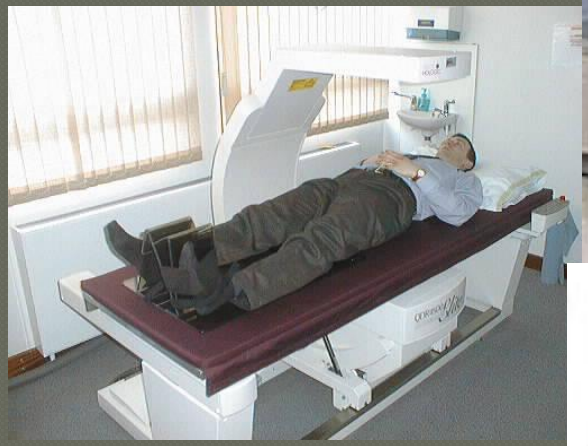
A short guide to DXA and BMD

Terry Watson
Freeman Hospital

How does it work?

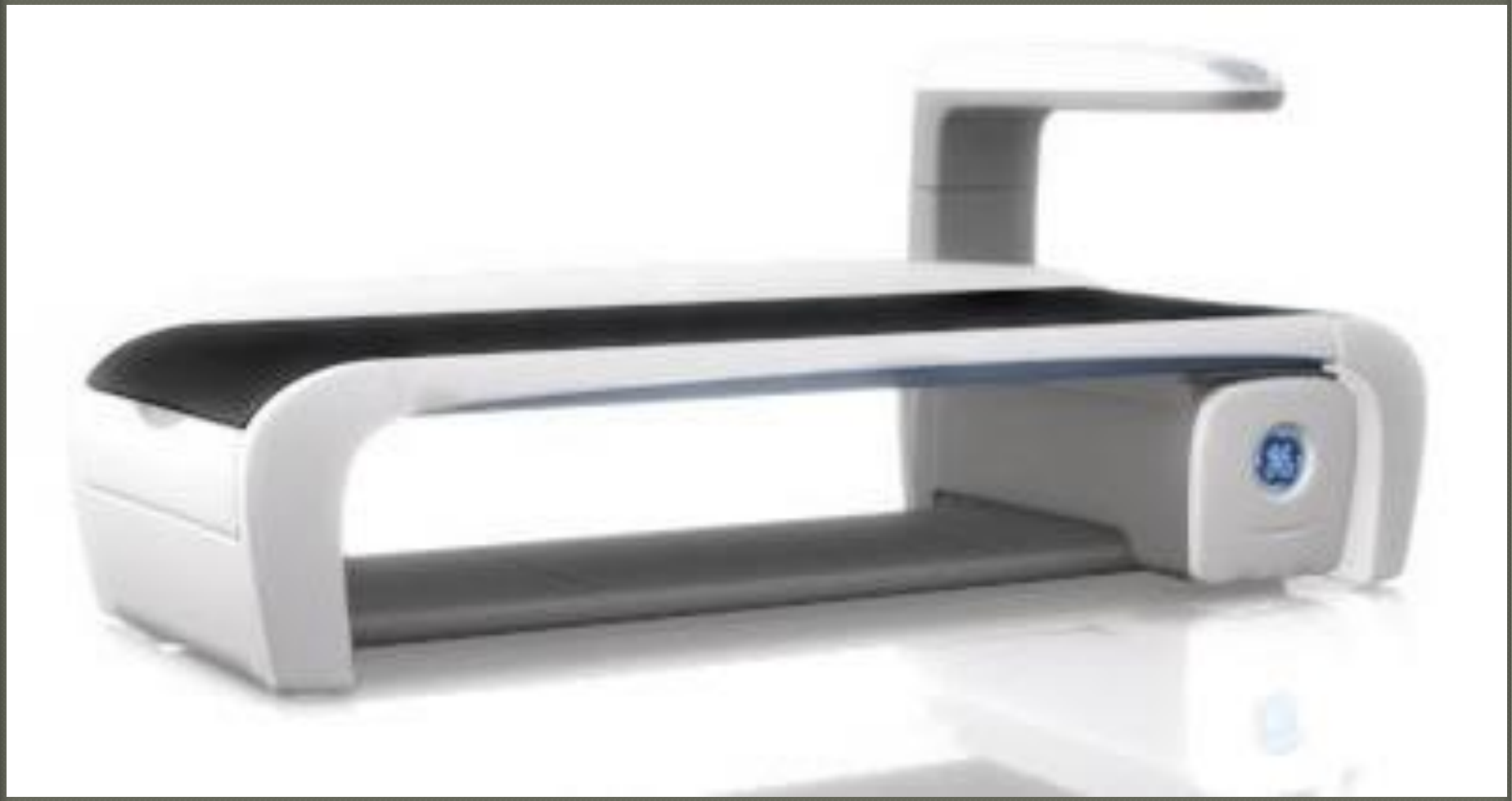
What's new?



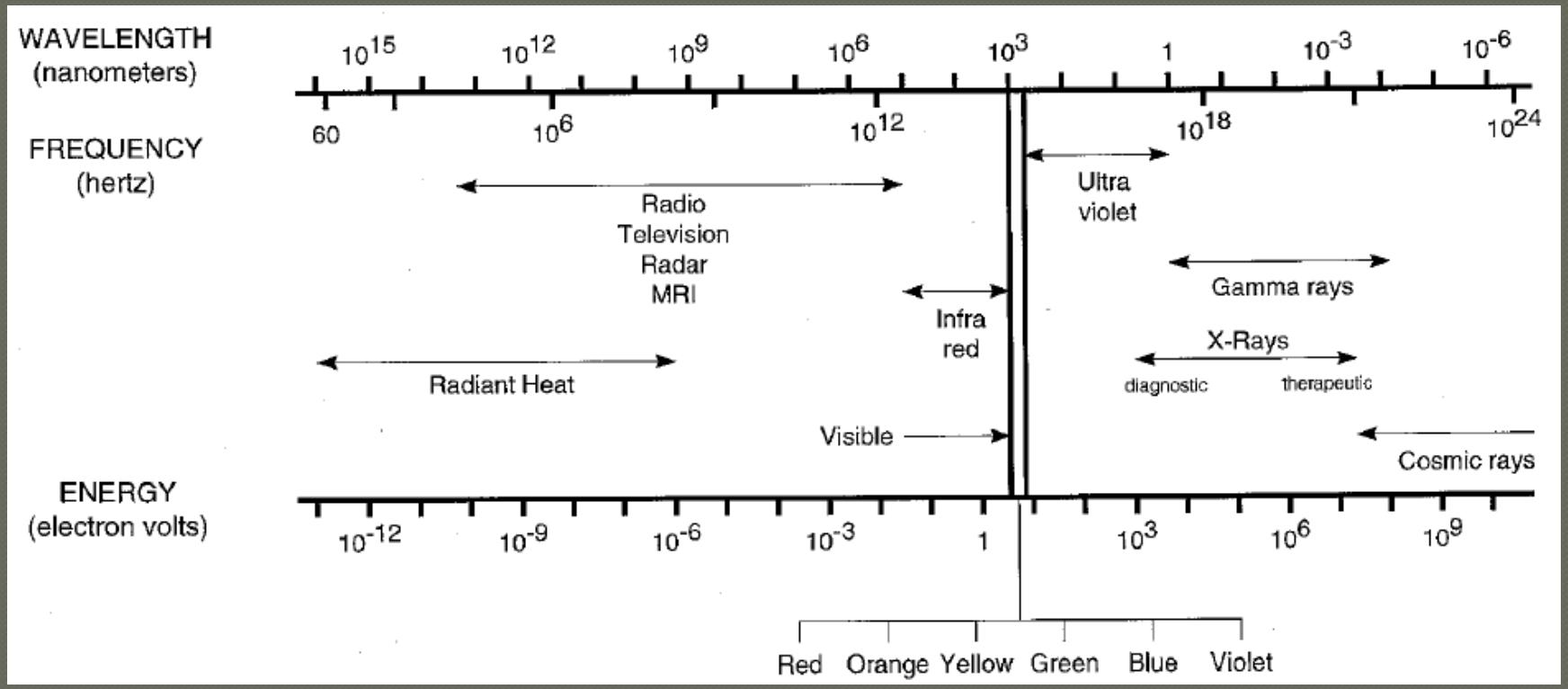
Patient pathways

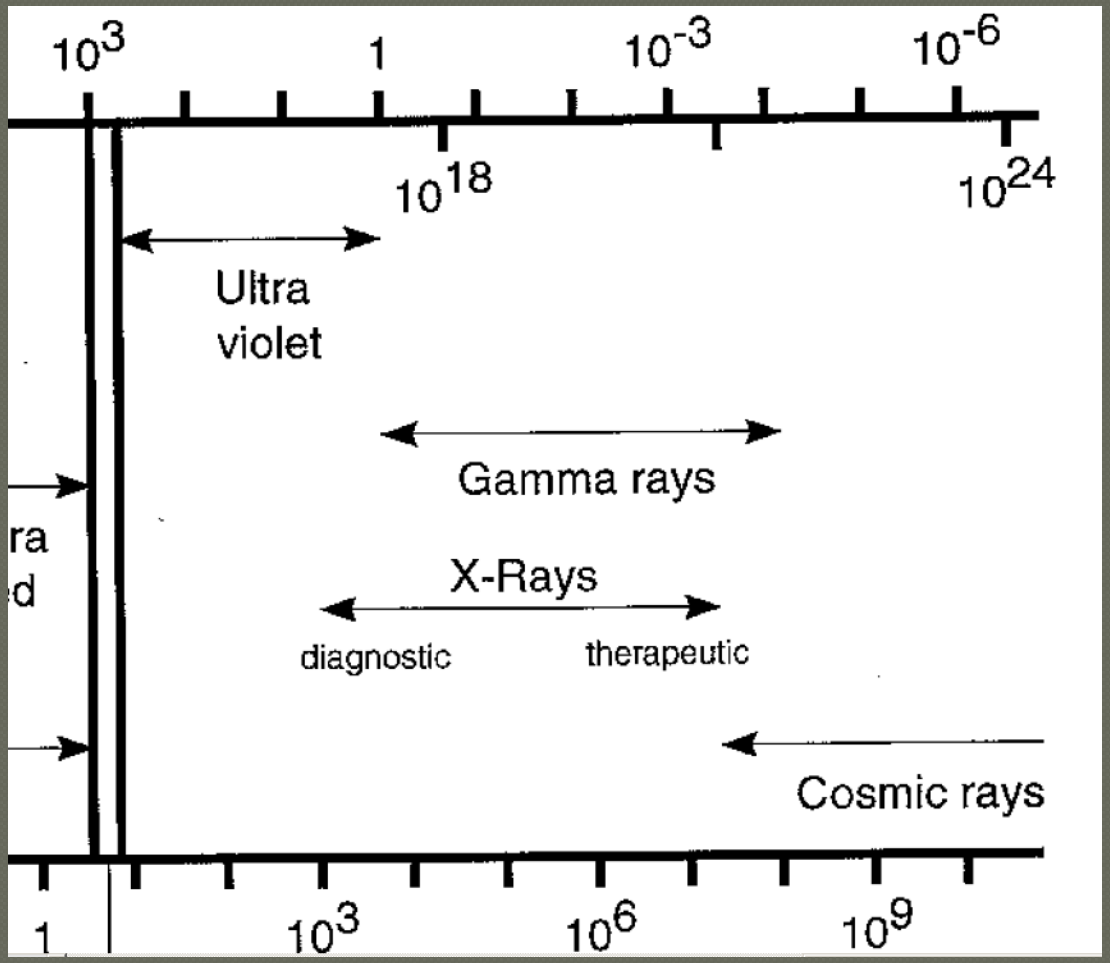
First Principles

- Why do we measure Bone Density?
- How do we measure Bone Density?
  - Number of *in vivo* of methods developed
    - SPA
    - QCT
    - Ultrasound
    - DEXA(DXA)
  - Most important are the methods of measuring the 'Attenuation' of a beam of electromagnetic radiation or ultrasound.



