



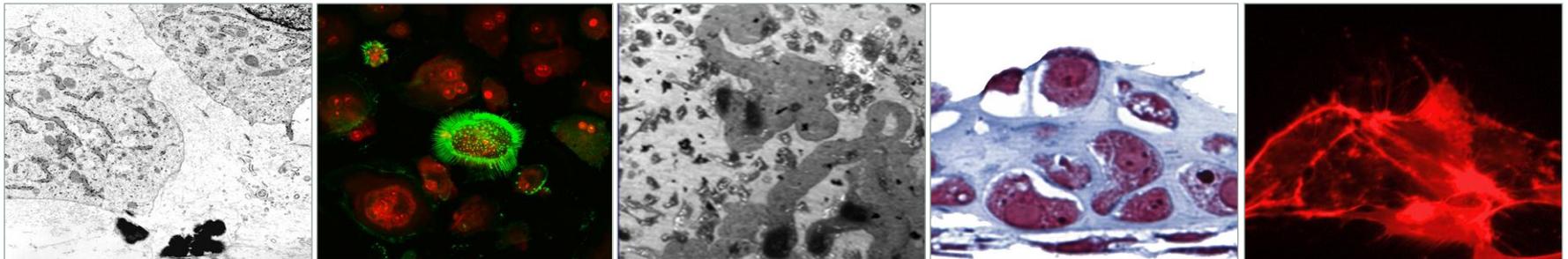
18<sup>th</sup> International Conference on Medical Image Computing and Computer Assisted Interventions –  
5<sup>th</sup> October 2015

# Vertebral Fracture Identification using Dual-Energy X-ray Absorptiometry

---

Margaret Paggiosi  
Research Fellow

The Mellanby Centre for Bone Research, The University of Sheffield, Sheffield, United Kingdom



# Outline

- An introduction to osteoporosis
- Osteoporosis and fragility fractures
  
- Dual-energy X-ray absorptiometry (DXA)
- Vertebral fracture assessment (VFA) by DXA
- VFA by DXA versus conventional radiography
  
- What is a vertebral fracture?
- Common non-fracture deformities
  
- Approaches used to identify osteoporotic vertebral fractures



Sheffield Teaching Hospitals **NHS**  
NHS Foundation Trust



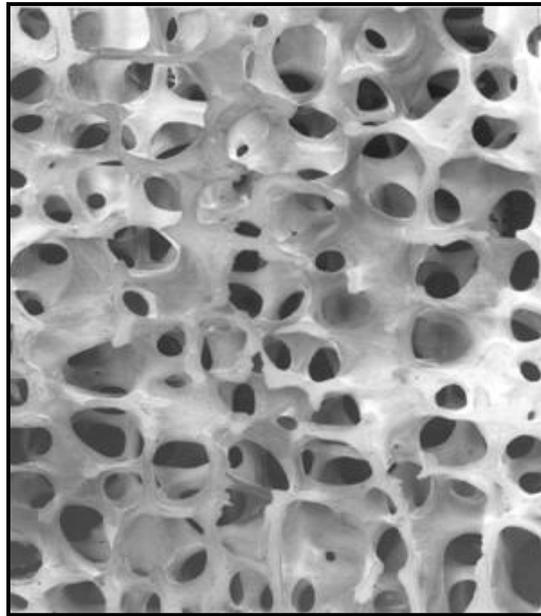
The  
University  
Of  
Sheffield.

# Osteoporosis and Fragility Fractures

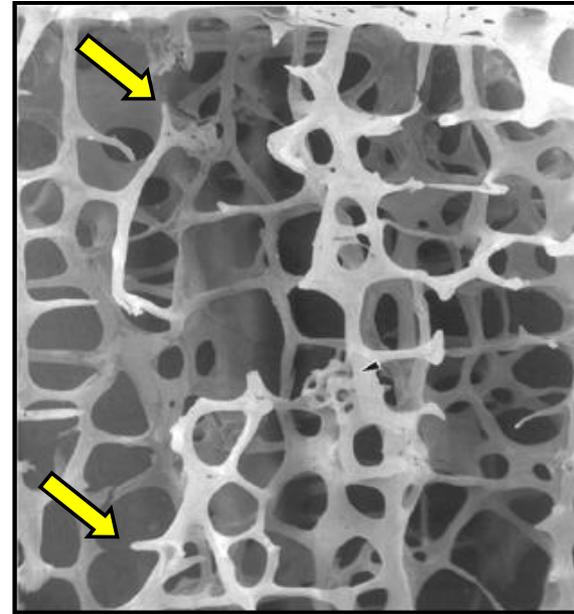
---

# Osteoporosis – A Definition

The World Health Organization (WHO) defines osteoporosis as:



