VERTEBRAL FRACTURE INITIATIVE
Part III

Densitometric Vertebral Fracture Assessment (VFA)

By John T. Schousboe, Tamara Vokes, Neil Binkley, and Harry K. Genant

International Osteoporosis Foundation
www.iofbonehealth.org

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

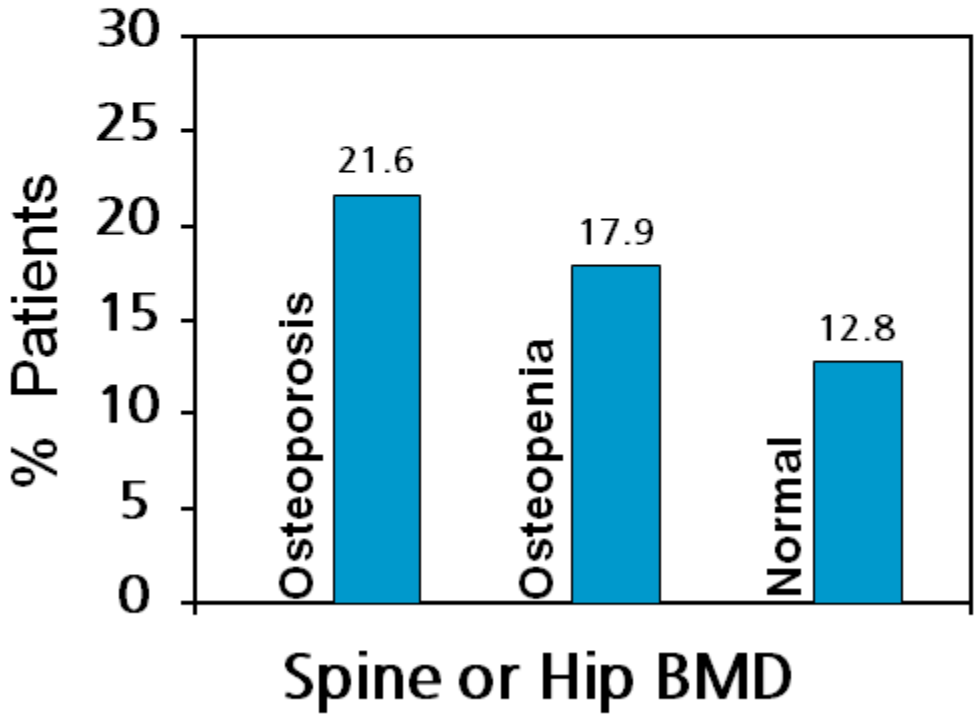
- **Prevalent radiographic vertebral fractures are an indicator of poor bone strength**
  - Confer 4 fold risk of incident vertebral fractures independent of BMD
  - Confer 1.8 fold risk of incident hip fractures independent of BMD
  - Confer 1.6 fold increased risk of non-vertebral fractures independent of BMD
- **Prevalent vertebral fracture without major trauma** = diagnosis of osteoporosis

Importance of vertebral fractures

- 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

Age	Femoral Neck T-score (SD)				
	-1.0	-1.5	-2.0	-2.5	-3.0
60	8%	9%	11%	14%	16%
65	10%	*12%*	*15%*	18%	21%
70	13%	*15%*	*18%*	22%	26%
75	16%	*19%*	*23%*	27%	32%
80	20%	*24%*	*28%*	33%	38%

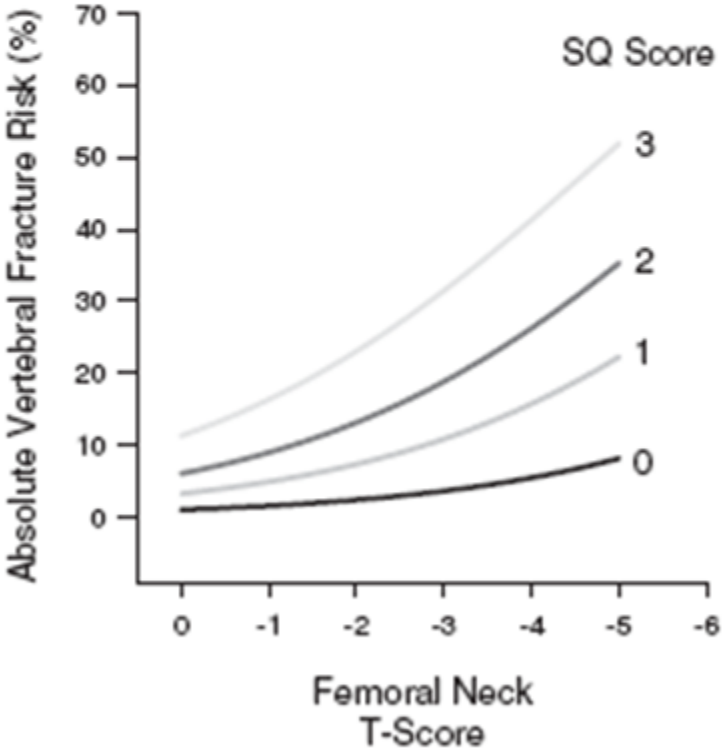
* Assuming 70% of prevalent vertebral fractures are clinically silent and an odds of 1.5 for one or more prevalent vertebral fractures being present per each Z-score decrease in BMD

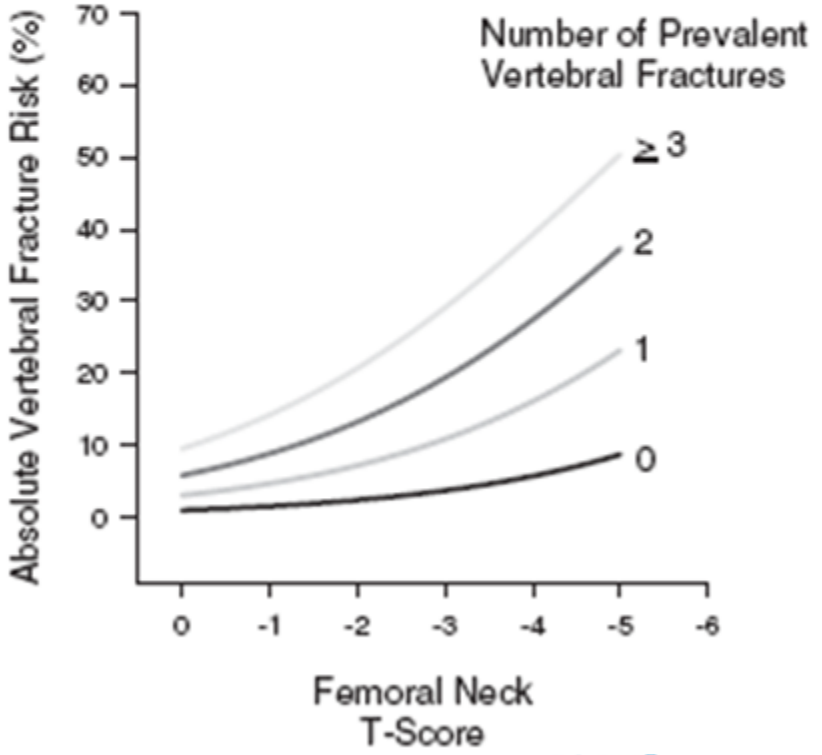
Adapted from Melton LJ et al. (1993) Osteoporosis Int 3(3): 113