Electromagnetic Spectrum




10^3
1
10^{-3}
10^{-6}
10^{18}
10^{24}
Ultra
violet
Gamma rays
X-Rays
diagnostic
therapeutic
Cosmic rays
1
10^3
10^6
10^9

For routine diagnostic x-rays…

Hot filament: regulates electron production and therefore beam current and x-ray output

Rotating anode: spreads heat over larger area so increasing output

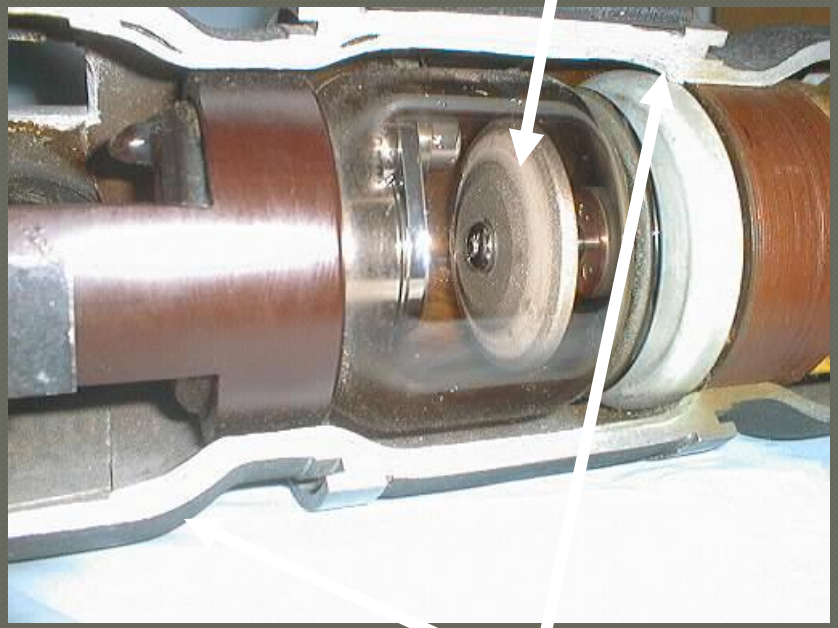
We need : a controlled source of high energy electrons, a suitable hard wearing small x-ray target, a means of cooling and a way to direct and control the x-rays passing through the patient

Cut away x-ray unit

X-ray window

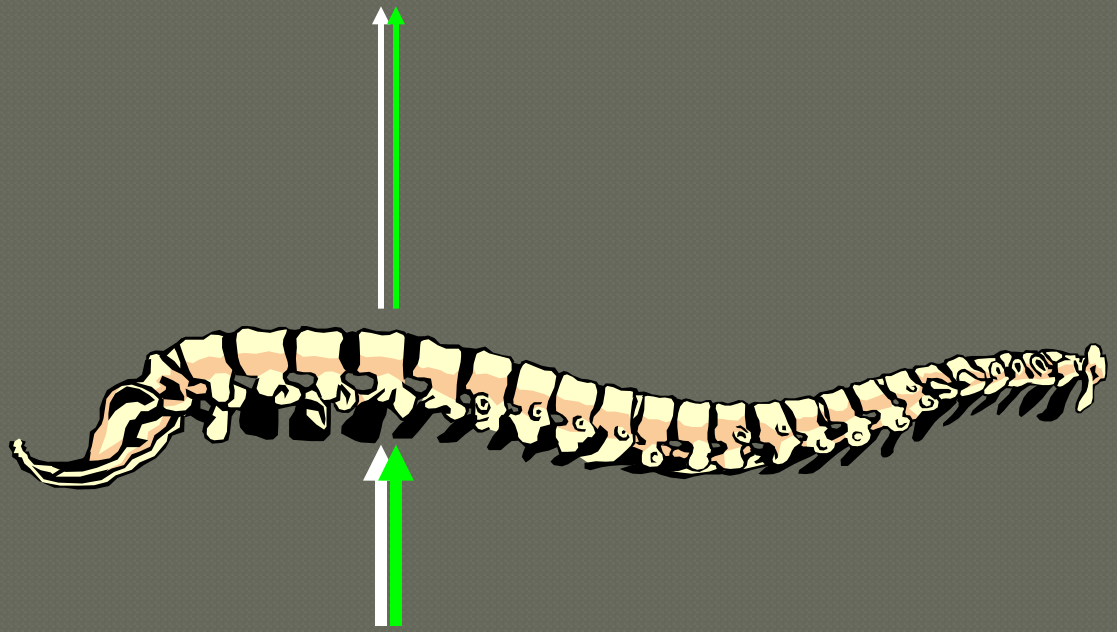
High voltage plugs

Anode disc showing damage pits



Radiation Shielding

DXA works by sending a narrow beam of x rays through bone. The bone density determines the amount that is absorbed by bone.

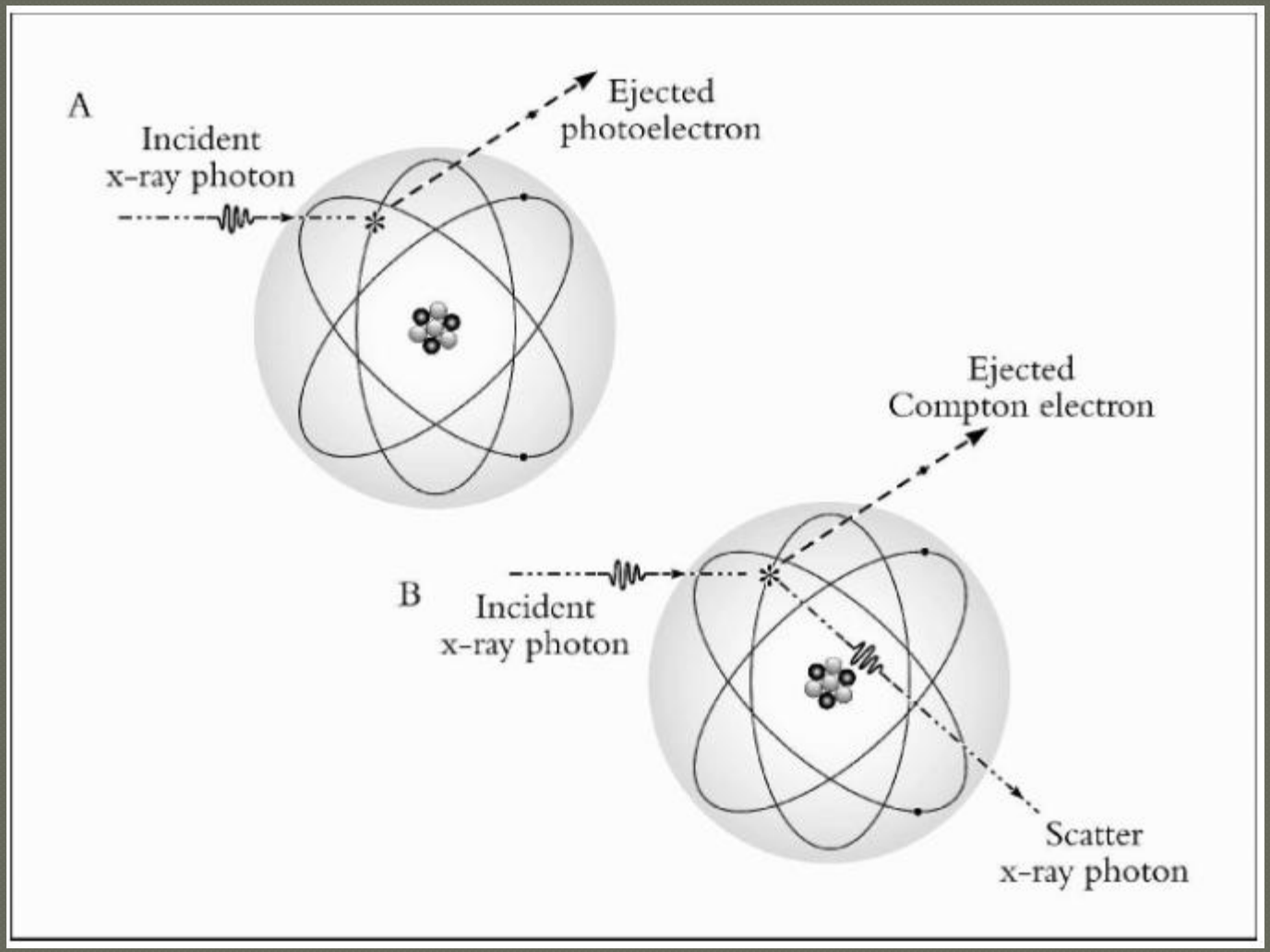


Two different energies x-ray energies are used to avoid influence from soft tissue

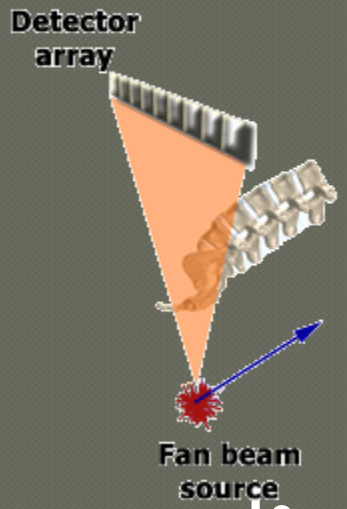
How do we create X-rays of two distinct energies?

- 'Hologic' machines – Fast switching in voltages (60 times per second)
- 'Lunar' machines – Constant single energy X-ray transmission that is filtered by thin sheet of metal near to the tube. (cerenium or samarium)

Attenuation in tissue



DXA works by measuring a narrow beam of x rays transmitted through bone

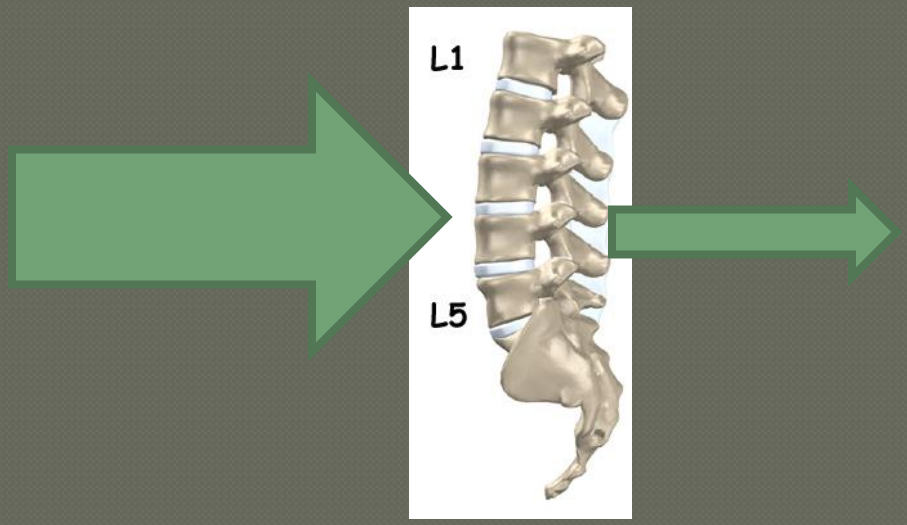


I_0

X Rays in

$I = < I_0$

X Rays out



Narrow x-ray beams obey a well defined exponential law of absorption

Linear Attenuation coefficients

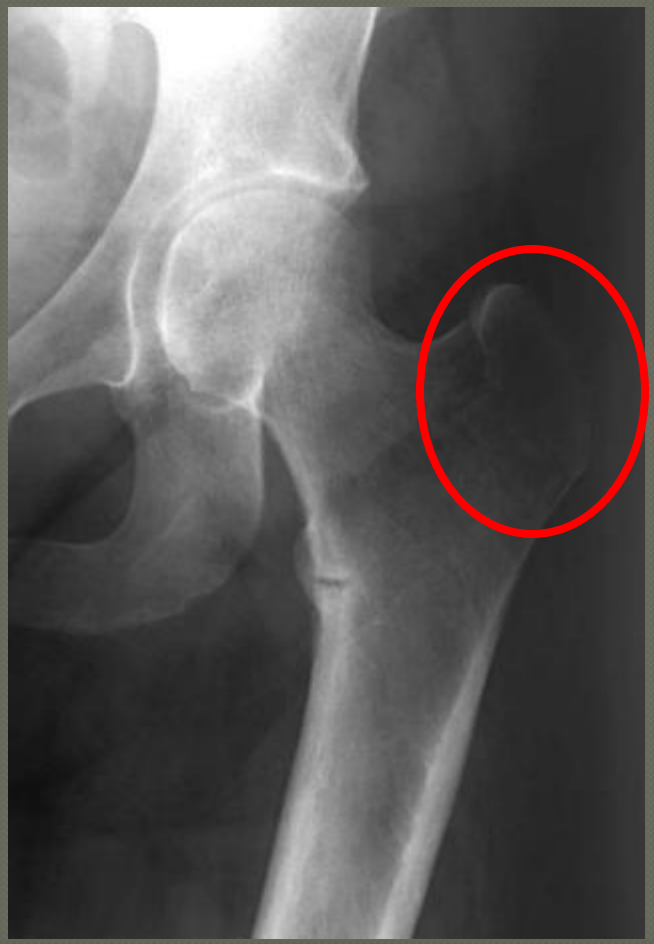
- Numerical value which can be applied to describe a tissues ability to stop(attenuate) a radiation beam
- Directly proportional to the physical density of the tissue
- For DEXA the simplest model is to identify two distinct tissue types:
  - Soft Tissue
  - Bone

