)</td>
<td>$H_a, H_m, H_p$</td>
<td>Wedge ratio, biconcave ratio, compress ratio.</td>
<td>&gt;3SD and &lt;4SD from mean (grade 1); &gt;4SD from mean (grade 2).</td>
</tr>
<tr>
<td>(Smith-Bindman et al., 1991)</td>
<td>$H_a, H_m, H_p$</td>
<td>Index of Radiographic Area</td>
<td>Adjusted height or area below 1st percentile of normative values.</td>
</tr>
<tr>
<td>(Black et al., 1991)</td>
<td>$H_a, H_m, H_p$</td>
<td>Wedge ratio, biconcave ratio, compress ratio.</td>
<td>Different cutoff values trim-curved normative data.</td>
</tr>
<tr>
<td>(Ross et al., 1993)</td>
<td>$H_a, H_m, H_p$</td>
<td>Height reduction.</td>
<td>3SD below individually adjusted Z-scores.</td>
</tr>
<tr>
<td>(McCloskey et al., 1993)</td>
<td>$H_a, H_m, H_p$</td>
<td>Predicted wedge, biconcave and posterior ratios.</td>
<td>3SD below mean for two criteria</td>
</tr>
</tbody>
</table>

PDAH, percent difference in anterior height between adjoining vertebrae; PRH, percent reduction of anterior to posterior height; $H_a$, anterior; $H_m$, middle; and $H_p$, posterior height of each vertebral body from T12 to L4.
QM: Eastell et al. 1991

Type of fracture

H_{ar} \quad H_{mr} \quad H_{pr}

Wedge \quad Bi-concavity \quad Compression

Degree of fracture

\[
\frac{H_{(a,m,p)} - H_{(ar,mr,pr)}}{SD_{(ar,mr,pr)}} \begin{cases} 
-4SD < \text{Grade 1} < -3SD \\
\text{Grade 2} \leq -4SD
\end{cases}
\]
Lateral Vertebral Assessment (using DXA):

Qualitative and quantitative
Six-point video-assisted Lateral Vertebral Assessment
Visual Assessment of Vertebral Fracture Using Lateral DXA Scan

- VFA showed good sensitivity (>80%) in identifying moderate/severe XSQ deformities.
- Excellent negative predictive value (>90%) in distinguishing subjects without from those with vertebral deformities on a per subject basis.
- Poor sensitivity to detect mild vertebral fractures, especially at the upper thoracic spine.

(Source: J. Rea et al Osteoporos Int 2000)
### Inter-agreement between expert readers (SQ)

<table>
<thead>
<tr>
<th></th>
<th>Visual XA (A)</th>
<th>Visual XA (B)</th>
<th>Visual MXA (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual XA (B)</td>
<td>0.86</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Visual MXA (B)</td>
<td>0.86</td>
<td>0.87</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Visual XR, visual assessment of spinal radiographs
Visual MXA, visual and quantitative assessment of MXA scan images

(Source: Ferrar et al. JBMR 2003;18:933-938)
Concordance between the three MQ and the SQ methods

<table>
<thead>
<tr>
<th>Criterion</th>
<th>French</th>
<th>Mixed European</th>
<th>Argentinean</th>
</tr>
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<tbody>
<tr>
<td>Mean-3SD cutoff</td>
<td>0.73</td>
<td>0.76</td>
<td>0.73</td>
</tr>
<tr>
<td>0.85 x mean cutoff</td>
<td>0.78</td>
<td>0.78</td>
<td>0.79</td>
</tr>
<tr>
<td>3SD/PPH cutoff</td>
<td>0.76</td>
<td>0.73</td>
<td>0.76</td>
</tr>
</tbody>
</table>

(Source: Szulc et al. BONE, 2003;27:841-846)
## SQ and MQ: A comparison

<table>
<thead>
<tr>
<th>Semi-quantitative (SQ)</th>
<th>Quantitative or Morphometric approach</th>
</tr>
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<tbody>
<tr>
<td>Make use of the entire spectrum of visible features</td>
<td>Obtain an objective and reproducible measurement</td>
</tr>
<tr>
<td>Using expertises of Radiologists and Clinicians</td>
<td>Using rigorous defined points placement and well-defined algorithms</td>
</tr>
<tr>
<td>Quick performance</td>
<td>Slower</td>
</tr>
<tr>
<td>Identify more fracture</td>
<td>Less</td>
</tr>
<tr>
<td>More false-positive rate</td>
<td>High sensitivity, lack of specificity</td>
</tr>
<tr>
<td>Not complicated</td>
<td>Complicated and tedious</td>
</tr>
<tr>
<td>Widely applied in clinical practices</td>
<td>Used in epidemiological studies or clinical trials</td>
</tr>
</tbody>
</table>

**Algorithm-based qualitative assessment (ABQ)**
Algorithm-based qualitative (ABQ) approach

• Differs from SQ method:
  – Focusing only on depression of the central endplate.
  – Introducing the concept of differential diagnosis of short vertebral height.

• Reduce false positive rate
Depression of endplate?

Yes

Close to centre of endplate?

Yes

True depression?

Yes

Whole of endplate depressed within rim?

Yes

Prior trauma, tumor, metabolic disease?

No

Osteoporotic fracture

Yes

Short vert. height?

No

Yes

Scheuermann’s disease, childhood fracture, Scoliosis, variant in vert. body size

Yes

Anterior location: step-like endplate in thoracic vertebrae (variant)

Posterior location: Cupid’s bow or balloon disc in lumbar vertebrae

No

Check for oblique projection or scoliosis

Yes

Focused area: Schmorl’s nodes

Yes

Non-fracture deformity, developmental variant, non-osteoporotic fx or abnormal appearances due to other diseases or conditions

Normal
Assessment of incident vertebral fracture

• Semi-quantitative: has not been adequately studied

• Quantitative Morphometry:
  – A new fracture: $\geq 15\%$ reduction in any one of the three measured vertebral heights ($H_a$, $H_m$ or $H_p$)
  – More stringent criteria: $\geq 20\%$ change or a change $> 3SD$ of the mean differences (on repeated X-ray) for that vertebral level.

• The best definition: has not been established
SQ Incident mild vertebral fx
SQ Incident moderate Vert fx
SQ Incident severe & moderate Fxs
Summary

- Assessment methods:
  - No “gold standard” for the identification
  - Three methods: SQ, QM and ABQ

- Vertebral fracture:
  - Serious but mostly asymptomatic
  - Apprx. ¼ vertebral deformities are symptomatic
Lời Cảm tạ

• Chúng tôi xin chân thành cảm ơn Công ty Dược phẩm Bridge Healthcare, Australia là nhà tài trợ cho hội thảo.
Thank you!