International Osteoporosis Foundation
www.iofbonehealth.org

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



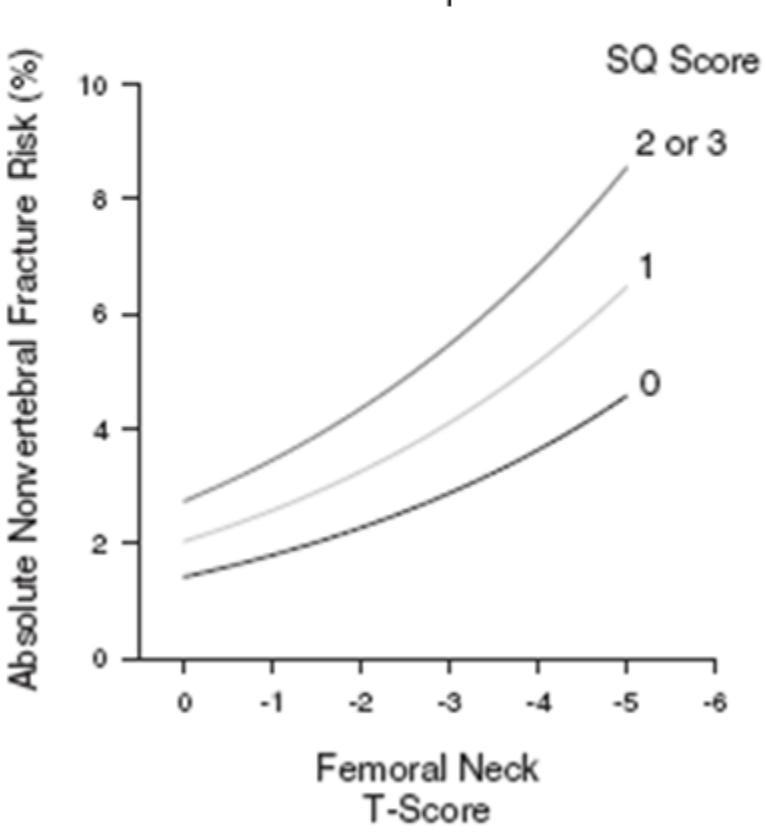


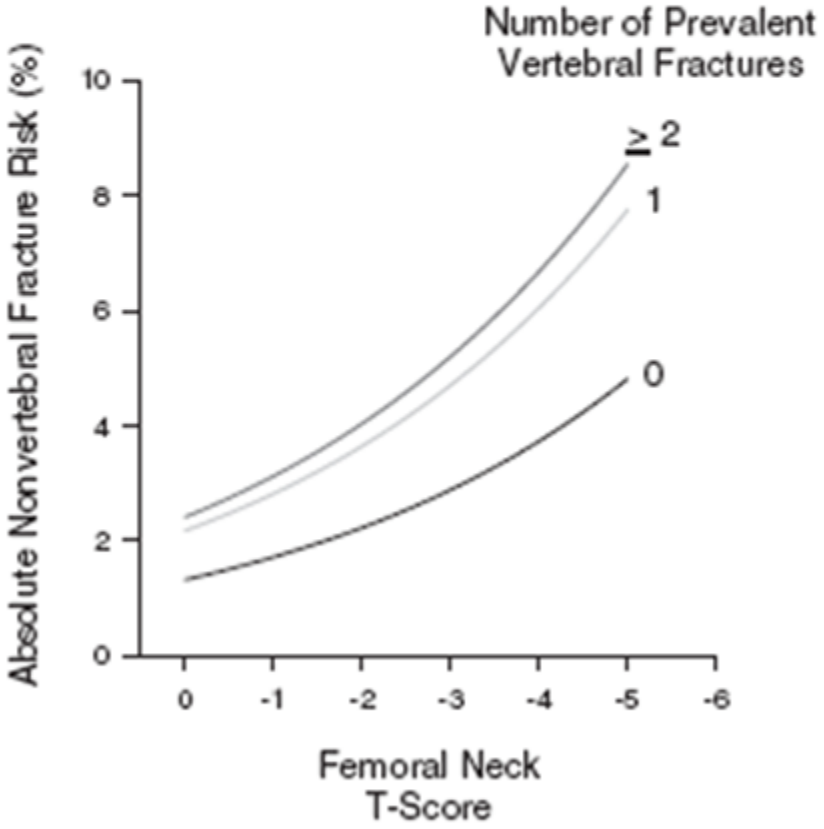
Siris ES et al. (2007) Osteoporosis Int 18: 761
With kind permission from Springer Science+Business Media

International Osteoporosis Foundation
www.iofbonehealth.org

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

	X-ray	VFA
Radiation dose	600 μSv	3 - 40 μSv
Access	Separate visit	Point of service
Cost	Higher ($92*)	Lower ($45*)
Obliquity	Common in LS	Less parallax effect
Resolution	Higher	Lower
Visualization	Superior above T7	May be superior in LS