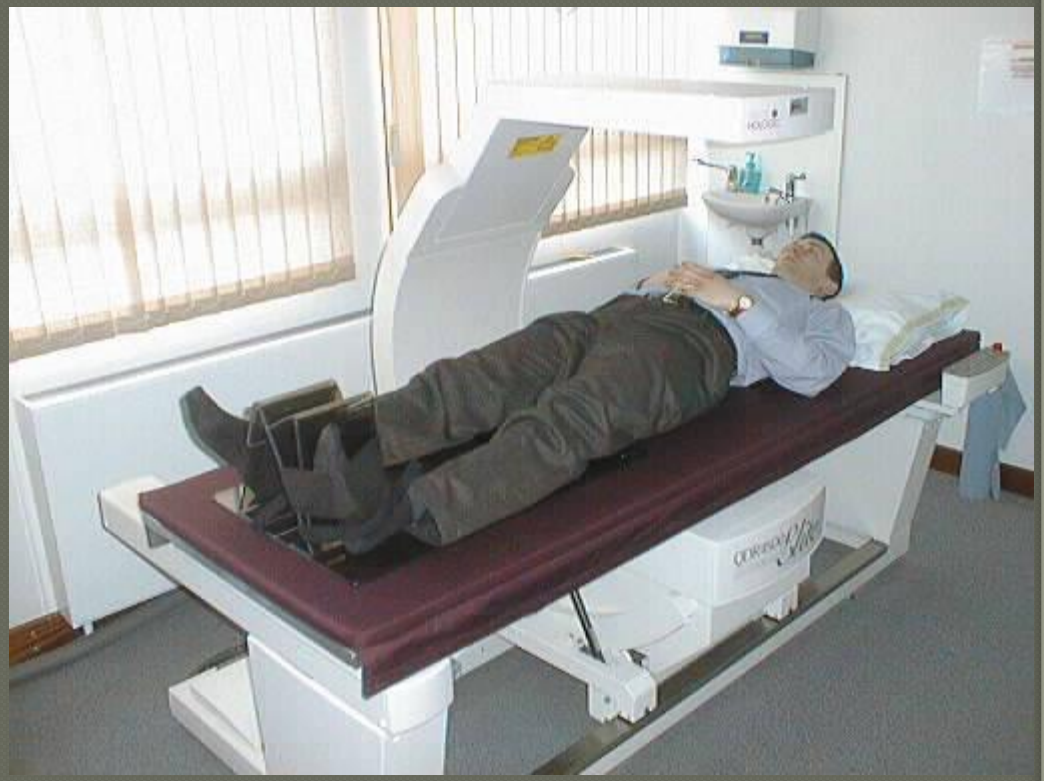
For narrow beam x-rays passing through a person …

- Absorption depends upon the bone mineral density (BMD) (g/cm2) which is what we want to know
- It also depends upon soft tissue thickness and fat content which varies within and between patients.
- DXA uses two x-ray energies at each point
- Changes in absorption with energy are much greater for bone than soft tissue
- The difference in the two signals at each point when compared to soft tissue baseline gives BMD

So why is DXA useful then?

x-rays can suggest deficiency in bone mineral..

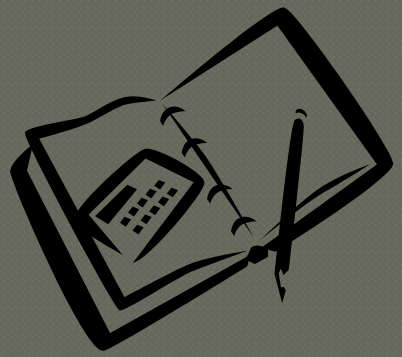




…but DXA provides both an image and a numerical assessment of bone density

Specifications DXA

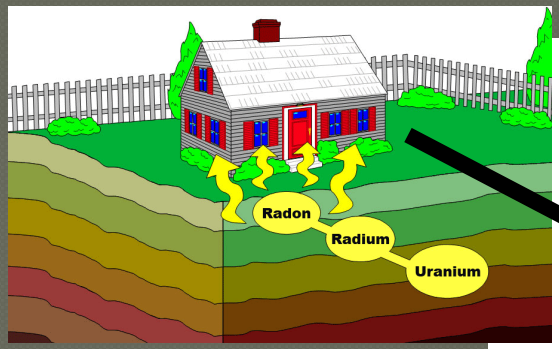
- Precise measurement of Bone mineral (g/cm^2)
- Reproducable
- Scan time 30secs per region
- Patient appointment time 20 mins
- Low radiation dose

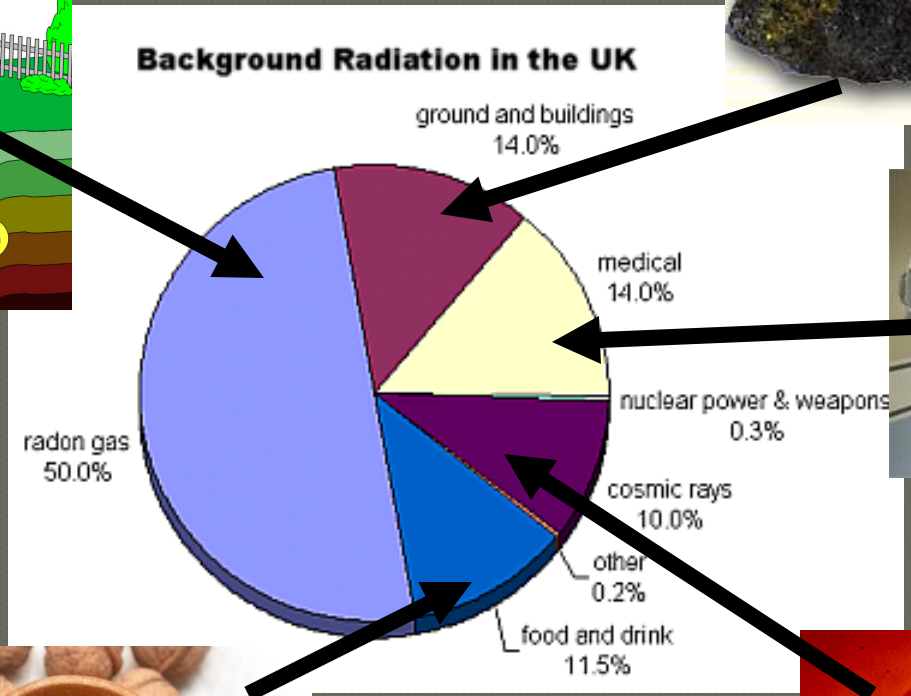


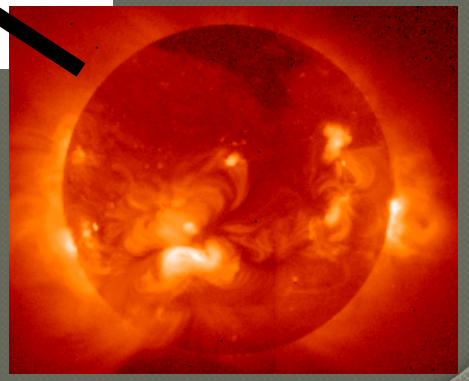
Typical radiation dose

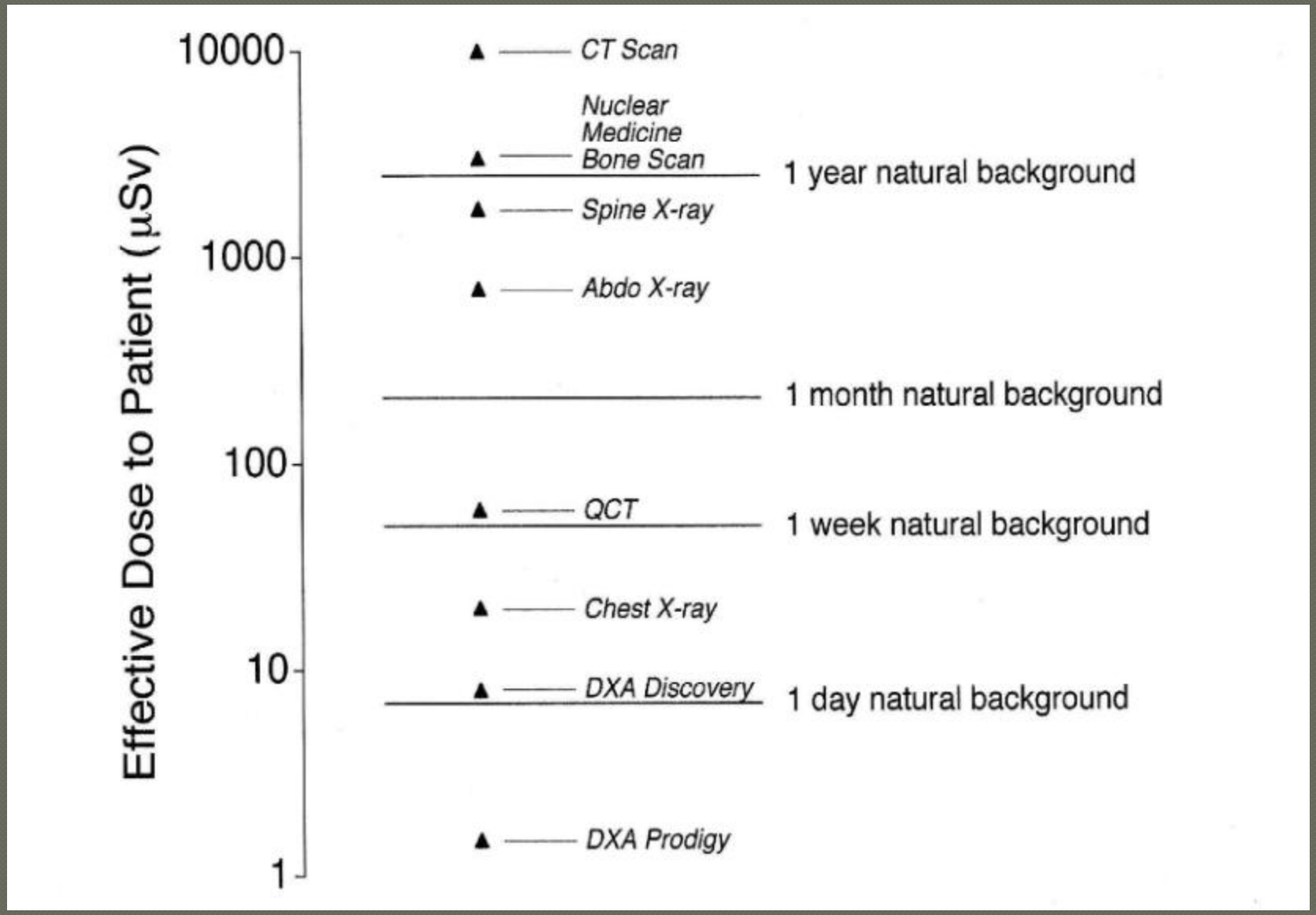
- The radiation dose of a Dexa scan to the patient is typically 1µSievert
  - Includes both spine and hip images
- Lets put this into context

Mean UK Background dose 2.7mSv per year







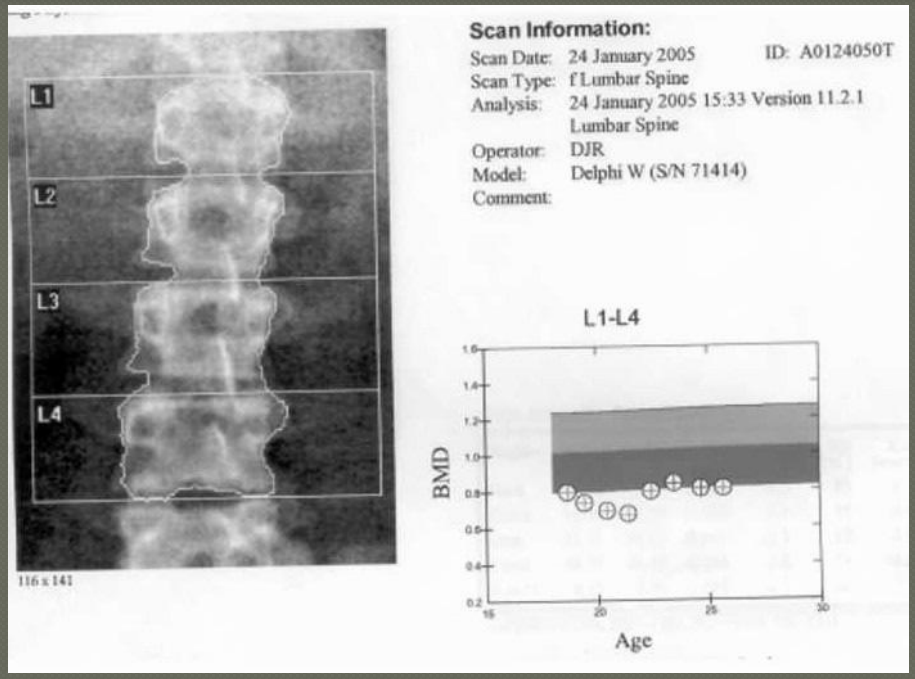

Effective Dose to Patient (μSv)
10000
1000
100
10
1
CT Scan
Nuclear Medicine Bone Scan
Spine X-ray
Abdo X-ray
QCT
Chest X-ray
DXA Discovery
DXA Prodigy
1 year natural background
1 month natural background
1 week natural background
1 day natural background