Normal



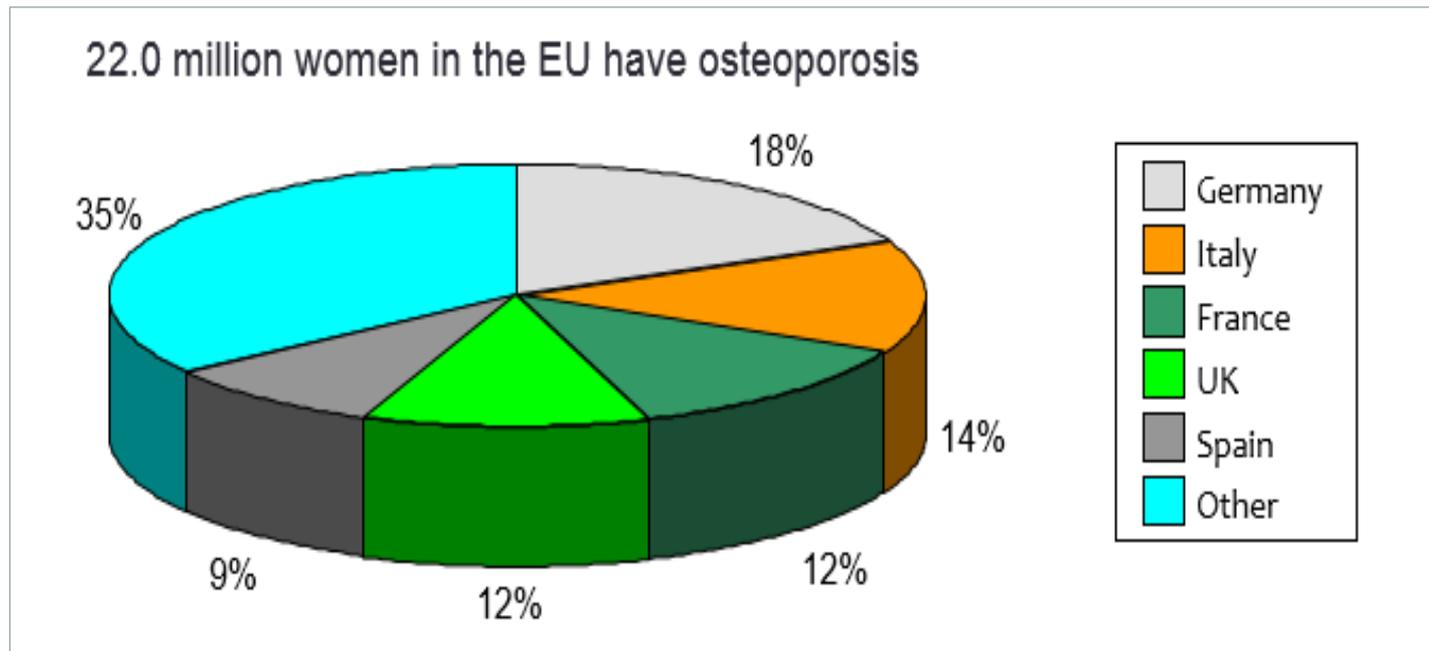
Osteoporotic

© 2000, David W. Dempster, PhD

**‘A disease characterized by low bone mass and microarchitectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk’**

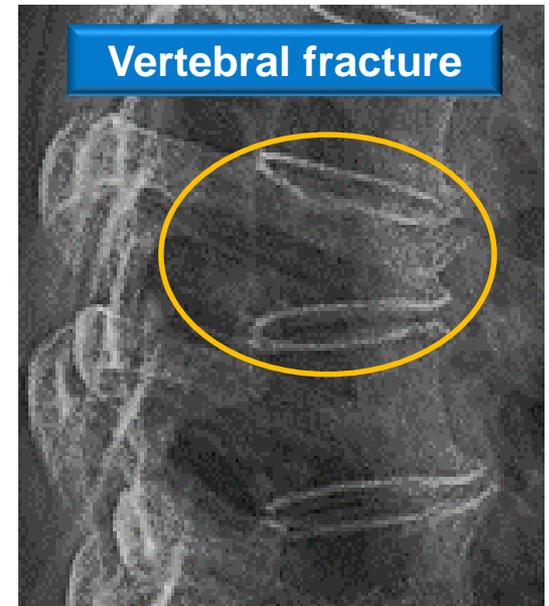
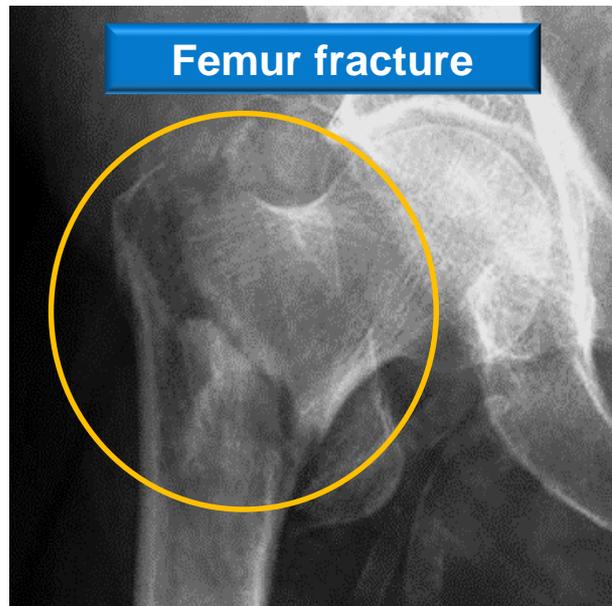
# Prevalence of Osteoporosis

- Osteoporosis affects 200 million women worldwide
  - 1/3 of women aged 60 to 70
  - 2/3 of women aged 80 or older
  - Nearly 1 in 2 women and 1 in 5 men will suffer an osteoporotic fracture



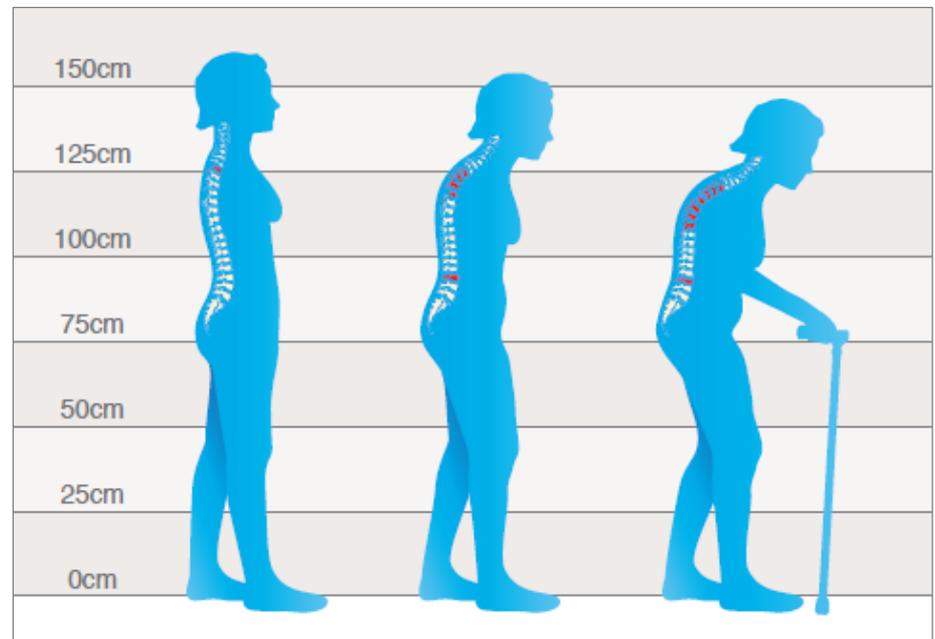
# Osteoporosis and Fragility Fractures

- Osteoporosis can lead to fragility fractures
- Fragility fractures can occur following a fall from standing height or less

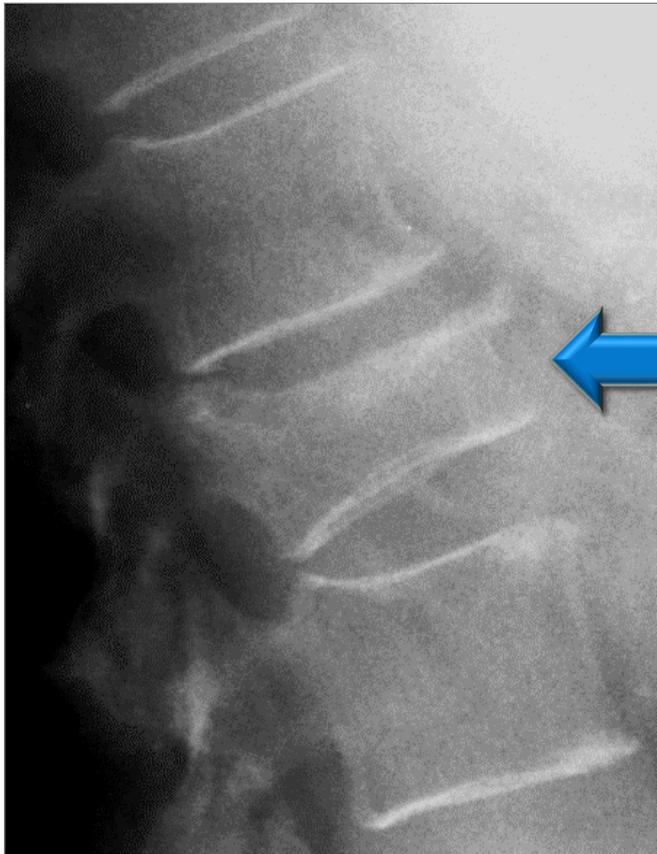


# Osteoporotic Vertebral Fractures

- Vertebral fractures occur most frequently in older people
  - High frequency among postmenopausal women
- Difficult to diagnose and are often only discovered when the spine is imaged
- Can cause significant morbidity:
  - Back pain caused by collapsed vertebrae
  - Kyphosis (stooped posture) due to height loss)
  - Impaired function and quality of life



# Vertebral Fractures Substantially Increase the Risk of New Fragility Fractures



- Women with vertebral fractures have a 5-fold increased risk of a new vertebral fracture and a 2-fold increased risk of hip fracture

*Black et al., J Bone Miner Res 1999*

*Melton et al, Osteoporos Int 1999*

- One woman in five will suffer from another vertebral fracture within a year

*Lindsay et al., JAMA, 2001*



Sheffield Teaching Hospitals **NHS**  
NHS Foundation Trust



The  
University  
Of  
Sheffield.