* 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

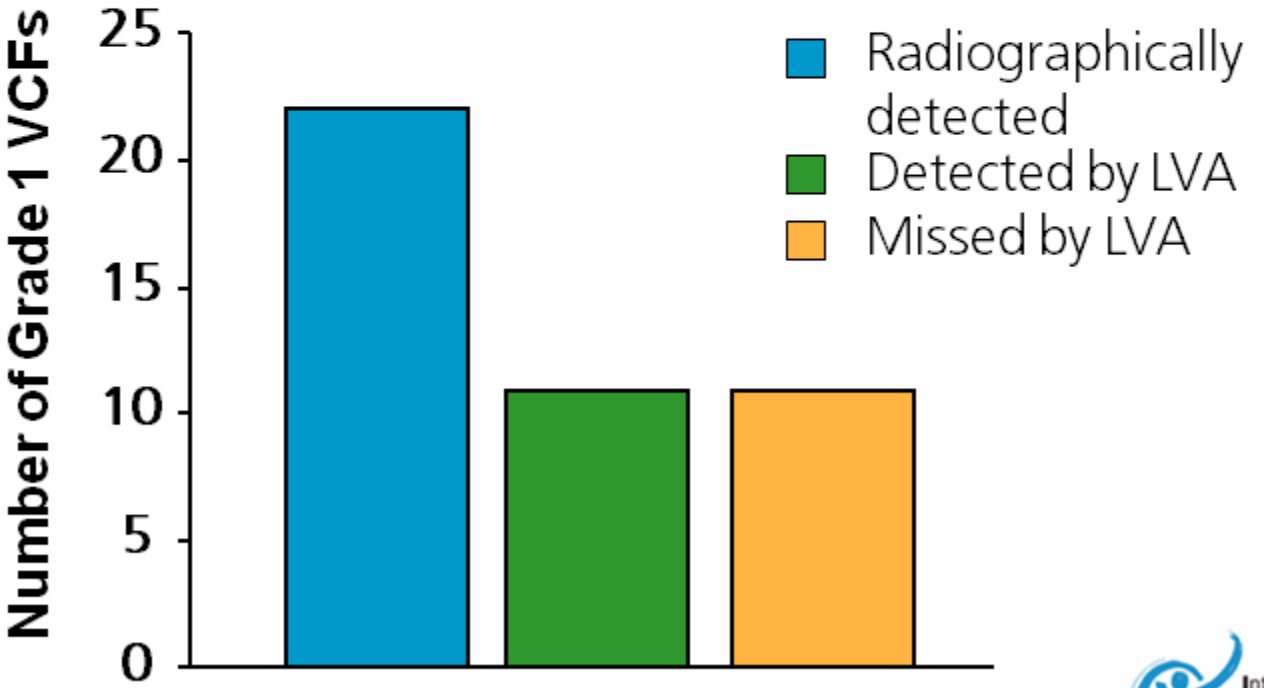
- **Poor visualization above T7**
  - T7 and below - 97% visualized[1]
  - T6 - 70%[2]
  - T5 - 60%[2]
  - T4 - 43%[2]

[1]*Rea JA et al. (1998) Osteoporos Int 8(2):177*
[2]*Ferrar L et al. (2000) J Bone Miner Res 15(3): 575*

T12 Fracture

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)

	Sensitivity	Specificity
Fracture Grades 1-3	53% - 70%	94% - 99%
Fracture Grades 2-3	57% - 95%	96% - 99%

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

Binkley N et al. (2005) Osteoporos Int 16: 1513; Fuerst T et. al. (2009) Osteoporos Int 20: 1199
Damiano J et al. (2006) 9(1): 66; Hospers IC et al. Radiology 251(3): 822
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

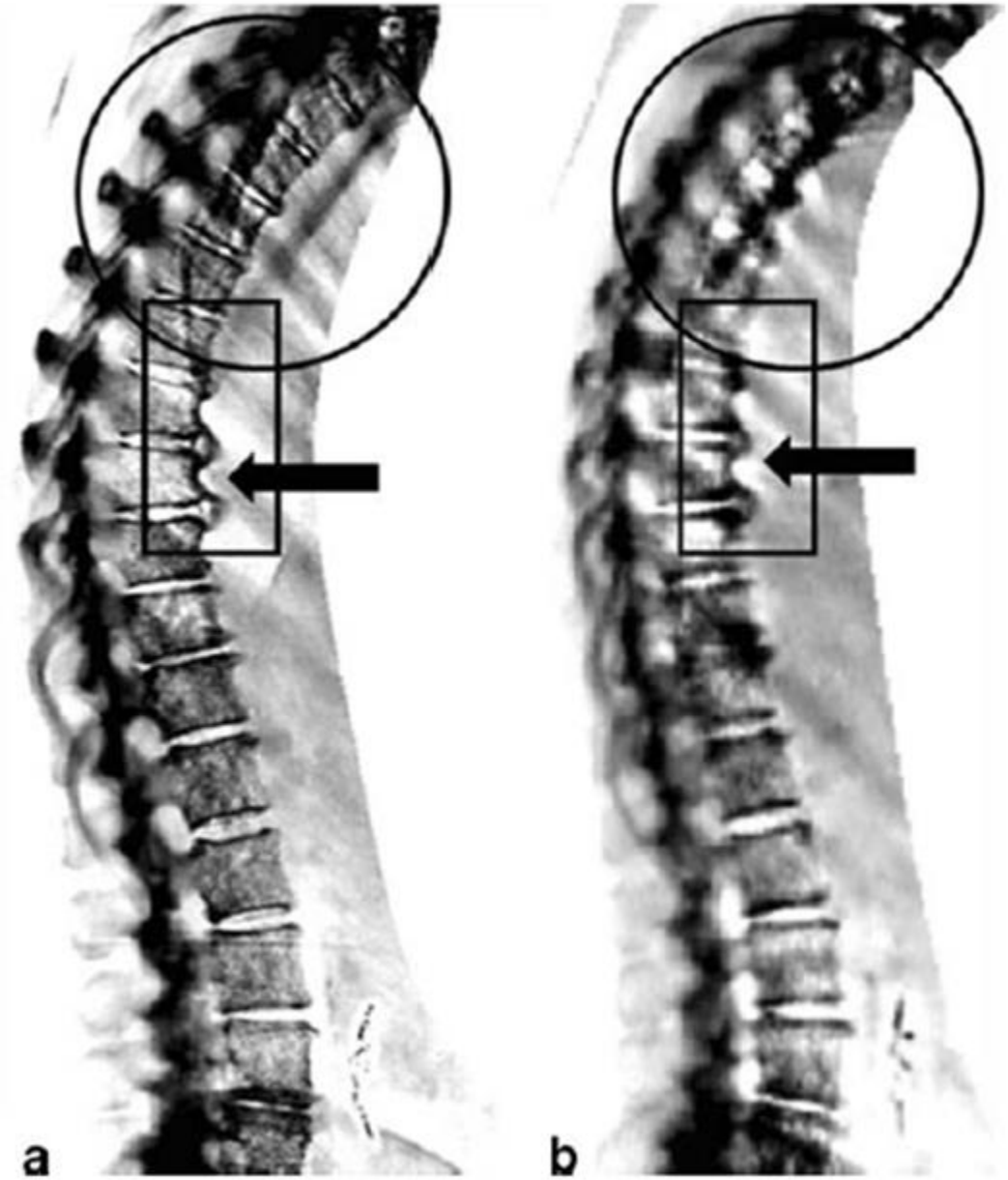
- Manufacturers of densitometers have changed their technologies to improve image quality

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

Buerhing B et al. (2010) Osteoporosis Int 21(3): 487-494

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%)
  - Vogt TM et al. (2000) *Mayo Clin Proc* 75: 888-896
  - Kaptoge S et al. (2004) *J Bone Miner Res* 19(12): 1982-1993
- Result will influence therapy

Association of prevalent vertebral fractures with clinical risk factors

Vertebral fracture prevalence by level of PVFI*

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

* 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)

Adapted from Vogt TM et al. (2000) Mayo Clin Proc 75: 888

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.

2007 ISCD Official Positions

International Osteoporosis Foundation
www.iofbonehealth.org

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

International Osteoporosis Foundation
www.iofbonehealth.org

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.