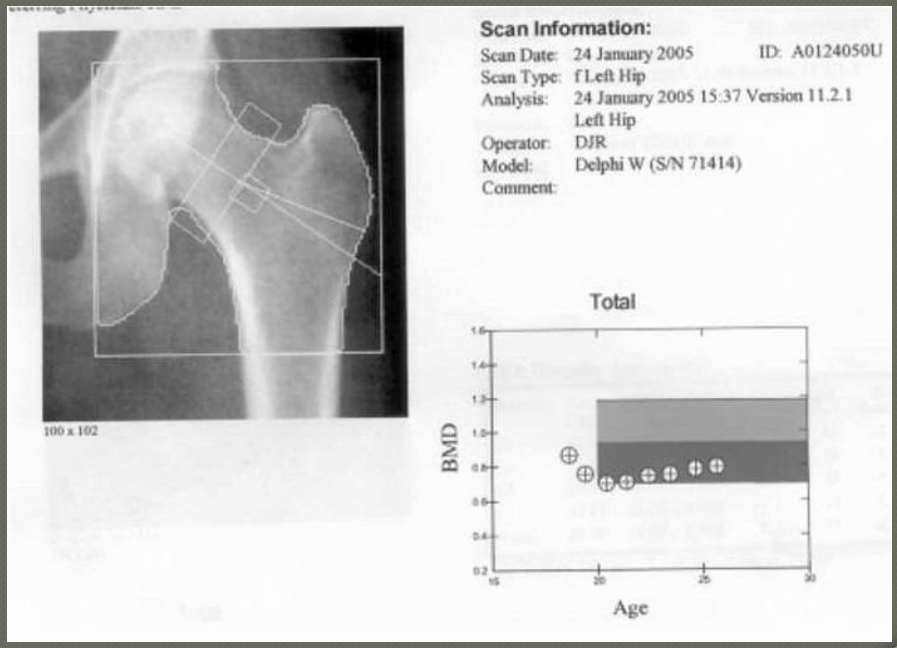
Risk of death comparable to having a DEXA

- Exposure to natural background radiation for 4 hours
- Smoking one-tenth of a cigarette
- Travelling 3 miles by car
- Travelling 15 miles in an airliner
- Rock climbing for 5 seconds
- Canoeing for 20 seconds
- Working in a factory for half a day
- Being a woman aged 30 for 60 minutes
- Being a woman aged 40 for 20 minutes
- Being a woman aged 50 for 8 minutes
- Being a woman aged 60 for 3 minutes
- Being a woman aged 70 for 1 minute

Why do we acquire an image if we are interested in the numbers?

The function of the image is to ensure the appropriate region of interest is measured every time…





Good precision depends critically on ROI placement …

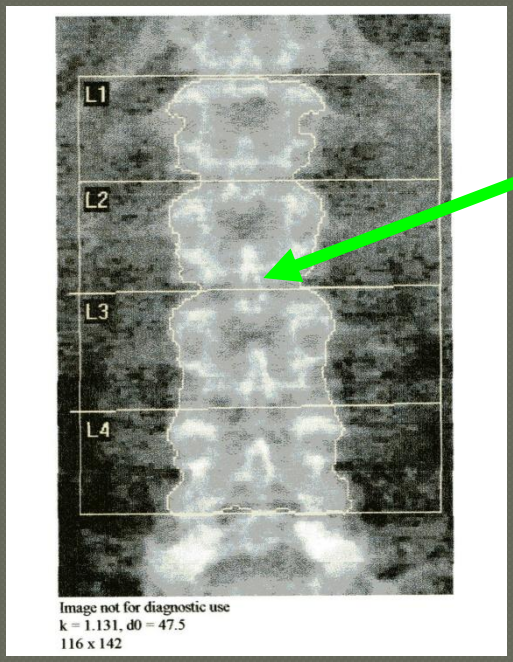
In bone densitometry, the gold standard is the ash weight of the skeletal site being tested. BMD testing is very precise and accurate compared to other tests commonly used in clinical practice, but precision and accuracy will vary according to the instrument used, the skeletal site being measured, ***and the skill of the technologist.***

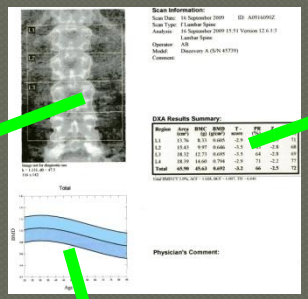
So image quality is an important factor ensuring precision

www.iscd.org

The report shows……

1) A skeletal image (lumbar spine or proximal hip)
2) Bone mineral densities (g/cm^2)
3) The patient result plotted against a normal population

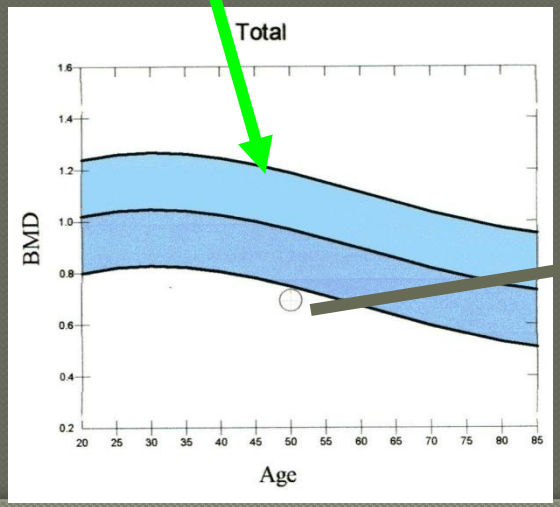




DXA Results Summary:

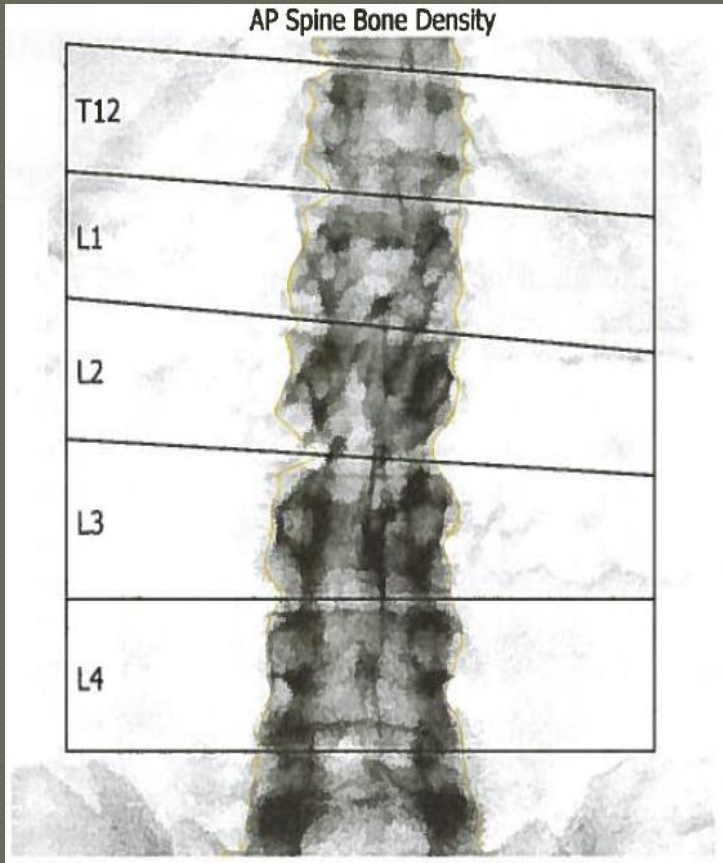
Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
L1	13.76	8.33	0.605	-2.9	65	-2.3	71
L2	15.43	9.97	0.646	-3.5	63	-2.8	68
L3	18.32	12.73	0.695	-3.5	64	-2.8	69
L4	18.39	14.60	0.794	-2.9	71	-2.2	77
Total	**65.90**	**45.63**	**0.692**	**-3.2**	**66**	**-2.5**	**72**

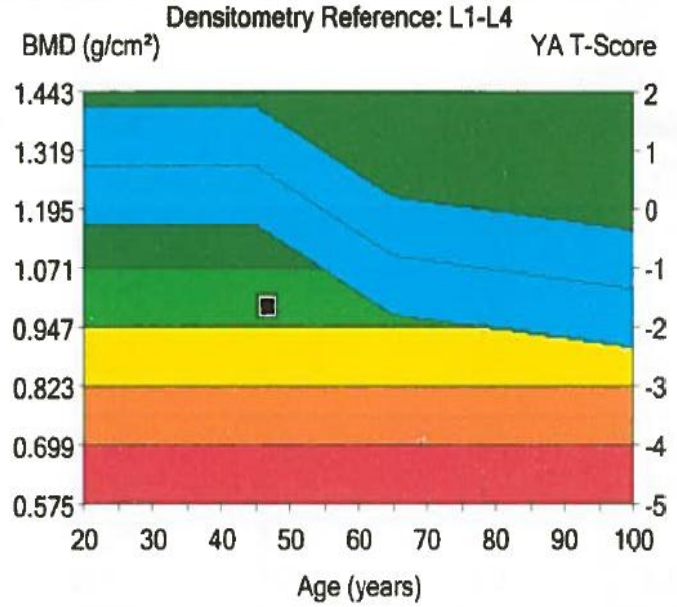
Total BMD CV 1.0%, ACF = 1.028, BCF = 1.007, TH = 6.646



Z= -2.5

T= -3.2





Region	1 BMD (g/cm²)	2 Young-Adult (%)	2 Young-Adult T-Score	3 Age-Matched (%)	3 Age-Matched Z-Score
L1	0.815	72	-2.7	67	-3.4
L2	1.036	86	-1.4	80	-2.2
L3	1.102	91	-0.9	85	-1.7
L4	0.982	82	-1.8	76	-2.6
L1-L4	0.989	83	-1.7	77	-2.4

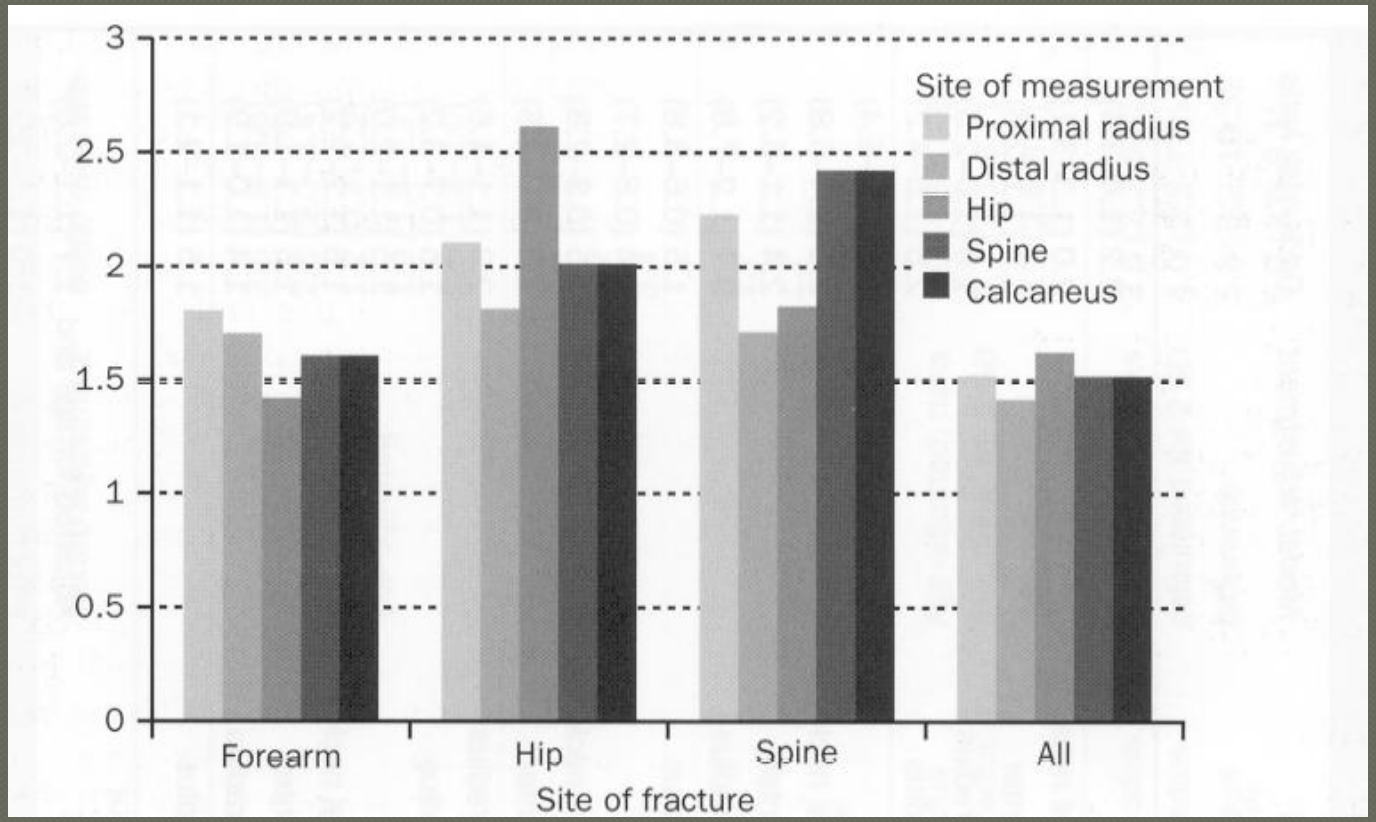
DEXA can be used to diagnose osteoporosis

- Osteoporosis is diagnosed in adults where T=-2.5 or less at the lumbar spine or hip (WHO criteria 1994)
- This may not necessarily represent a treatment threshold as a full clinical assessment is indicated prior to treatment

DEXA can be used to diagnose osteoporosis

- Normal bone: T-score better than -1
- Osteopenia: T-score between -1 and -2.5
- Osteoporosis: T-score less than -2.5
- Established (severe) osteoporosis
  includes the presence of a non-traumatic fracture.