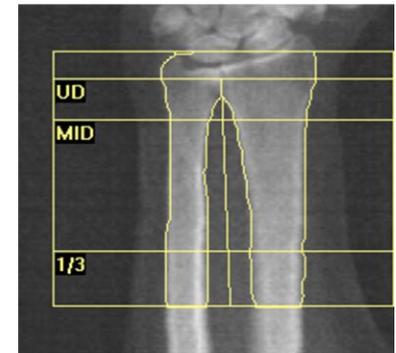
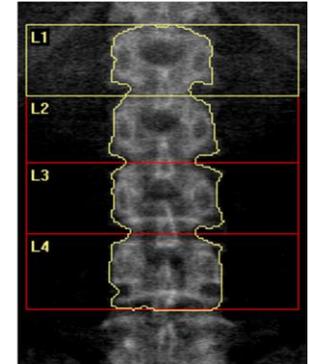
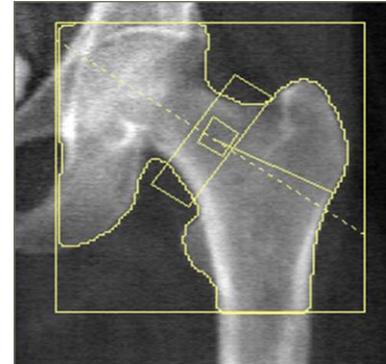
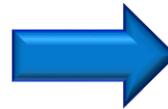
# Dual-Energy X-ray Absorptiometry and Vertebral Fracture Assessment

---

# Dual-Energy X-ray Absorptiometry (DXA)



**Discovery DXA scanner  
(Hologic Inc.)**



# Performing a Vertebral Fracture Assessment (VFA) using DXA



## Posteroanterior view

(x-rays enter through the back and exit via the front)



## Lateral view

(x-rays enter through one side and exit via the other side)

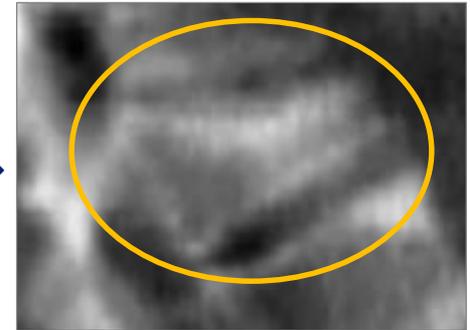
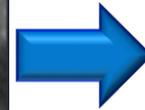
# VFA by DXA



No Fracture



Fracture





The  
Mellanby  
Centre  
*for Bone Research*



Sheffield Teaching Hospitals **NHS**  
NHS Foundation Trust



The  
University  
Of  
Sheffield.

## Why use VFA by DXA?

---

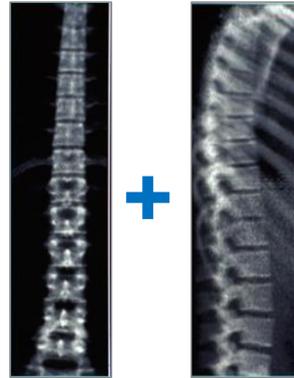
# Ionising Radiation Doses to the Patient

## Natural Daily Background Radiation



= 6  
microSv

## VFA by DXA



24 microSv  
≈ 4 days background  
radiation

## Conventional Radiography



Thoracic spine  
- AP and lateral

+



Lumbar spine  
- AP and lateral

1700 microSv (1.7 milliSv)  
≈ 9 months background  
radiation

# Image Quantity



## Conventional Radiography

4 images are required to capture the thoracic and lumbar spine (AP and lateral views)

## VFA by DXA

Only 2 images are required to capture the thoracic and lumbar spine (PA and lateral views)

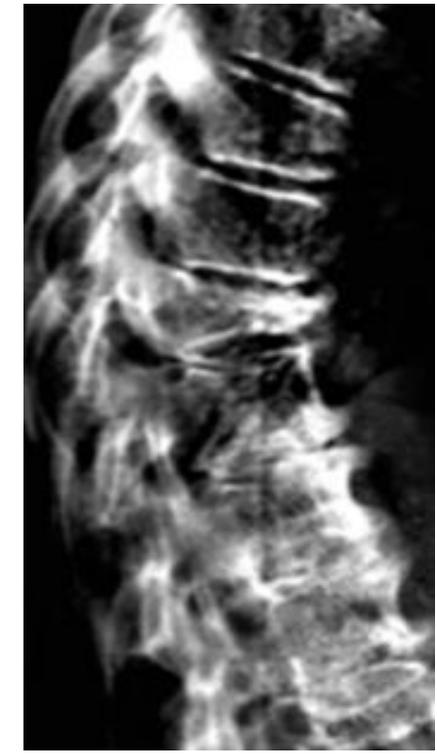
# Image Resolution and Quality



## Conventional Radiography

Resolution = 0.25 to 0.1 mm

Superior image quality  
(compared to VFA by DXA)



## VFA by DXA

Resolution = 1.0 to 0.35 mm

Good image quality  
(but slightly poorer than conventional  
radiography)



The University of Sheffield.