2007 ISCD Official Positions

International Osteoporosis Foundation
www.iofbonehealth.org

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.

2007 ISCD Official Positions

International Osteoporosis Foundation
www.iofbonehealth.org

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

2007 ISCD Official Positions

International Osteoporosis Foundation
www.iofbonehealth.org

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

2007 ISCD Official Positions

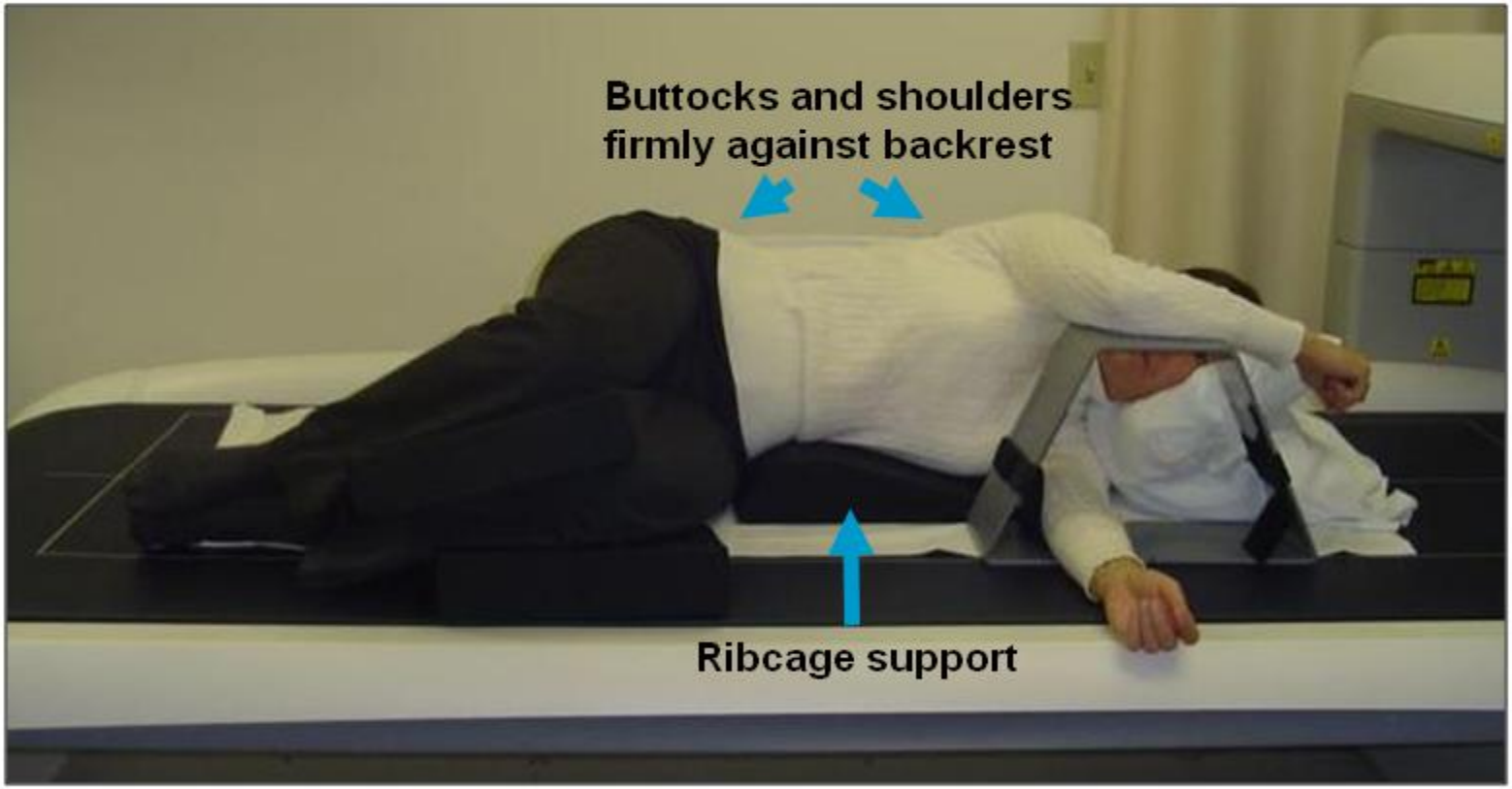
How are VFA images obtained?