Risk of future fracture increases by factor of between 1.4 and 2.6 for every 1SD decrease in BMD Marshall et al 1996



How do we use DXA?

- Bone Density (DXA) is a sensitive indicator of future fracture but is not very specific
- It cannot therefore be used for population screening
- It can however be used along with clinical risk factors as part of a case finding strategy

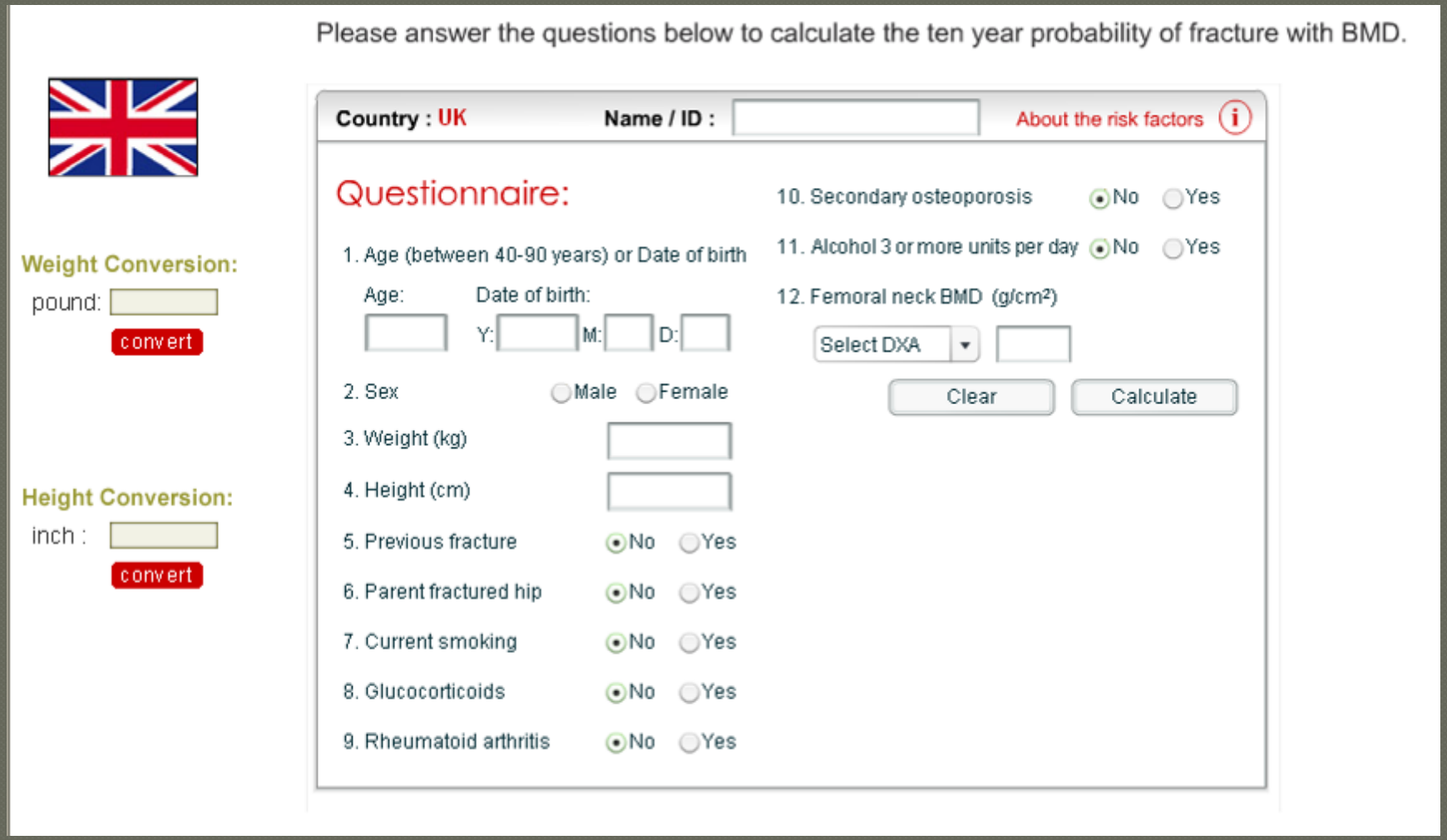
The indications for DEXA

based upon NOS 'Local Provision for Osteoporosis' and AGO report

- Early Menopause
- Prolonged Amenorrhoea
- HRT Critical
- Vertebral Deformity
- Low Trauma Fractures
- Osteopenia on X-ray
- Long term/high dose steroids
- Eating disorders
- Chronic Liver disease
- Alcohol abuse
- Kidney dialysis
- Hyperparathyroidism
- PBC
- Hypogonadism
- Malabsorption Syndrome
- Transplant Assessment
- Growth Hormone
- JCA
- Thyroid Dysfunction
- Follow up/previous abnormal DEXA
- Other indication / trial patient

Point of care clinical risk assessment

http://www.shef.ac.uk/FRAX/



Now available as an i-phone app !

Calculation Tool

Please answer the questions below to calculate the ten year probability of fracture with BMD.

Country: UK Name/ID: female aged 60 About the risk factors

Questionnaire:

1. Age (between 40 and 90 years) or Date of Birth
   Age: 60 Date of Birth: Y: M: D:
2. Sex — Male / Female
3. Weight (kg): 70
4. Height (cm): 169
5. Previous Fracture — No / Yes
6. Parent Fractured Hip — No / Yes
7. Current Smoking — No / Yes
8. Glucocorticoids — No / Yes
9. Rheumatoid arthritis — No / Yes
10. Secondary osteoporosis — No / Yes
11. Alcohol 3 or more units/day — No / Yes
12. Femoral neck BMD (g/cm^2)

Select BMD

Clear Calculate

BMI: 24.5

The ten year probability of fracture (%)

without BMD

Major osteoporotic	6.0
Hip Fracture	0.8

View NOGG Guidance

Print tool and information

Weight Conversion

Pounds → kg Convert

Height Conversion

Inches → cm Convert

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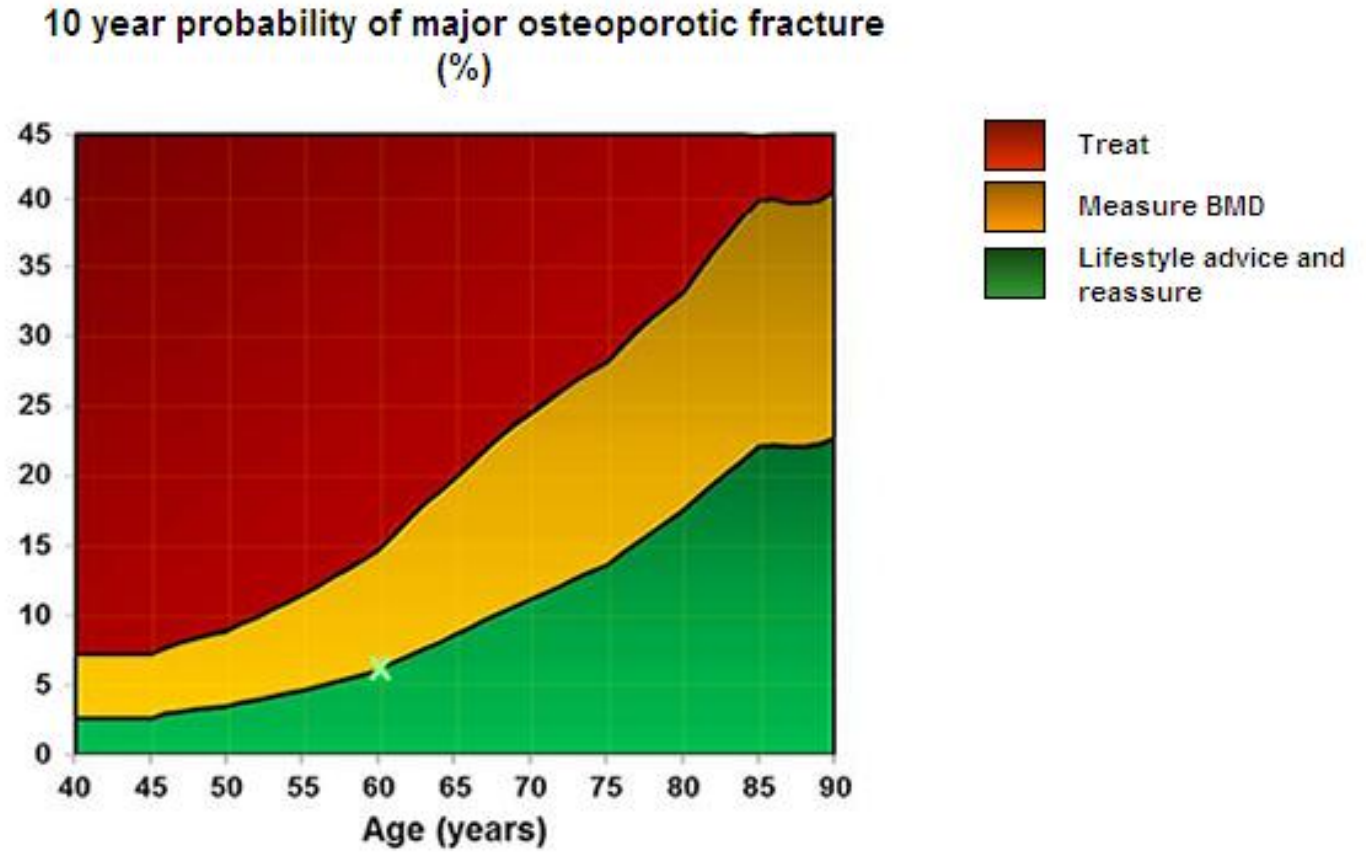
Individuals with fracture risk assessed since 1st June 2011

www.nos.org.uk

National Osteoporosis

Assessment threshold - Major fracture



FRAX WHO Fracture Risk Assessment Tool

Home | Calculation Tool | Paper Charts | FAQ | References | English

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12. Femoral neck BMD (g/cm^2): Select BMD