The Mellanby Centre  
for Bone Research



Sheffield Teaching Hospitals **NHS**  
NHS Foundation Trust

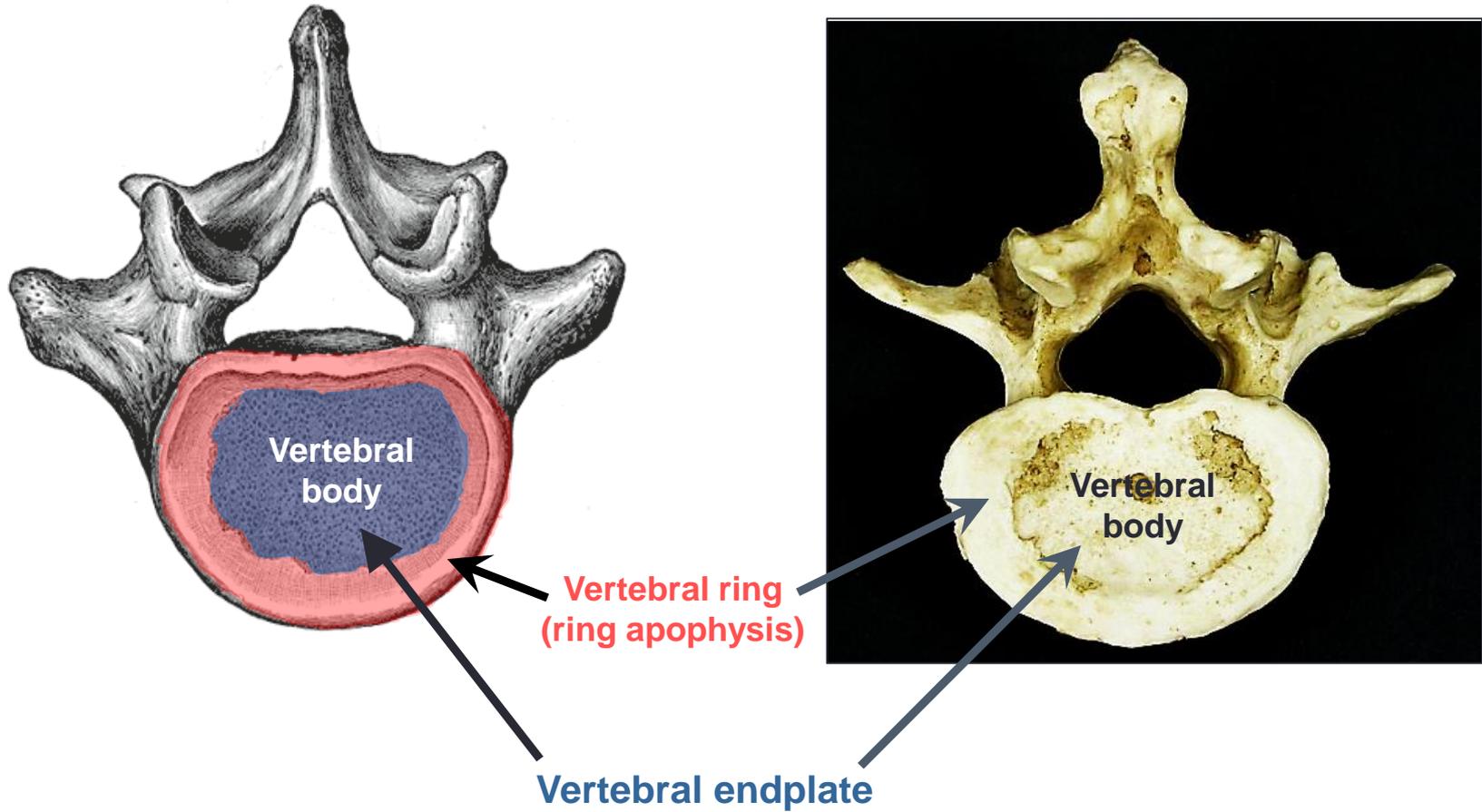


The University of Sheffield.

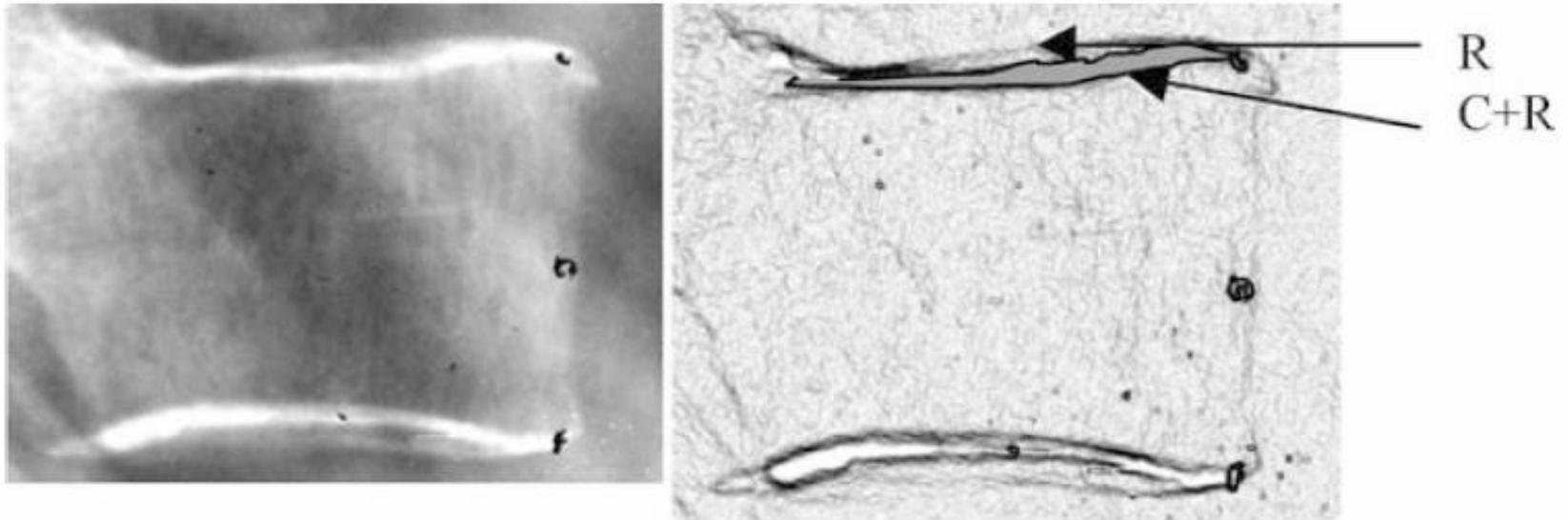
# What is an Osteoporotic Vertebral Fracture?

---

# Identification of the Vertebral Ring and Endplate

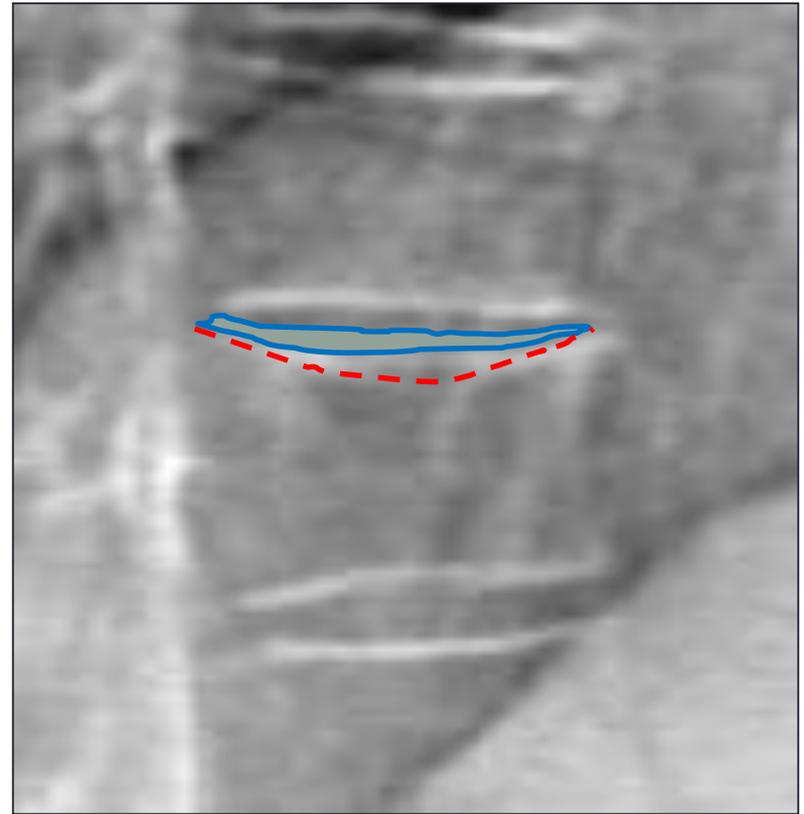


## Vertebral Endplates in a Normal Vertebra



**Fig. 3** Appearance of vertebral endplates in a normal vertebra. *R* represents the vertebral ring line, *C+R* represent the central endplate within the vertebral ring overlapping the vertebral ring line