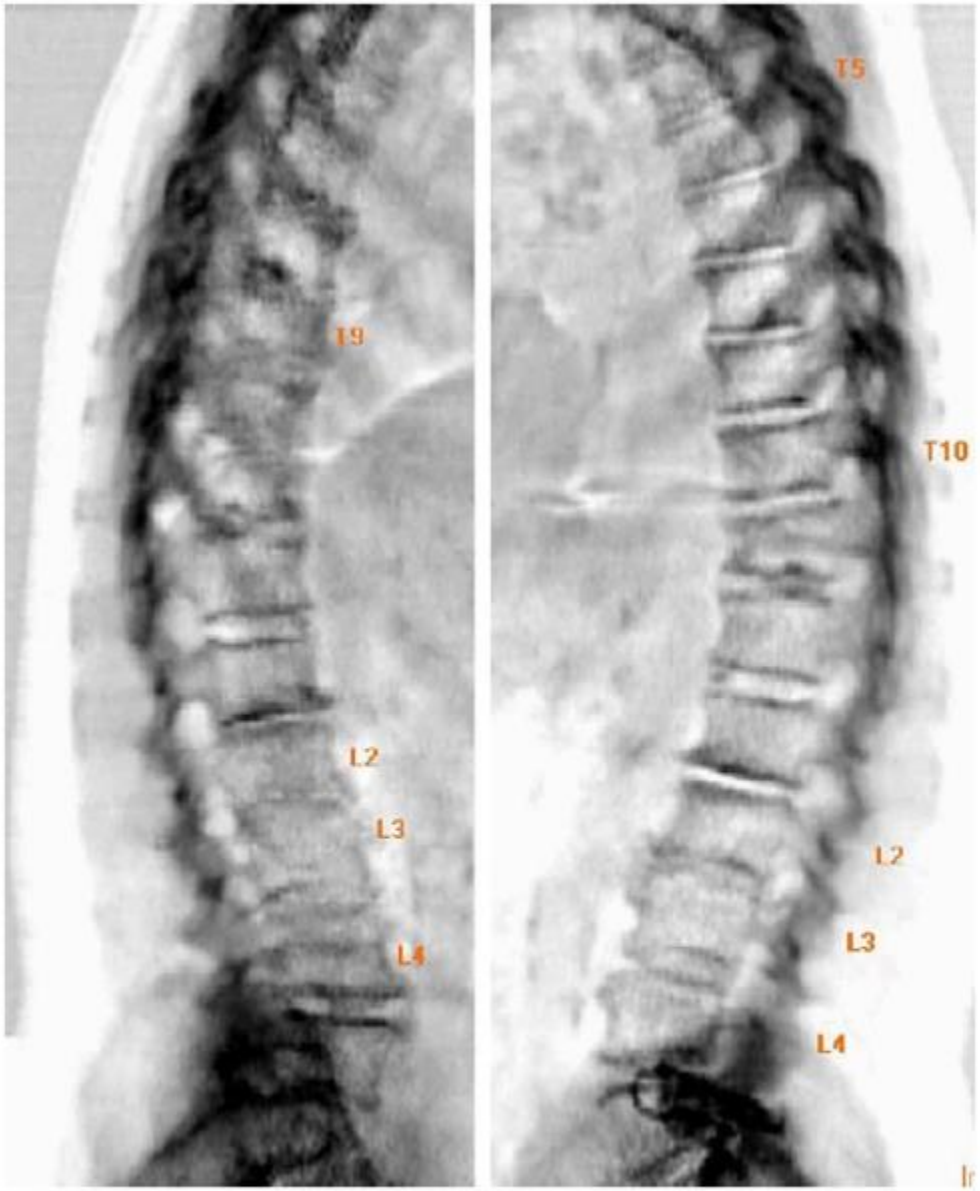
Positioning

- **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





a b

Reverse lateral positioning:

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

Vallarta-Ast N et al. (2006) J Clin Densitom 9(3): 375

AP spine image

- Not essential for vertebral fracture assessment

BUT

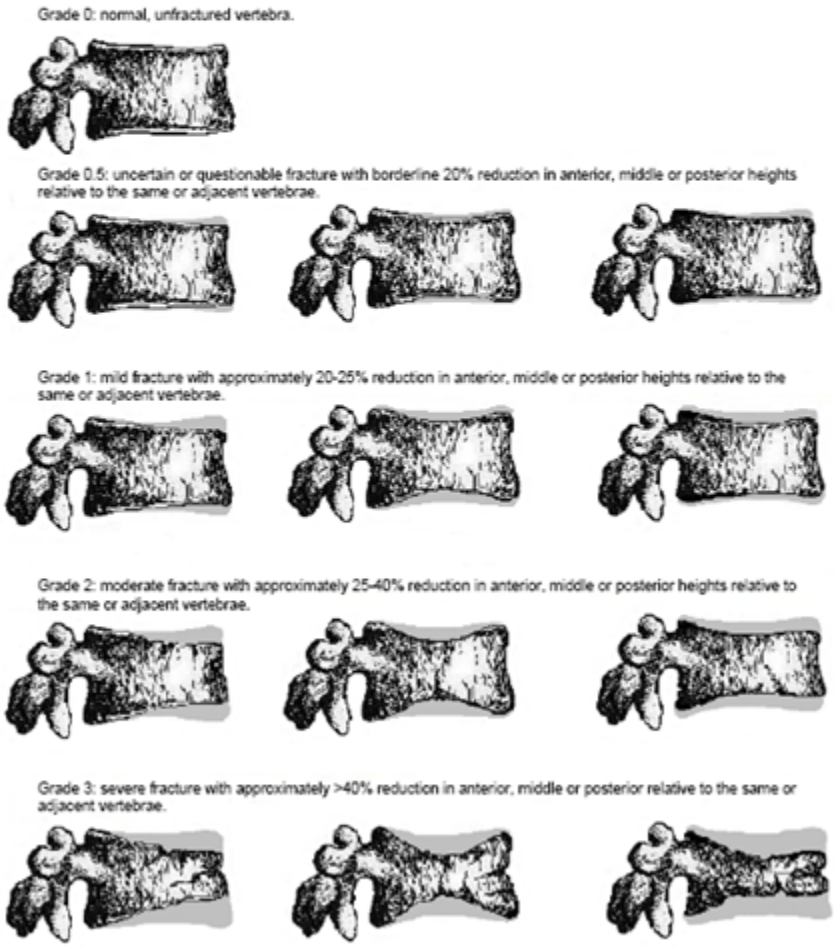
- Can aid identification and labeling of vertebra
- Can aid evaluation of scoliosis severity if present
- Can aid detection of lateral cortex / endplate compression fractures

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



Combines both visual inspection and selected measurement of vertebral heights.

Note, borderline grade is not used in practice

Genant HK et al. (1993) J Bone Min Res 8: 1137 & (2000) J Clin Densitom 3(3): 281

International Osteoporosis Foundation
www.iofbonehealth.org

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

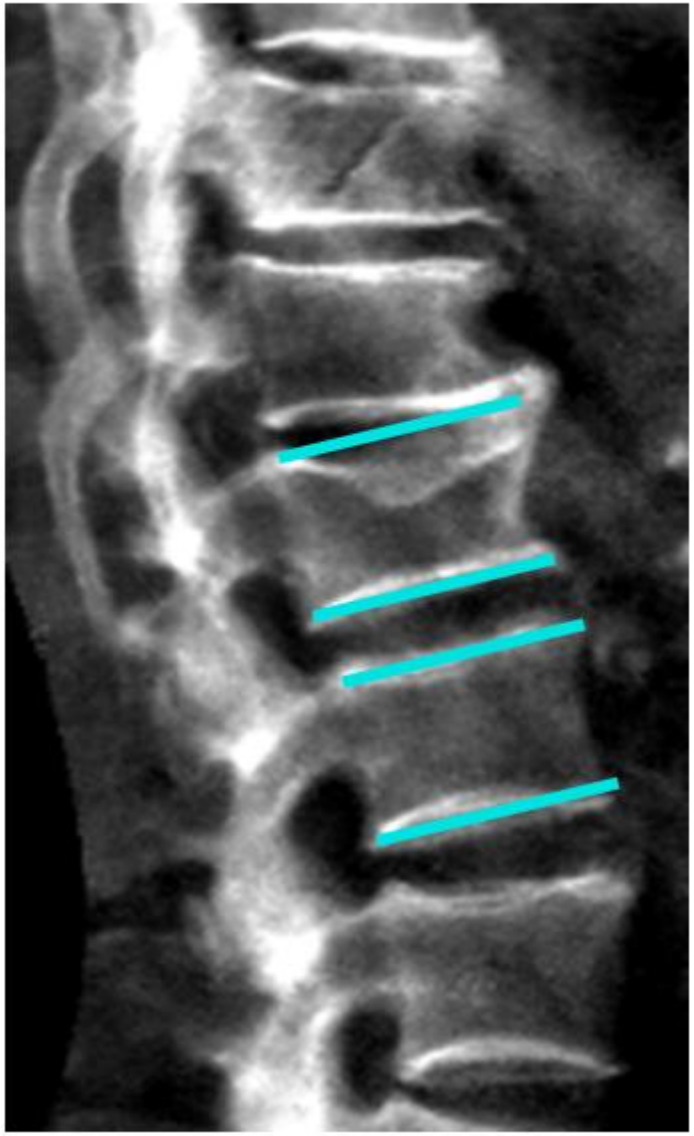
Schousboe JT et al. (2008) Osteoporos Int 11(1): 92