Clear | Calculate

BMI: 24.5

The ten year probability of fracture (%)

without BMD

Major osteoporotic	14
Hip Fracture	2.2

View NOGG Guidance

Print tool and information

Weight Conversion

Pounds → kg Convert

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Inches → cm Convert

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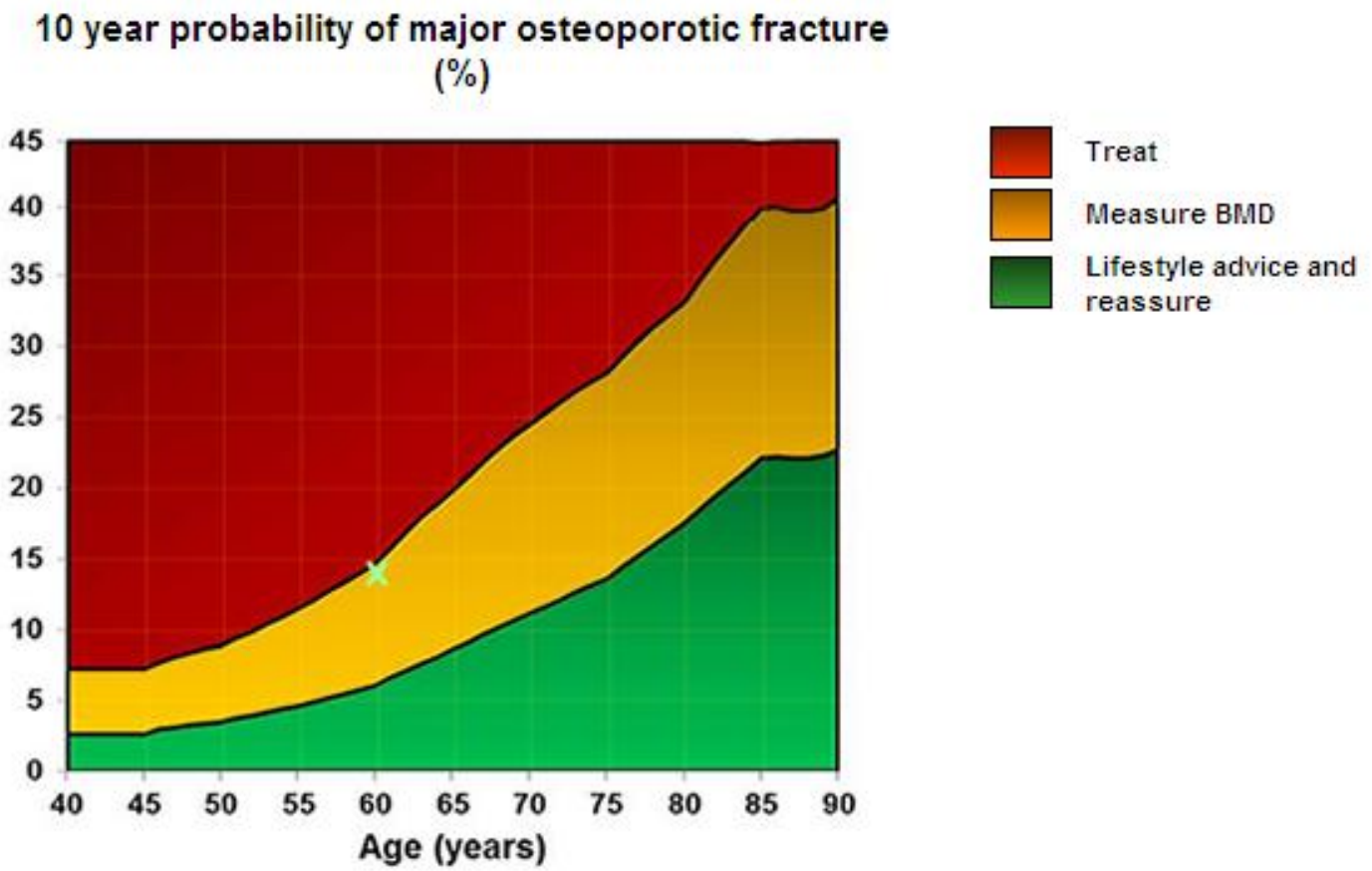

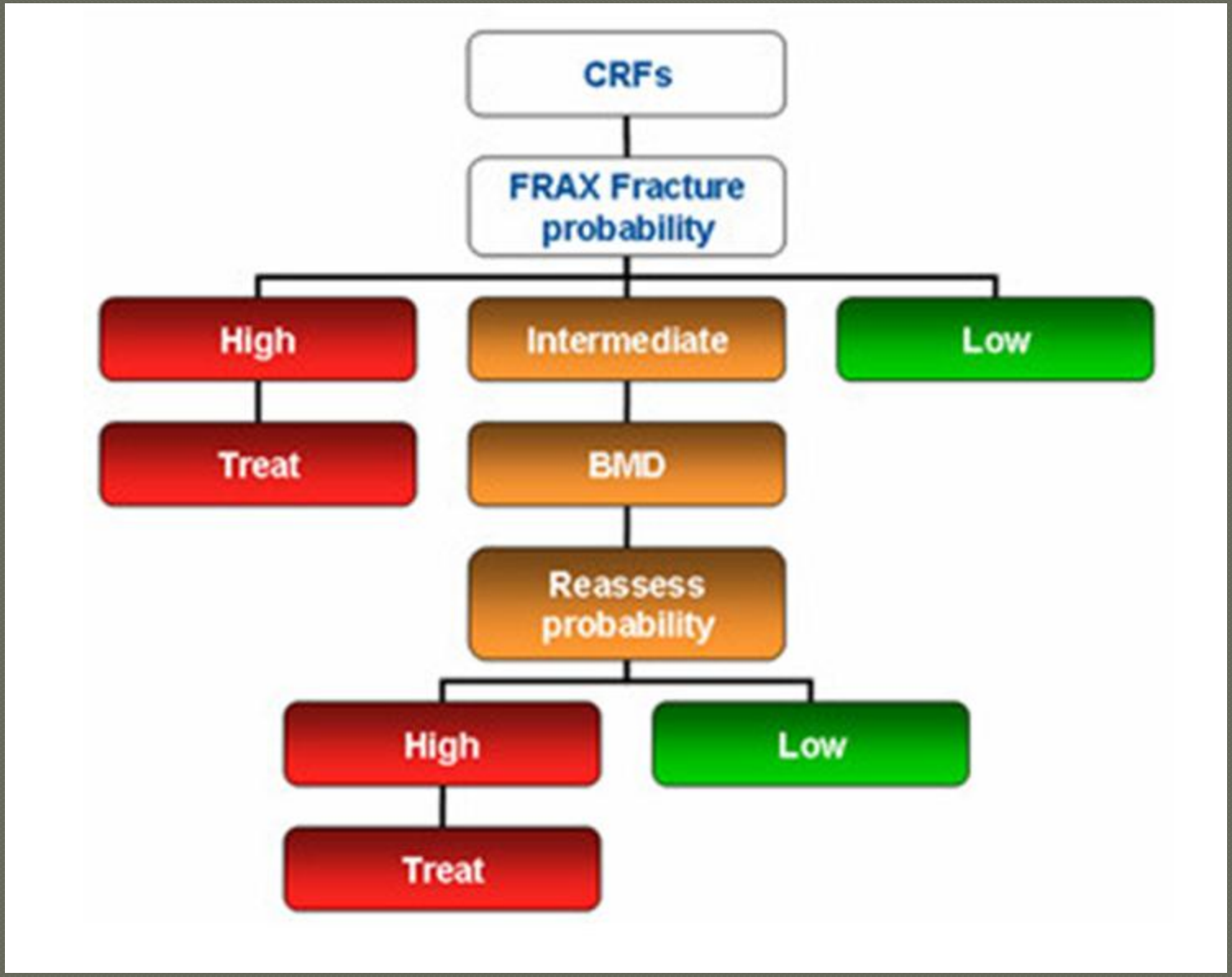
CRFs
FRAX Fracture probability
High
Intermediate
Low
Treat
BMD
Reassess probability
High
Low
Treat

Calculation Tool

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10. Secondary osteoporosis — No / Yes
11. Alcohol 3 or more units/day — No / Yes
12. Femoral neck BMD (g/cm^2): GE-Lunar 0.715 T-score: -2.3

Clear Calculate

BMI: 24.5

The ten year probability of fracture (%) with BMD

Major osteoporotic	20
Hip Fracture	5.2

View NOGG Guidance

Print tool and information

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Pounds → kg Convert

Height Conversion

Inches → cm Convert

01208987

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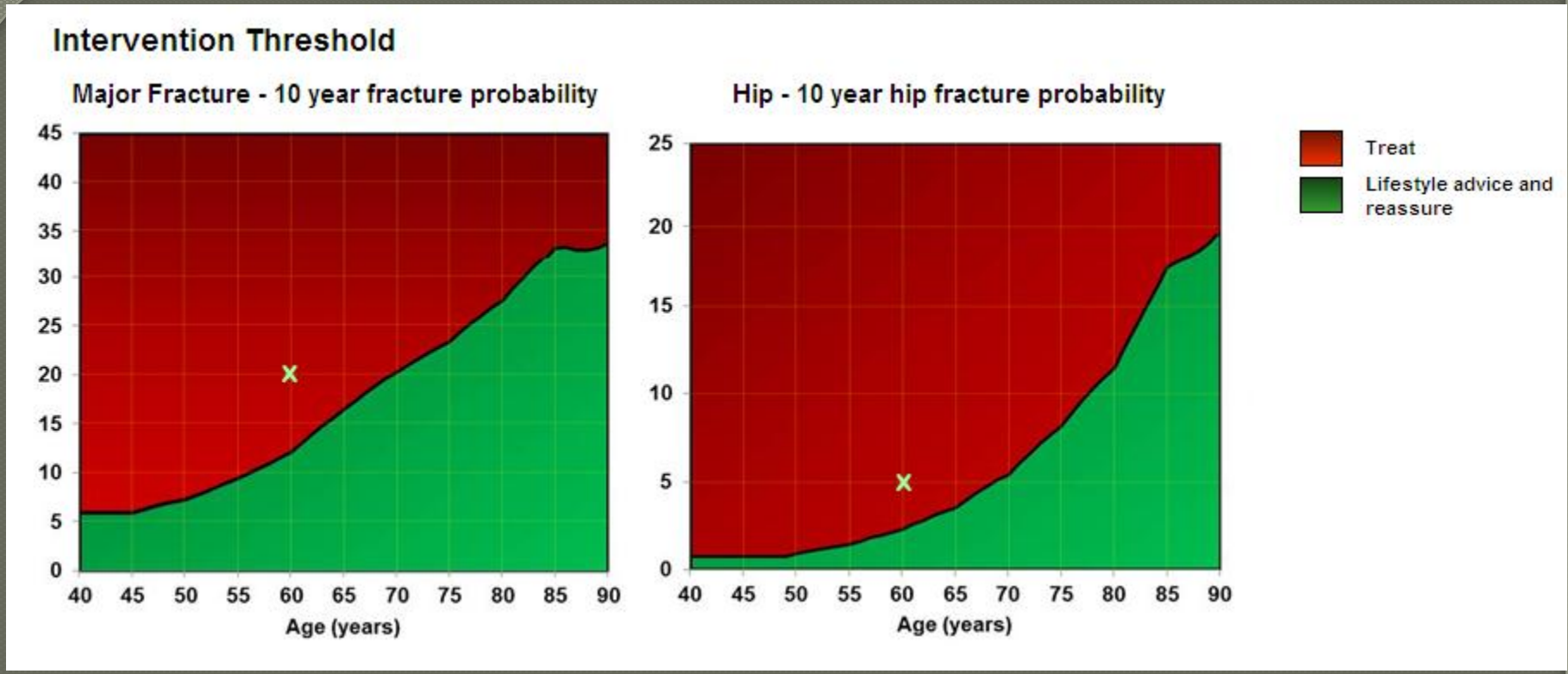
National Osteoporosis



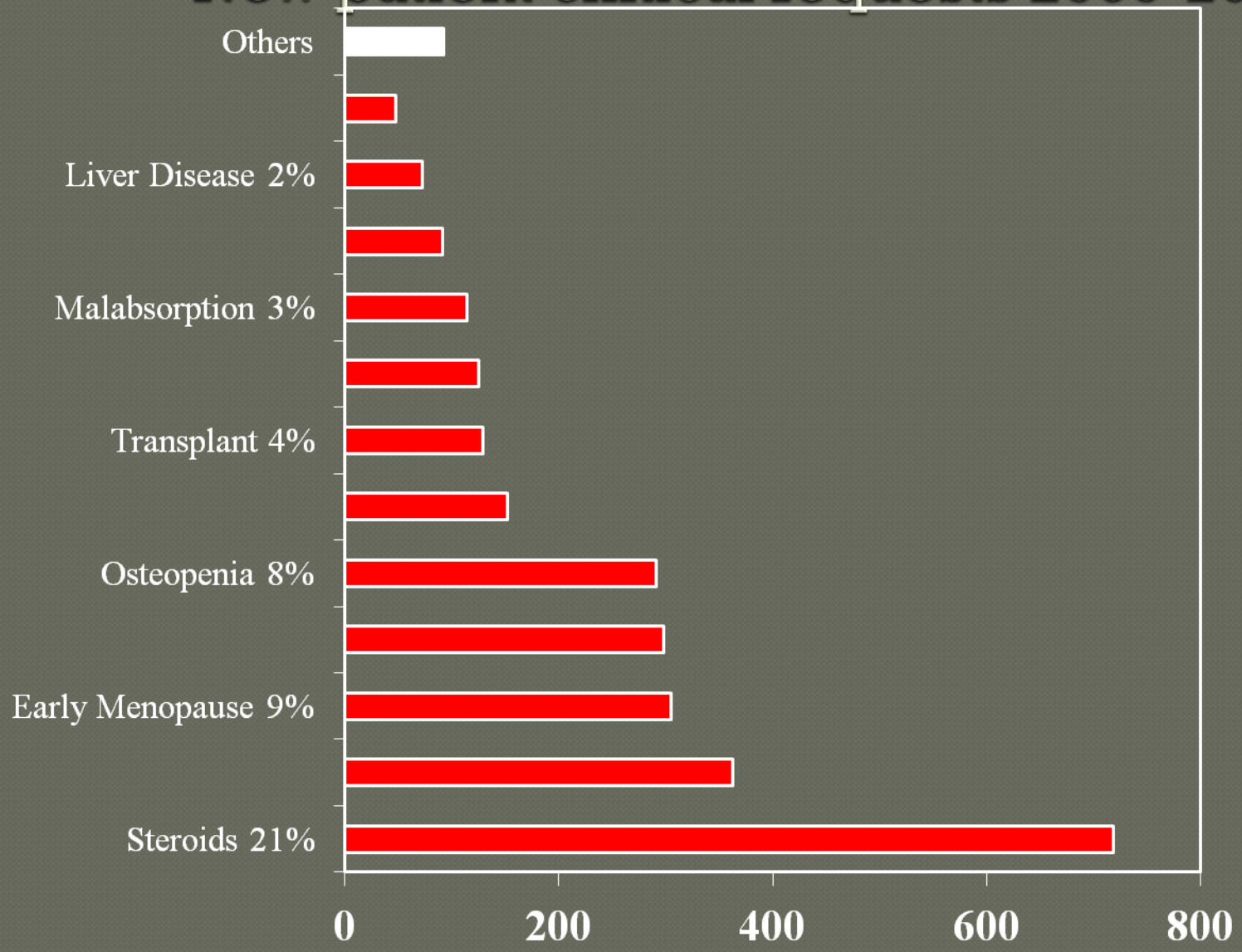
The low cost of generic alendronate, which has a broad spectrum of anti-fracture efficacy, makes this the first line treatment in the majority of cases.