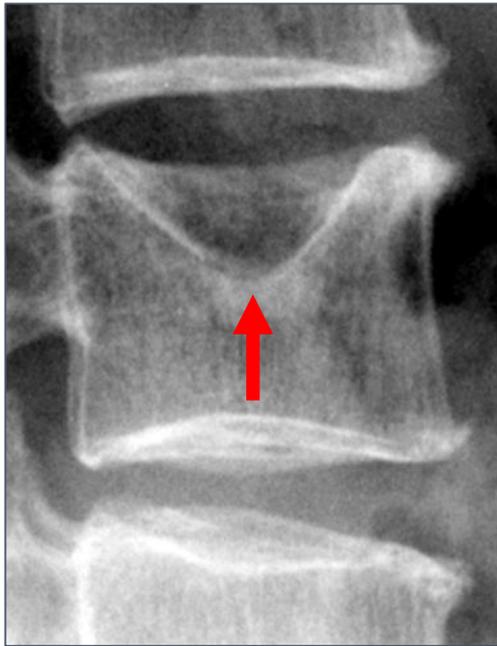
## An Osteoporotic Vertebral Fracture



**‘Evidence of depression of the central endplate with or without a fracture of the vertebral ring or the cortex of the vertebral body’**

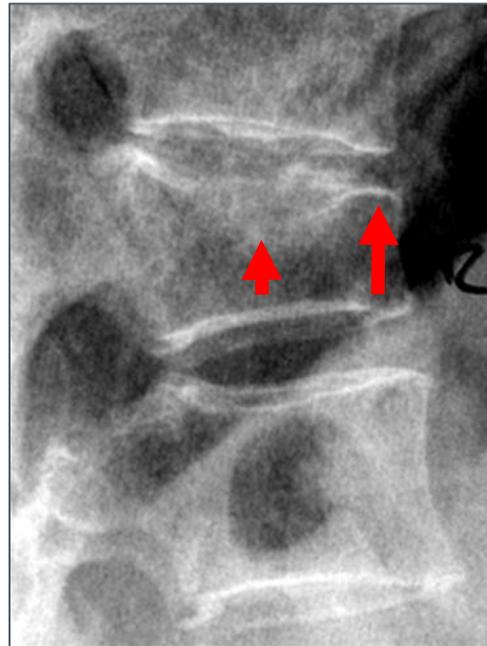
# Typical Osteoporotic Vertebral Fractures: Endplate Fracture is an Essential Feature

## Concave



Collapse of the central upper endplate -  
Reduction of the mid vertebral height

## Wedge



Reduction of both the mid and anterior vertebral heights

## Crush



Collapse of the whole vertebral body

# When is a Vertebral Fracture not an Osteoporotic Vertebral Fracture?



## Traumatic Fracture

- Angulation of the endplate
  - Bone fragmentation



Sheffield Teaching Hospitals **NHS**  
NHS Foundation Trust

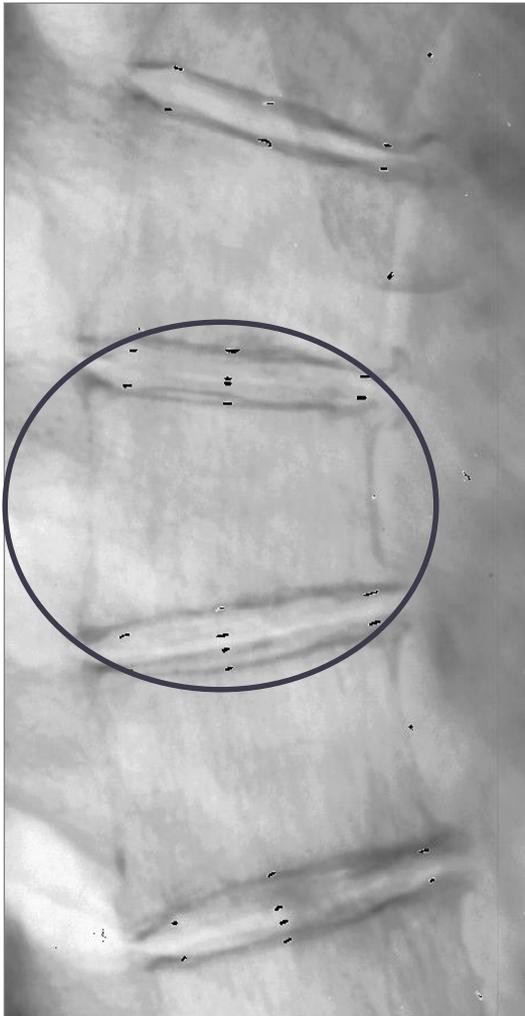


The University of Sheffield.

# Common Non-fracture Deformities

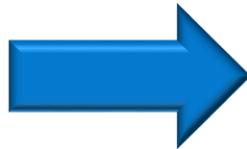
---

# Short Vertebral Height with Normal Endplates

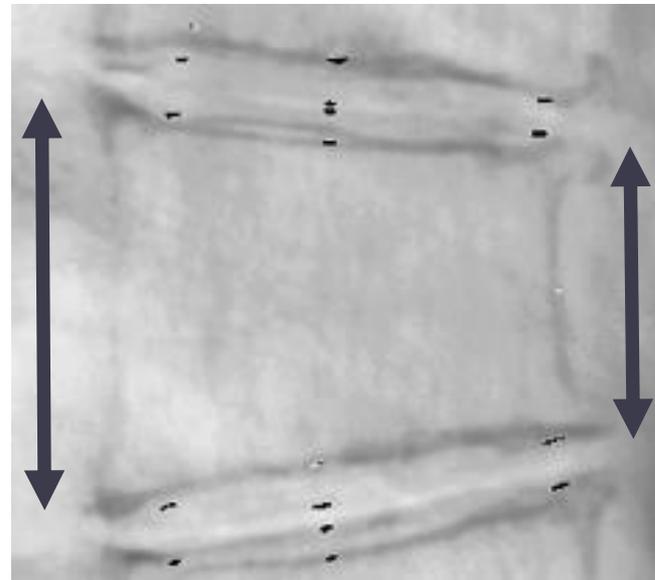


Short vertebral height (SVH)

- Anterior height < posterior height
- No apparent fracture of the endplate



Posterior

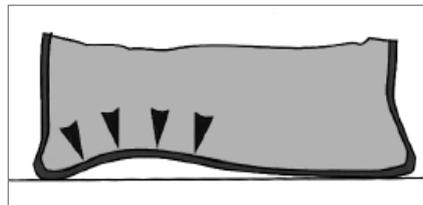
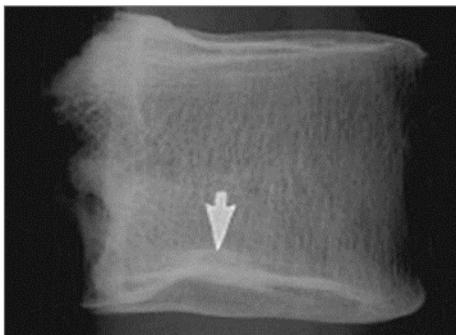
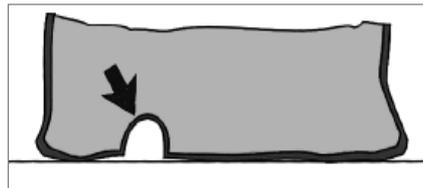
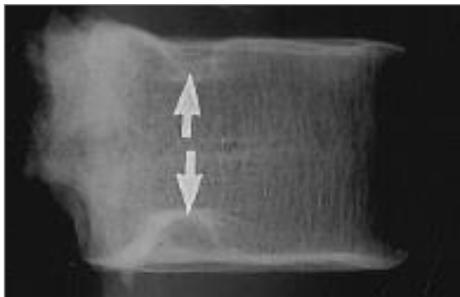