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

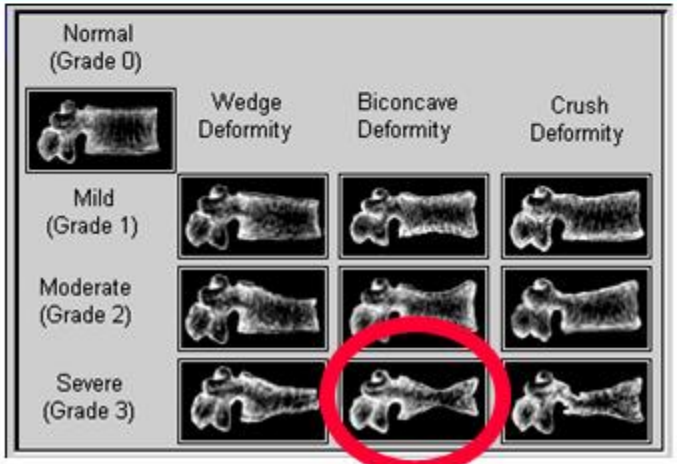
Identification of vertebral fracture



Courtesy of ISCD VFA Course

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

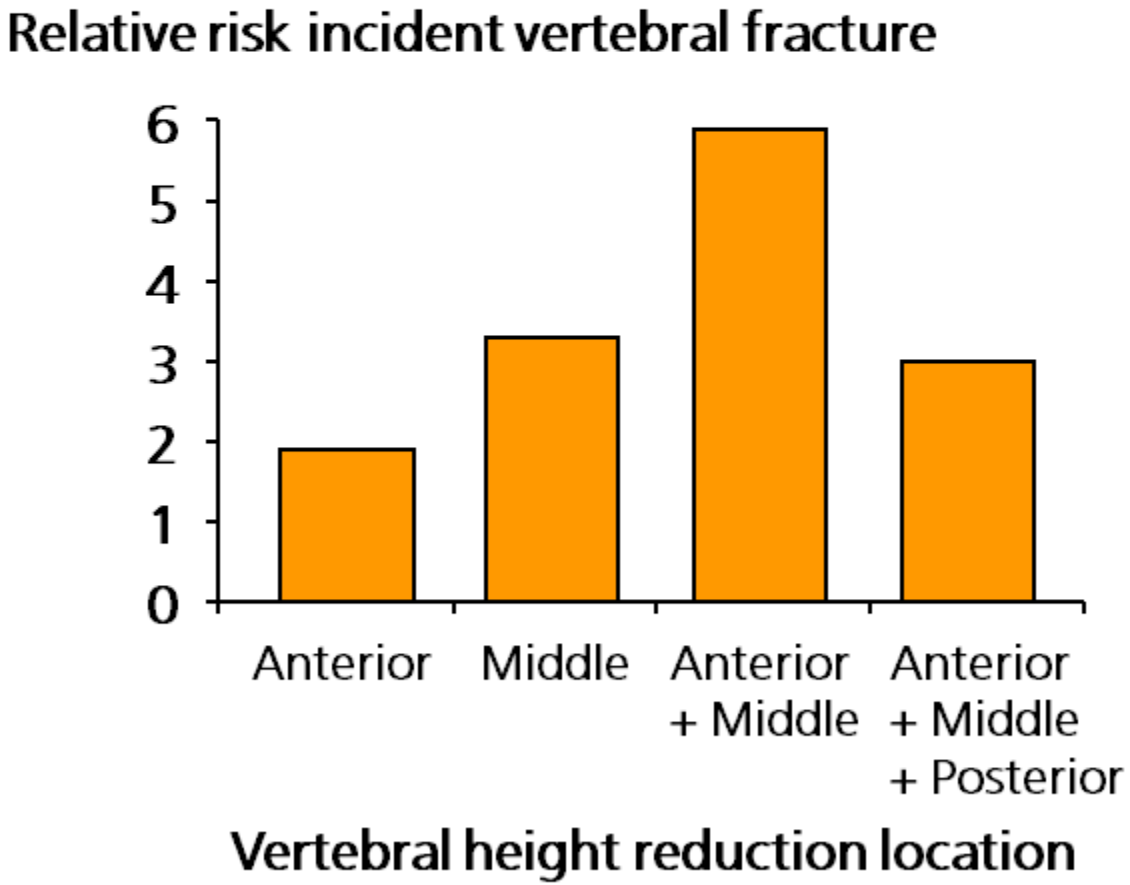


~20-25%

~25-40%

>40%

Isolated mild anterior height reduction



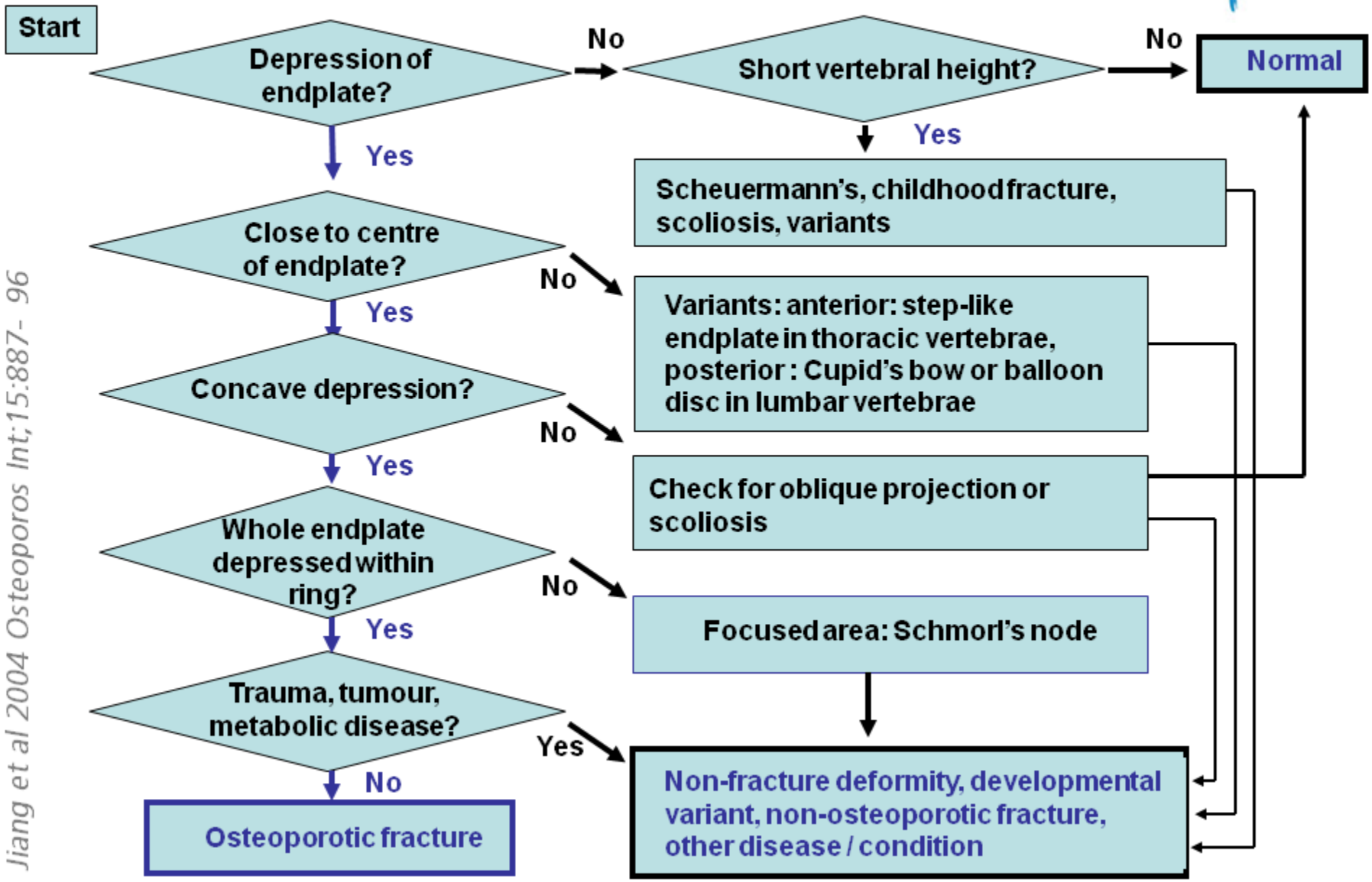
Isolated mild anterior height reduction may not be associated with incident vertebral fracture