In women who are intolerant of alendronate or in whom it is contraindicated, other bisphosphonates, denosumab, strontium ranelate or raloxifene may provide appropriate and cost-effective treatment options

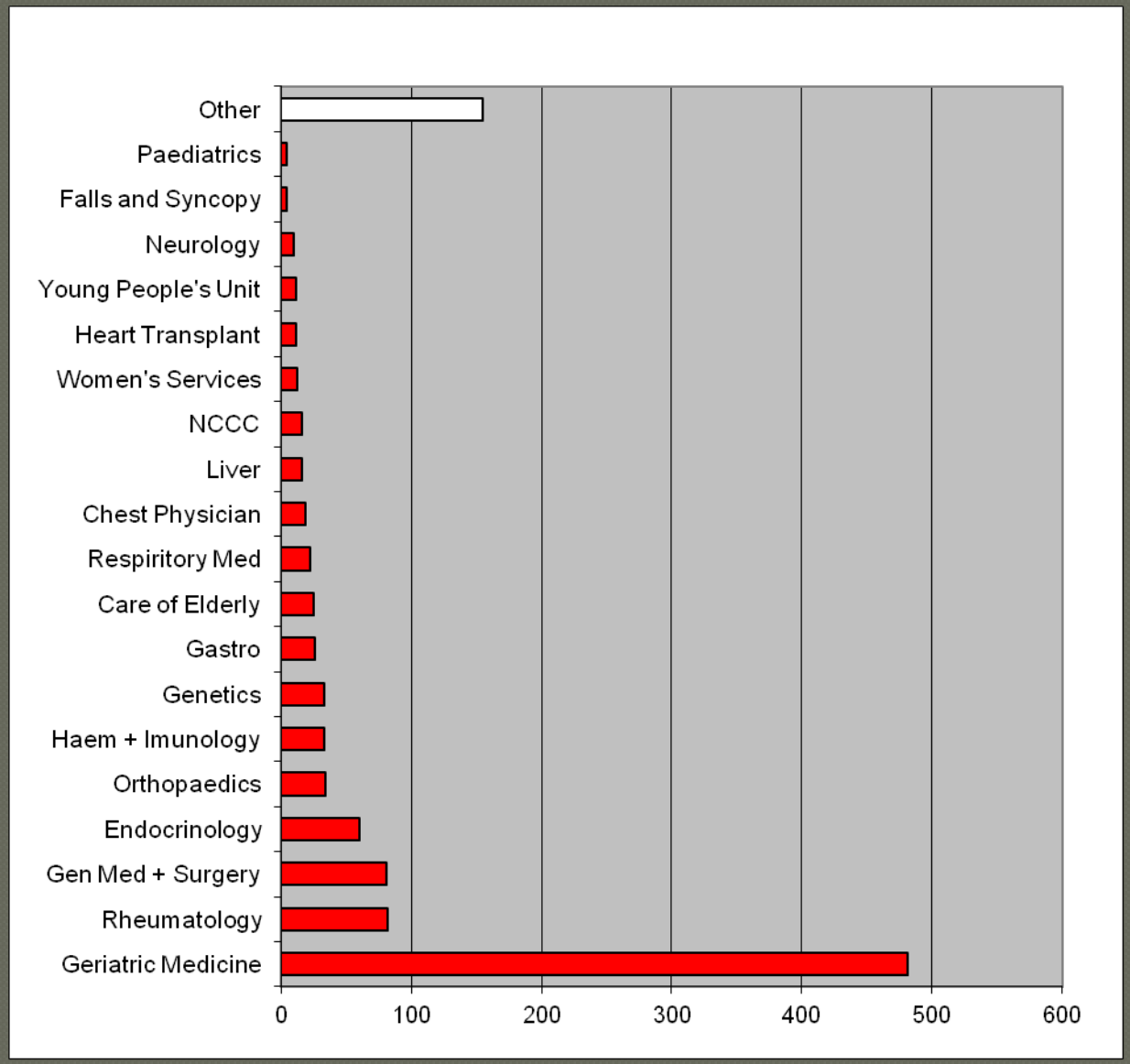
Dexa requests at FH

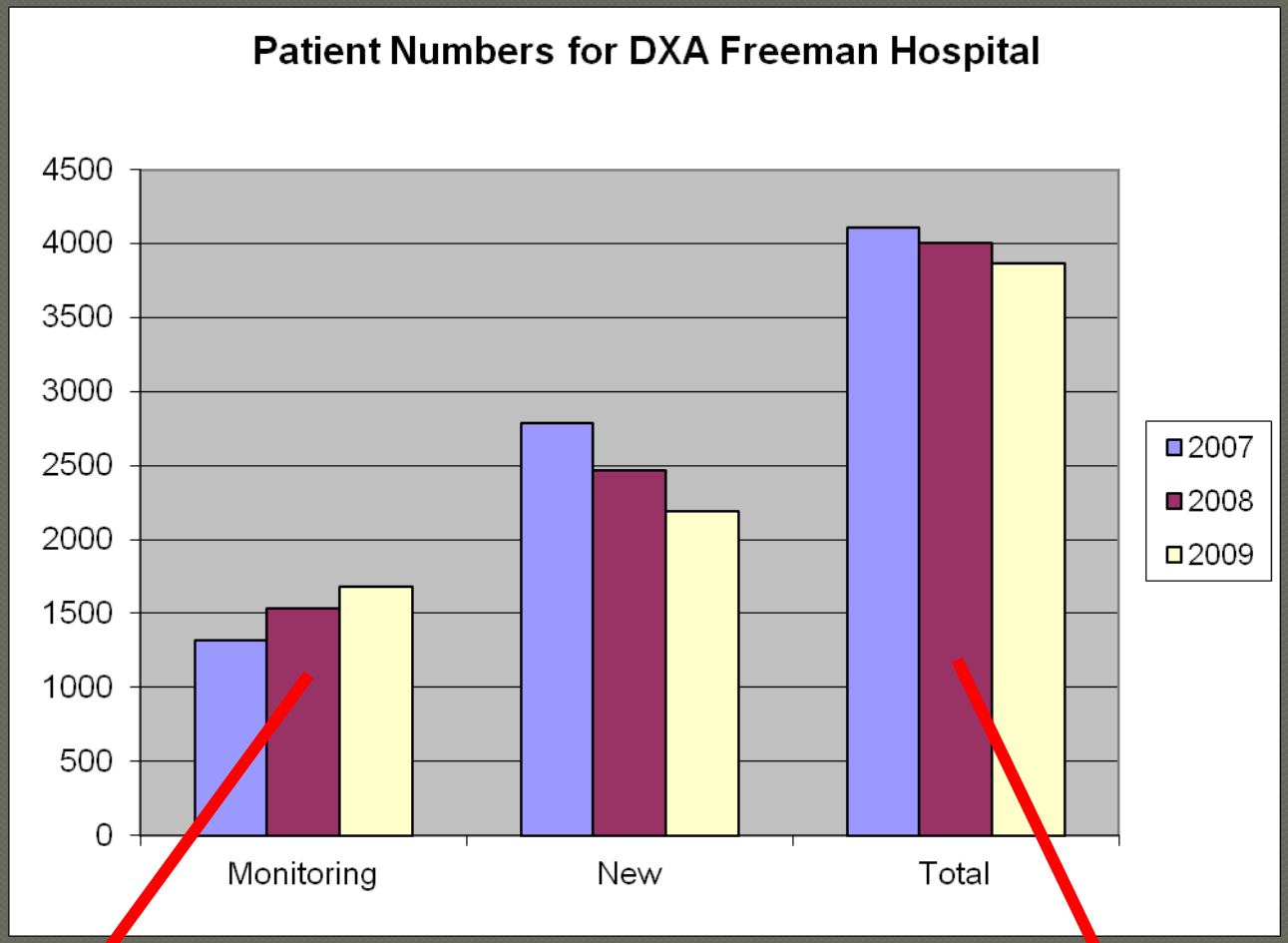
How many new patients?
How many review patients?

New patient clinical requests 2000-2001



Clinical requests by NUTH speciality snapshot July 2008





Min 2 years or about 5% change in BMD

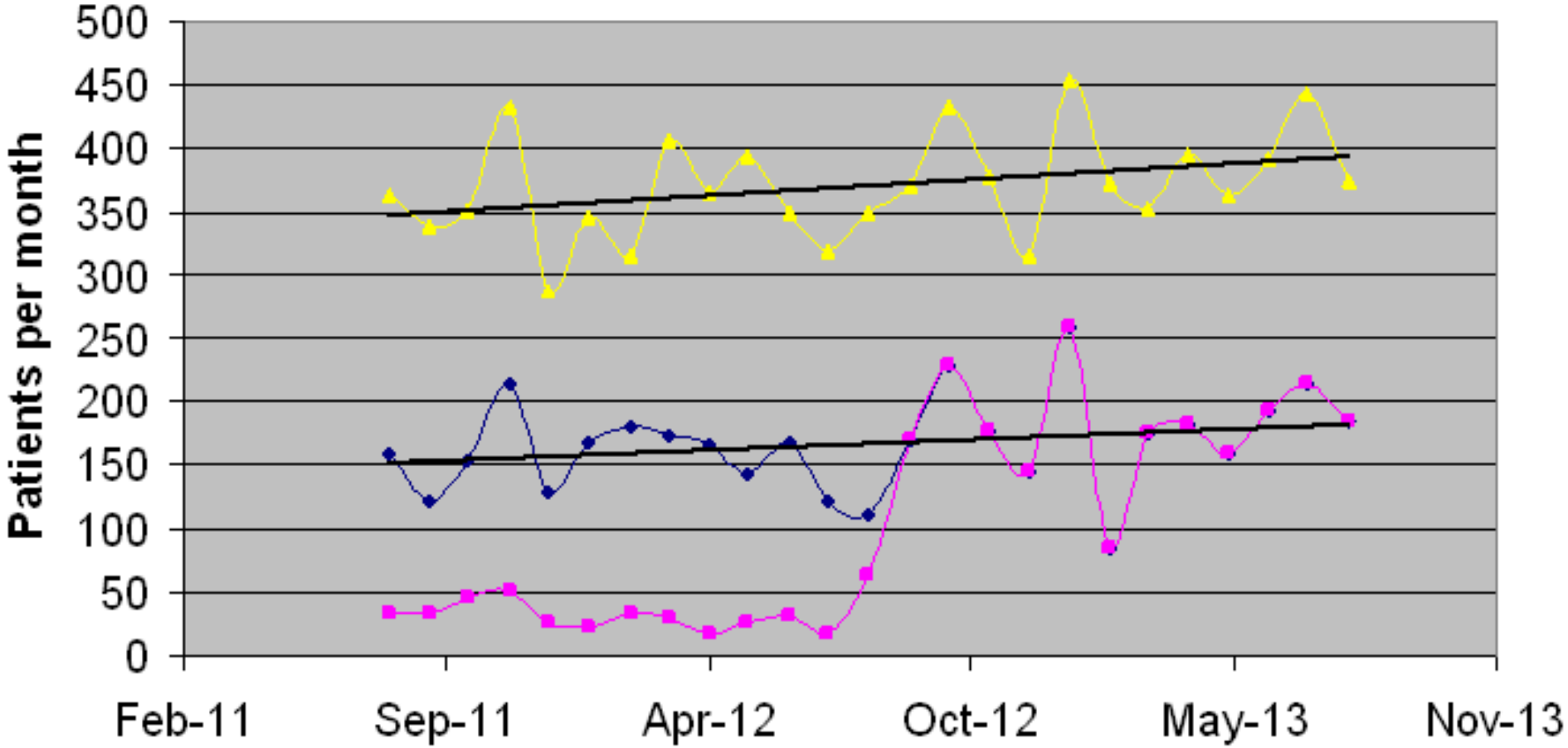
Broadly consistent with NOS guidelines

DXA Freeman Patient numbers Aug 2011 - Aug-13 (25 Months)