Anterior

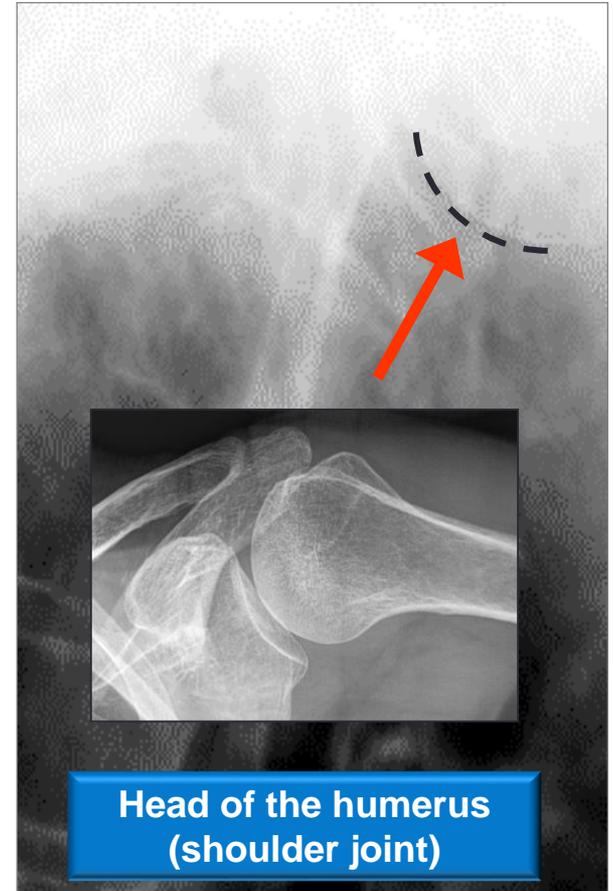
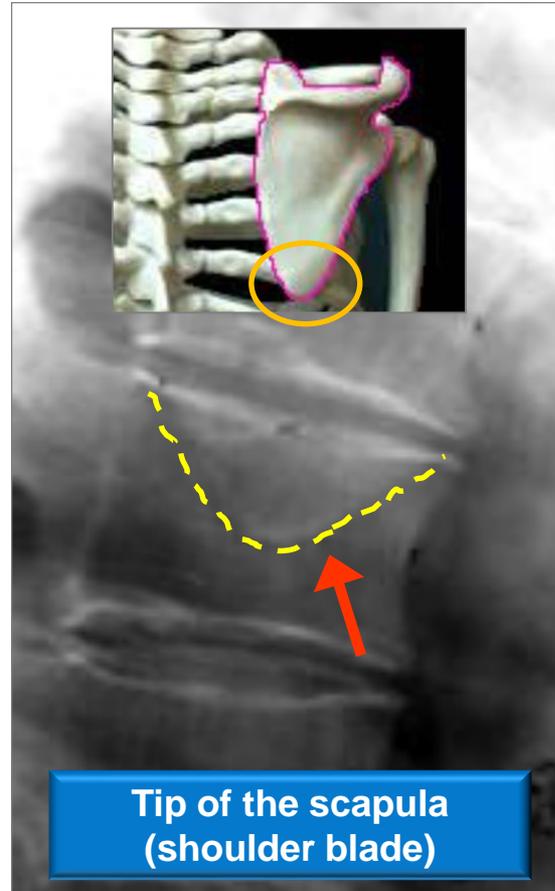
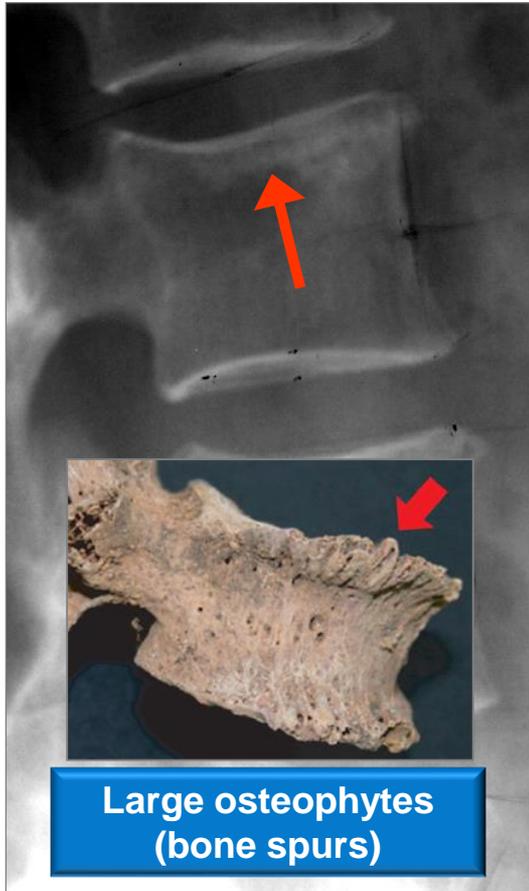
# Schmorl's Nodes

## Schmorl's node

An upward and downward protrusion (pushing into) of the soft tissue of an intervertebral disc into the bony tissue of the adjacent vertebrae



# Artefacts – Overlying Structures

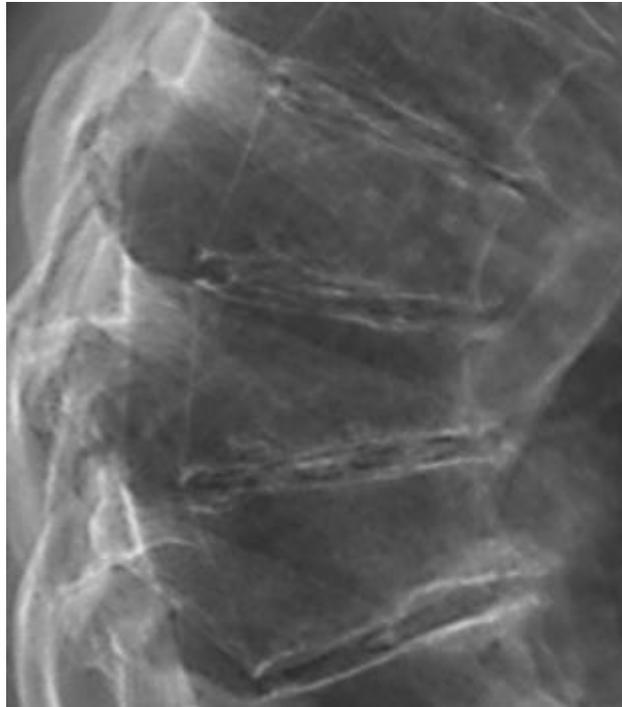


# Scheuermann's Disease



Scheuermann's Disease

- Anterior wedging of the vertebrae
- Irregularities of the bone/disc interface
  - Kyphosis