Adapted from Lunt M et al. (2003) Bone 33: 505

Algorithm-Based Qualitative (ABQ) method

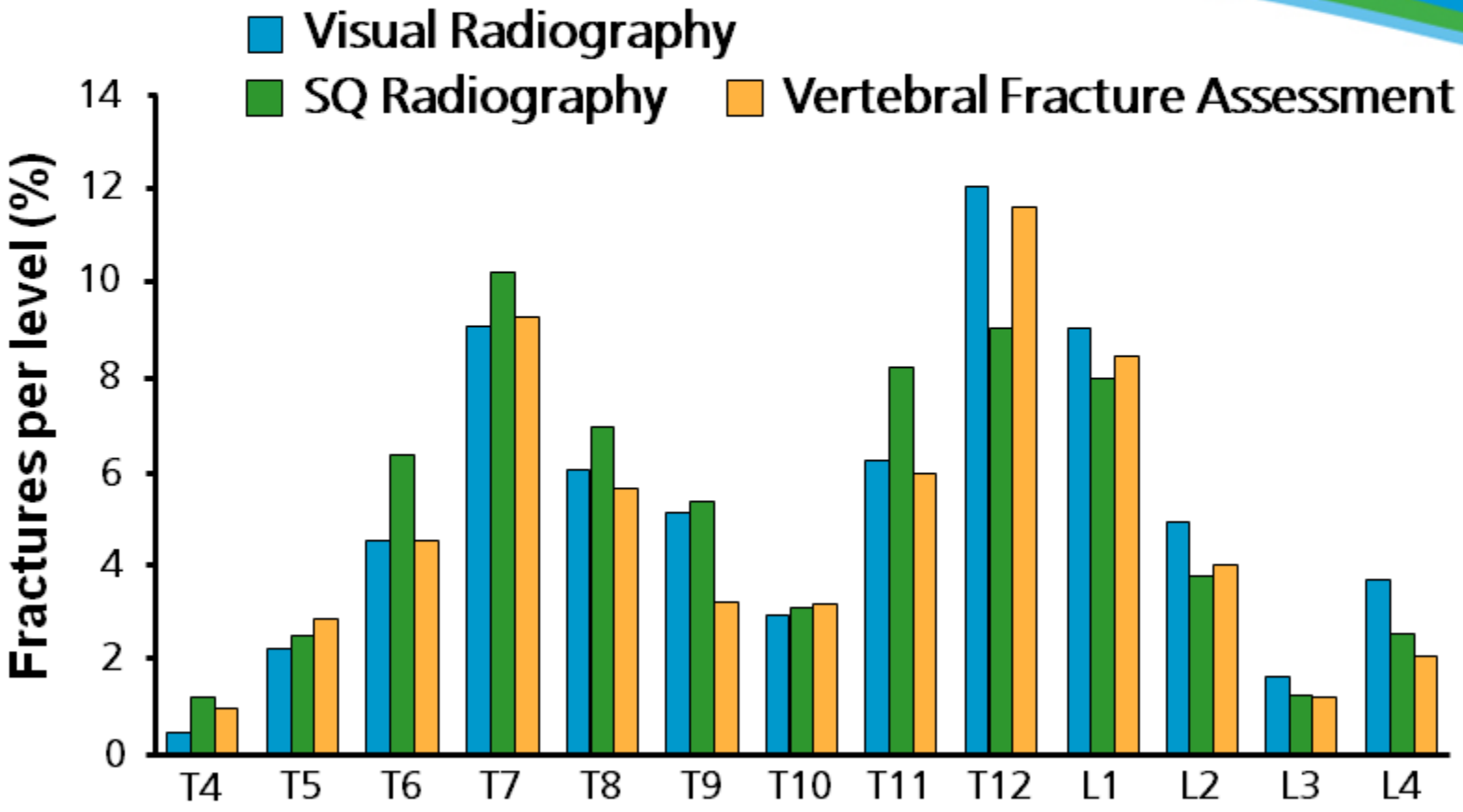
- Endplate depression is central to definition of a vertebral fracture
- ABQ is a qualitative method developed to avoid labeling vertebral bodies with short vertebral height as fractured
- Reliable, reproducible on both standard radiographs and VFA images
- Predictive validity (eg prospective fracture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