Sheffield Teaching Hospitals **NHS**  
NHS Foundation Trust

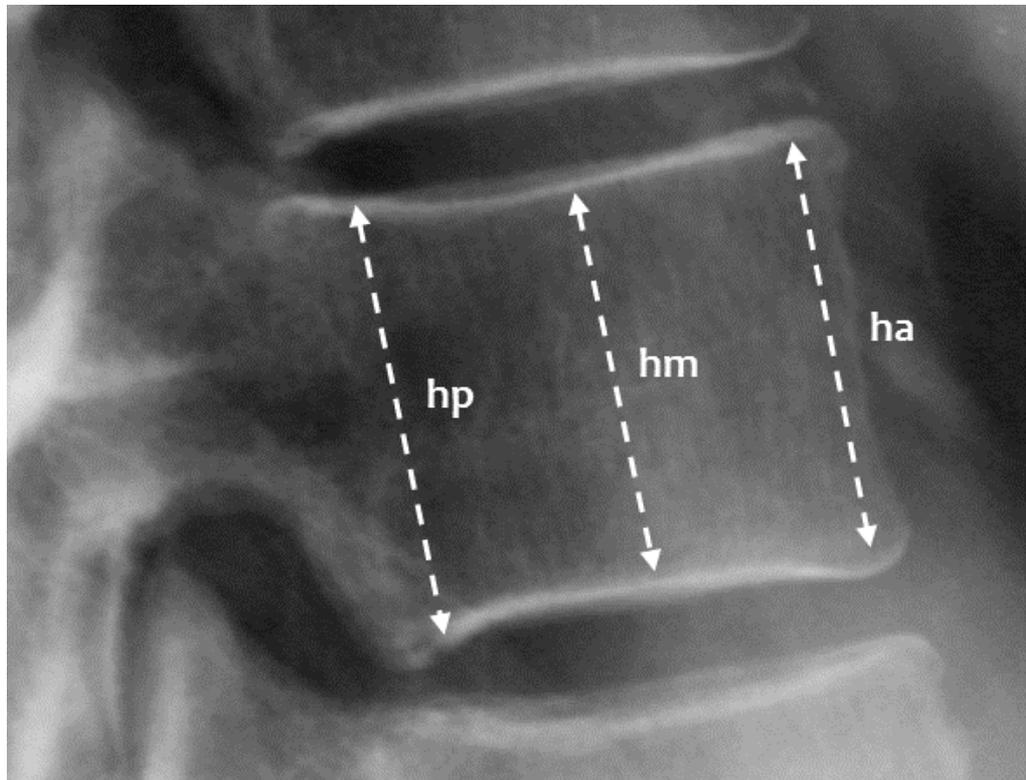


The  
University  
Of  
Sheffield.

# Approaches used to Identify Osteoporotic Vertebral Fractures

---

# Quantitative Morphometry (QM) – Measurement of Vertebral Dimensions



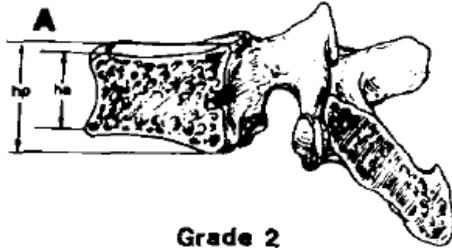
hp =	posterior height
hm =	mid height
ha =	anterior height

# Classification of Vertebral Fractures by QM

## Wedge deformity

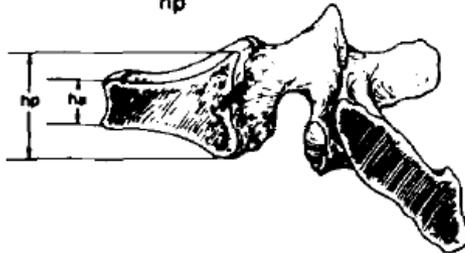
Grade 1

$$4.0 \leq \frac{ha}{hp} < 3.0 \text{ SD}$$



Grade 2

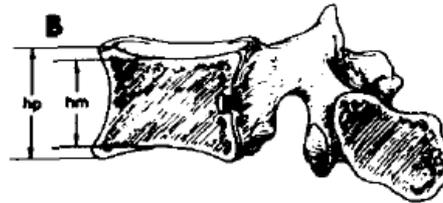
$$\frac{ha}{hp} < 4.0 \text{ SD}$$



## Biconcavity deformity

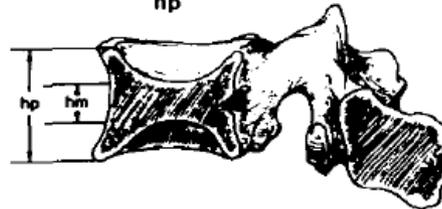
Grade 1

$$4.0 \leq \frac{hm}{hp} < 3.0 \text{ SD}$$



Grade 2

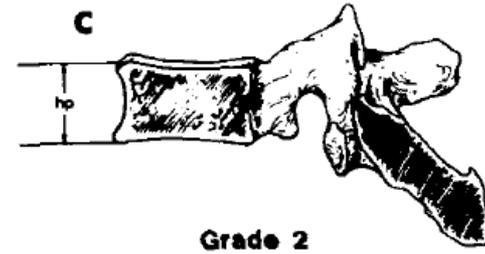
$$\frac{hm}{hp} < 4.0 \text{ SD}$$



## Compression deformity

Grade 1

$$4.0 \leq \frac{hp}{hp} < 3.0 \text{ SD}$$



Grade 2

$$\frac{hp}{hp} < 4.0 \text{ SD}$$

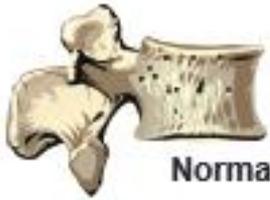
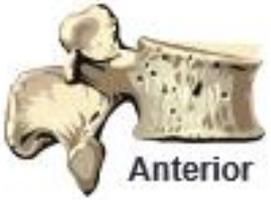
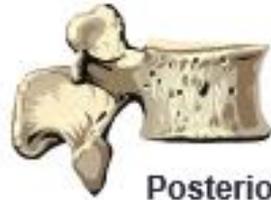
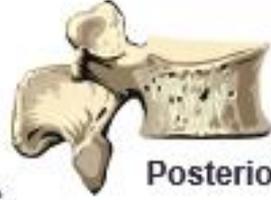
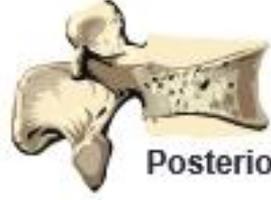


Normal



MAYO  
© 1990

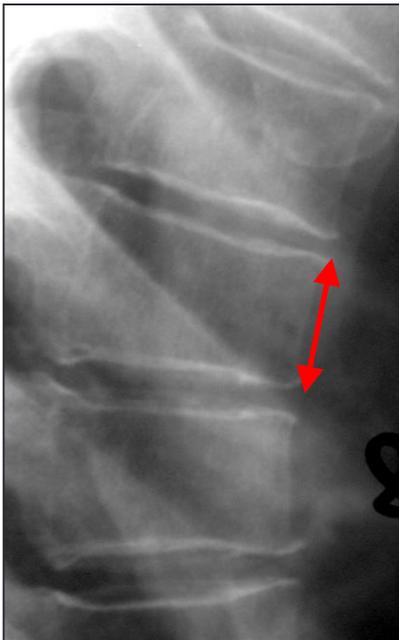
# Semi-Quantitative (SQ) Method – A Visual Assessment Tool Allowing Fracture Severity Grading

			Grade	Height Reduction
	 Normal		0	0 %
 Anterior	 Middle Mild fracture	 Posterior	1	20 to 25 %
 Anterior	 Middle Moderate fracture	 Posterior	2	25 to 40 %
 Anterior	 Middle Severe fracture	 Posterior	3	≥ 40 %

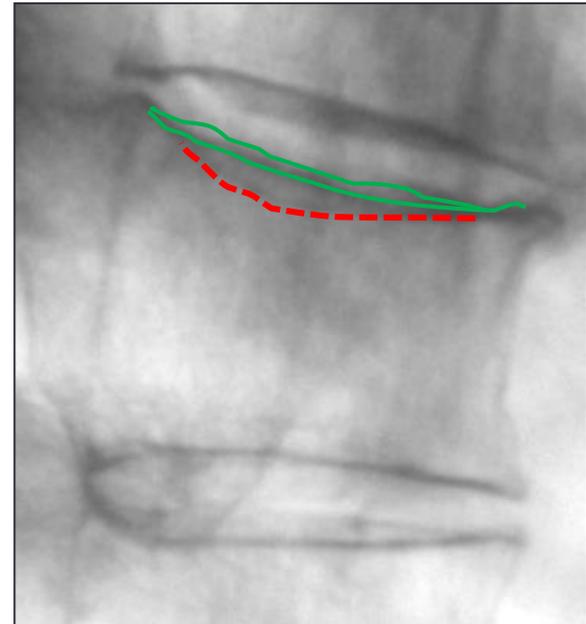
# Algorithm-Based Qualitative Method (ABQ) – A Visual Assessment Tool Requiring Endplate Involvement

## Main advantages:

- Requires evidence of fracture of the vertebral endplate
- No minimum threshold for apparent reduction in vertebral height



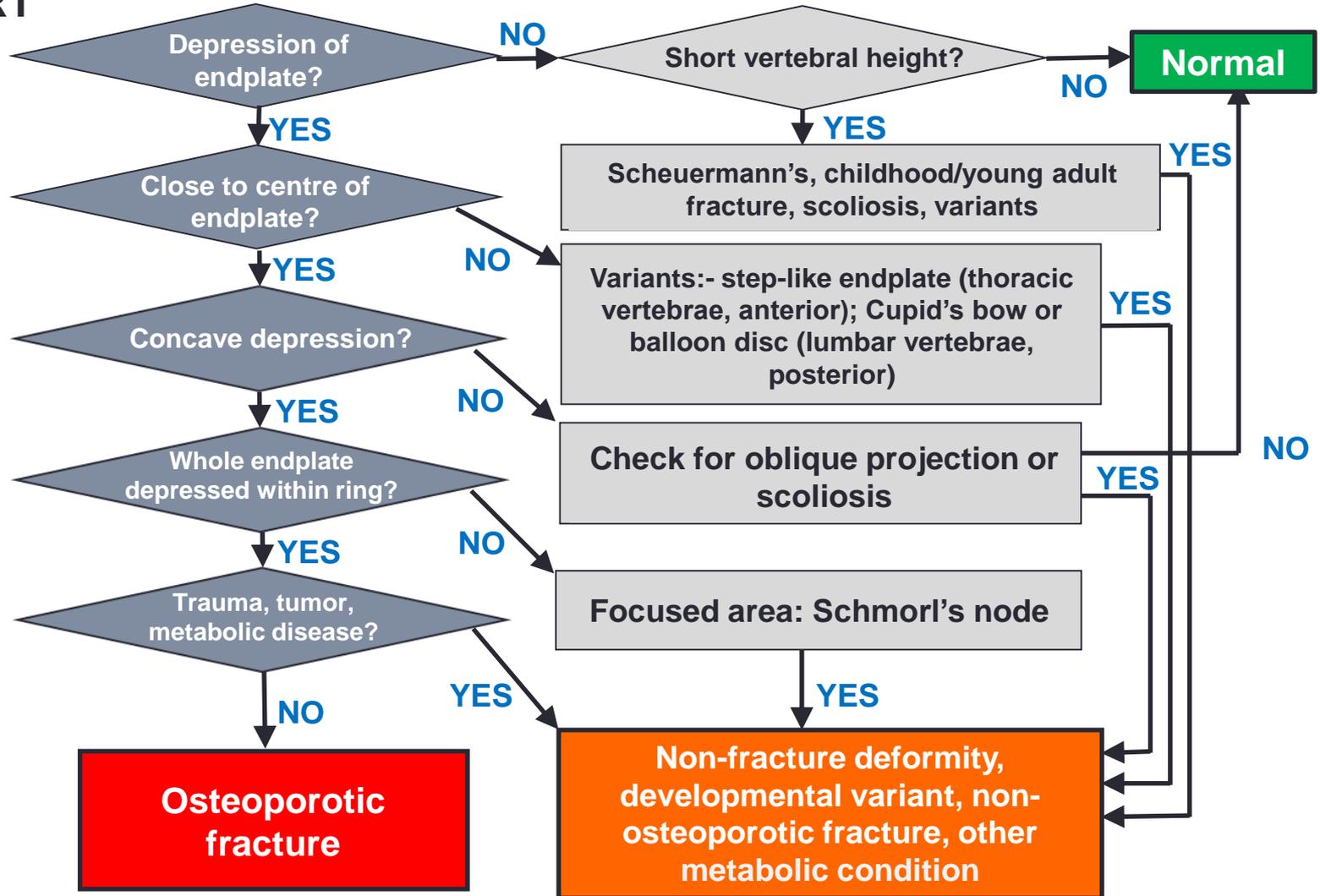
**Short vertebral height,  
normal endplate (normal variation)**



**Mild concave fracture at  
superior endplate**

# The ABQ Diagnostic Algorithm

START



# Computation Methods for the Identification of Vertebral Fractures



**SpineAnalyzer™ (Optasia Medical, Cheadle, UK)**

- Currently, standard VFA image evaluation methods rely on the visual identification of fractures
- It would be an advance if these approaches could be automated
- Several computational methods have been developed
  - Some are commercially available (e.g. SpineAnalyzer)
- Typically, these fracture identification tools:
  - Do not examine the vertebral endplates for deformities
  - Are based on 2D image computation approaches

# Summary (1)

- VFA by DXA and spine radiographs are complimentary techniques for identifying vertebral fractures
- The identification of vertebral fractures represents a challenge
- Several approaches have been developed, but in practice we have found that the ABQ algorithm is the most reliable

# Summary (2)

- Vertebral fractures:
  - Often remain unreported
  - Are frequently inadequately characterized
- Automation of the vertebral fracture identification process could:
  - Ensure that a standardized approach is adopted
  - Allow those fractures which are often missed (mild fractures) to be identified and reported
- Several computational methods have been developed
  - Do not examine the vertebral endplates for deformities
- More sophisticated approaches need to be developed
  - Examination of the 3D structure of the vertebrae

Thank you!