Algorithm-based Qualitative (ABQ) Assessment



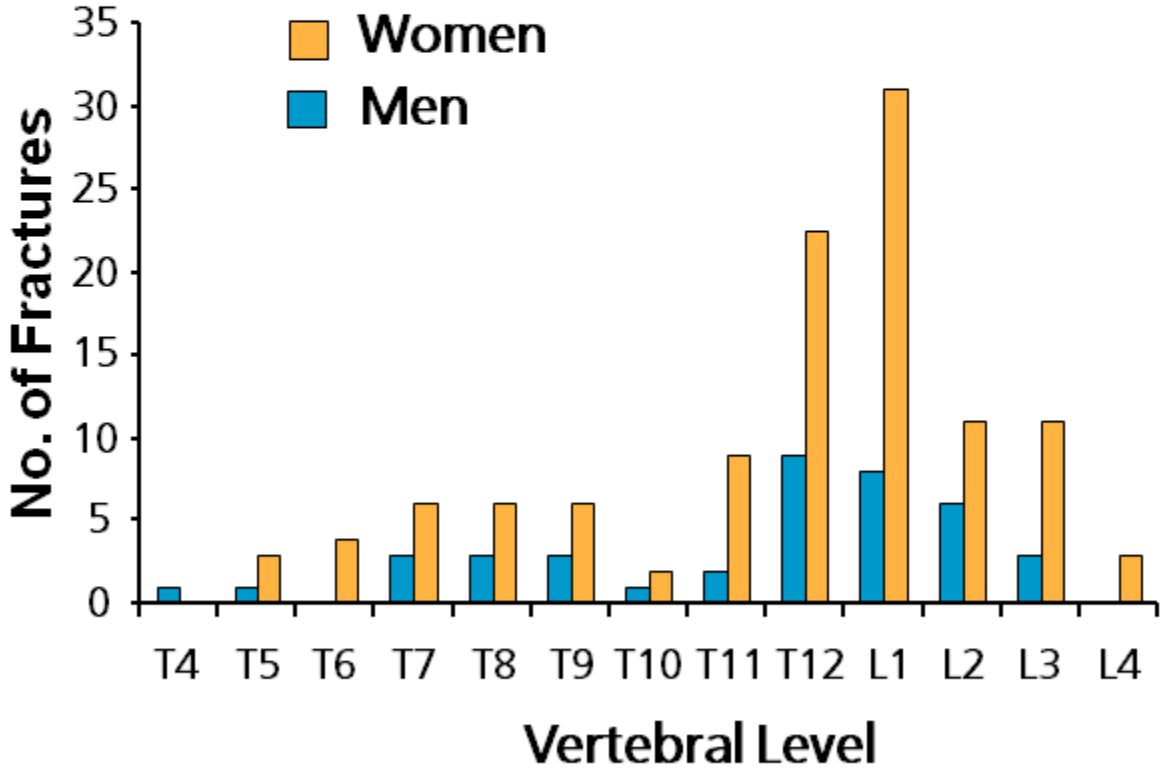
Jiang et al 2004 Osteoporos Int;15:887- 96

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

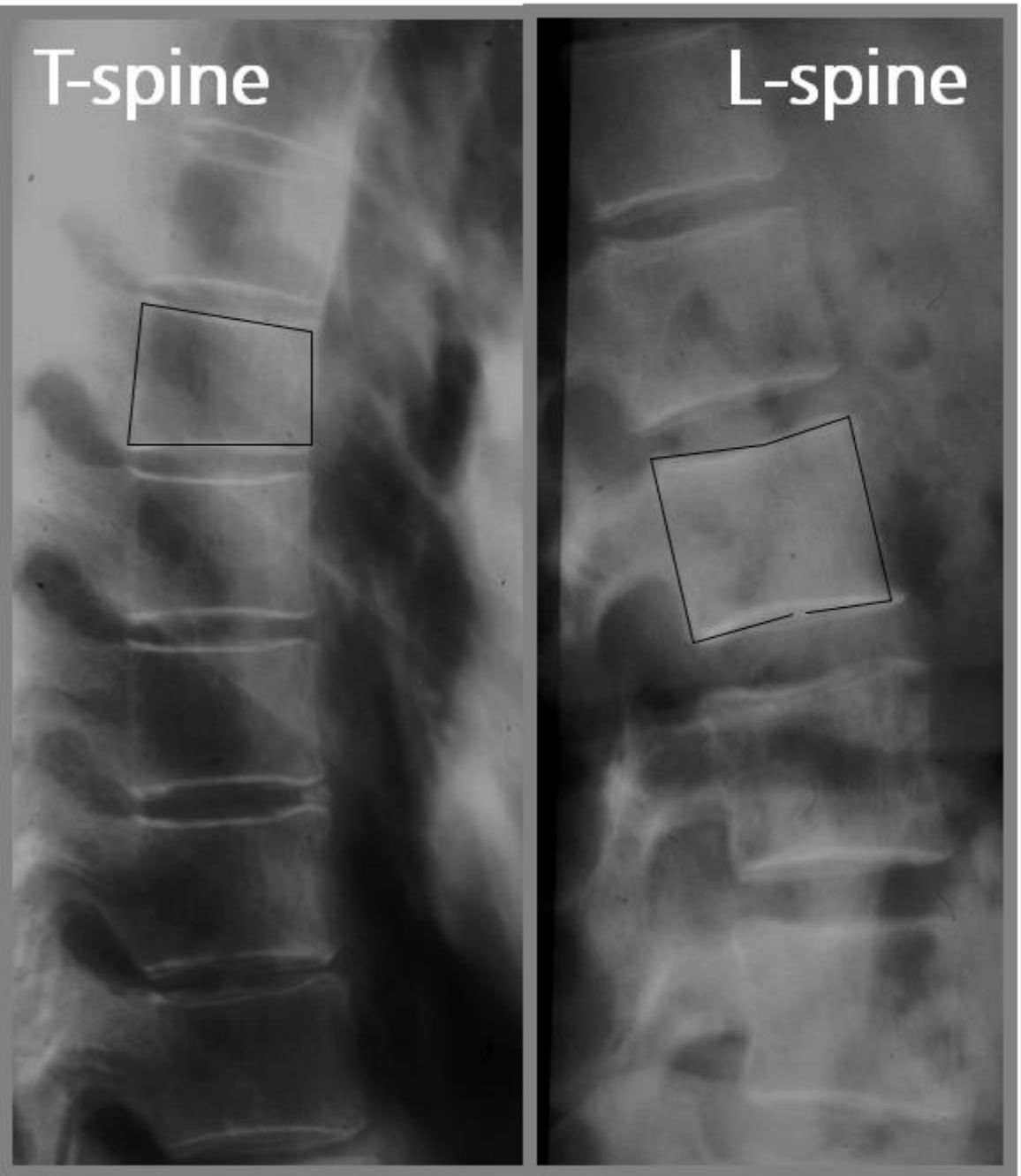


Incident fractures:
6.3 years,
Rotterdam study

240 new fractures
in 176 of 3469
persons

Adapted from van der Klift M et al. (2002) J Bone Miner Res 6: 1051

International Osteoporosis Foundation
www.iofbonehealth.org



International Osteoporosis Foundation

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

International Osteoporosis Foundation

Schmorl's nodes

Here associated with vertebral fractures

Schmorl's nodes are herniations of the intervertebral disc through the vertebral end-plate

International Osteoporosis Foundation

Not all vertebral fractures are due to osteoporosis

Metastatic prostate carcinoma

Courtesy of ISCD VFA Course

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