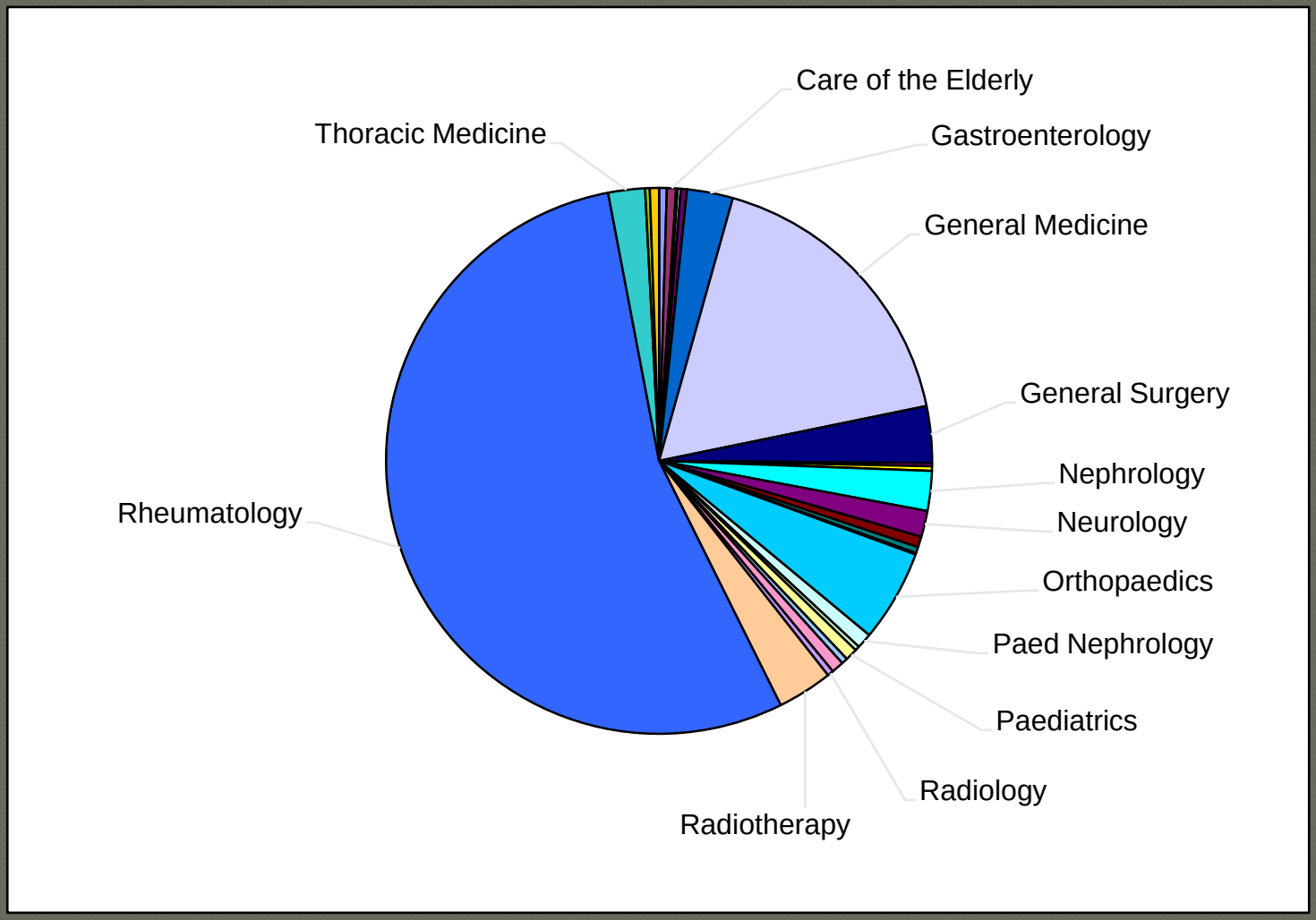
Total Scans (Yellow) : Extra 40 scans per month (11%) over period

Bone Clinic (Blue): Extra 30 scans per month (19.5%) over period

One Stop (Pink): new bone clinic patients only up to Aug 2012



First Quarter 2013

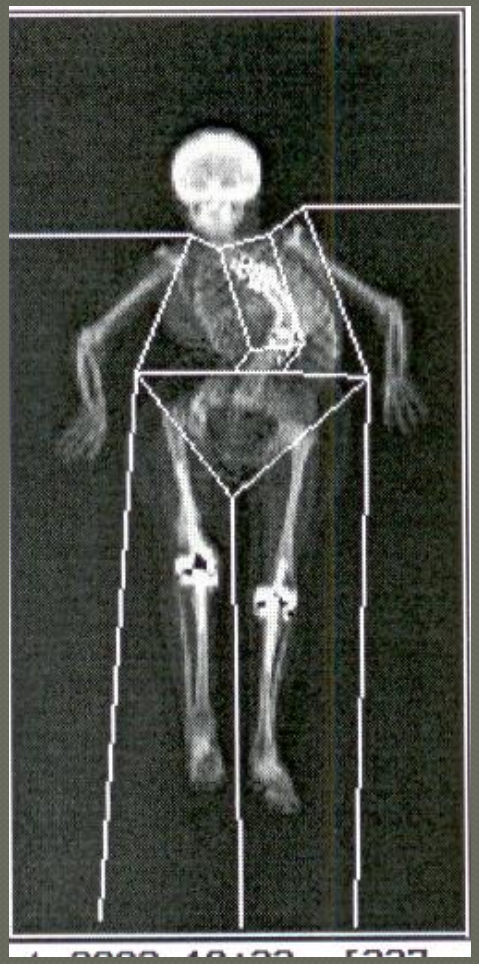


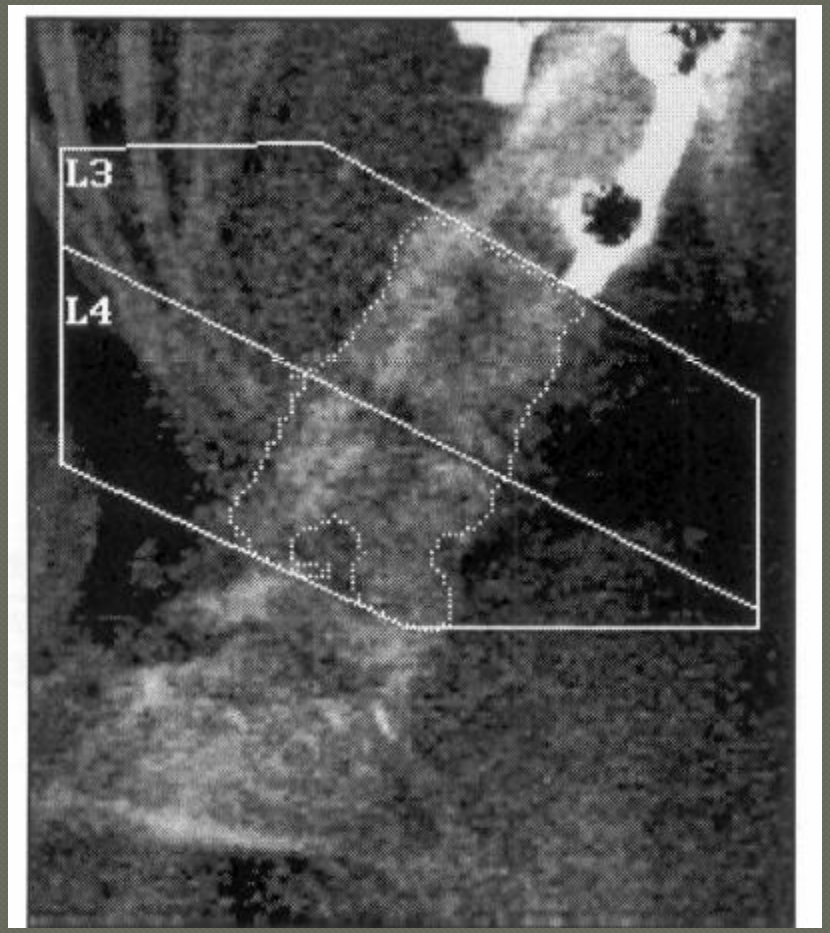
Case study

- A young women with severe scoliosis

Relevant History

- Young woman aged 31
- Severe Scoliosis
- Multiple joint replacements
- Limited Mobility



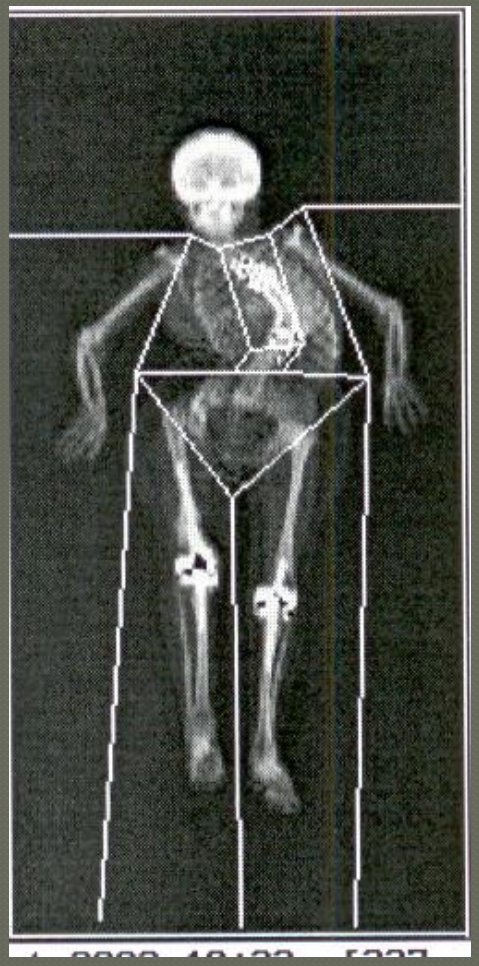

L3
L4

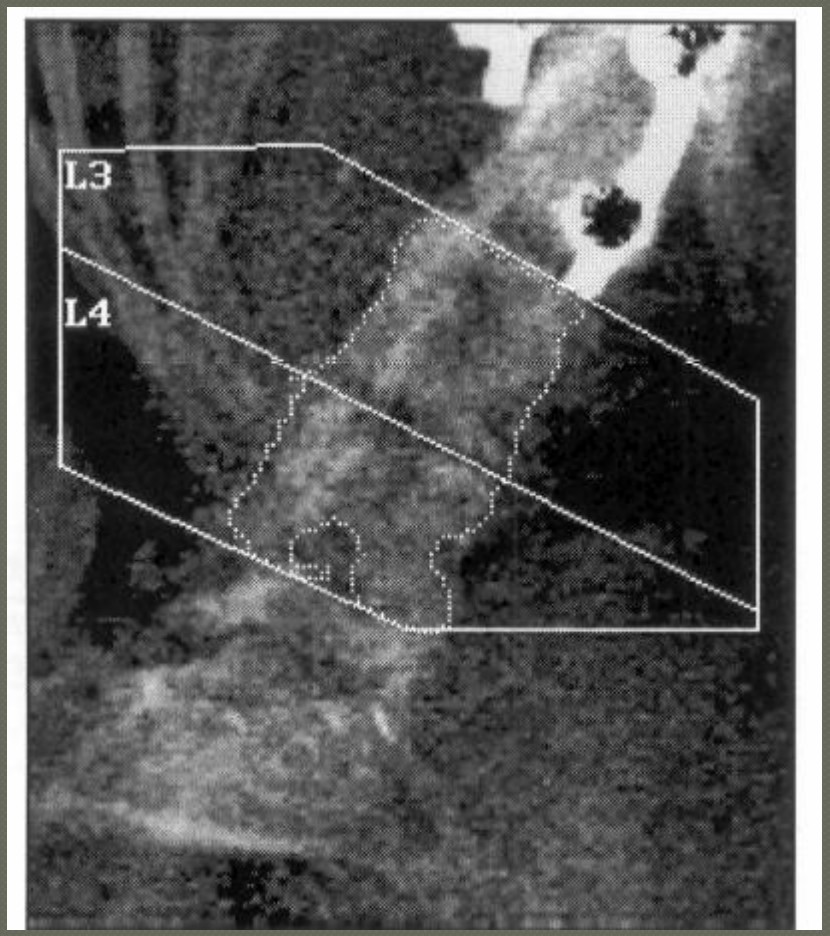
Findings

- Measured at 26 years and 32 years
- Z(L3/L4) = -2.0 and -2.5
- Z(WB) @32: +8.73 [influenced by metal]
- BMD(pelvis) @32: close to expected
- BMD(arms) @32: 20-30% below expected

Conclusions?

- L3/4 may not be representative
- Whole body BMD not diagnostic
- Some evidence of localised bone loss
- Utility of forearm measurements?
- Interpret all BMD with caution

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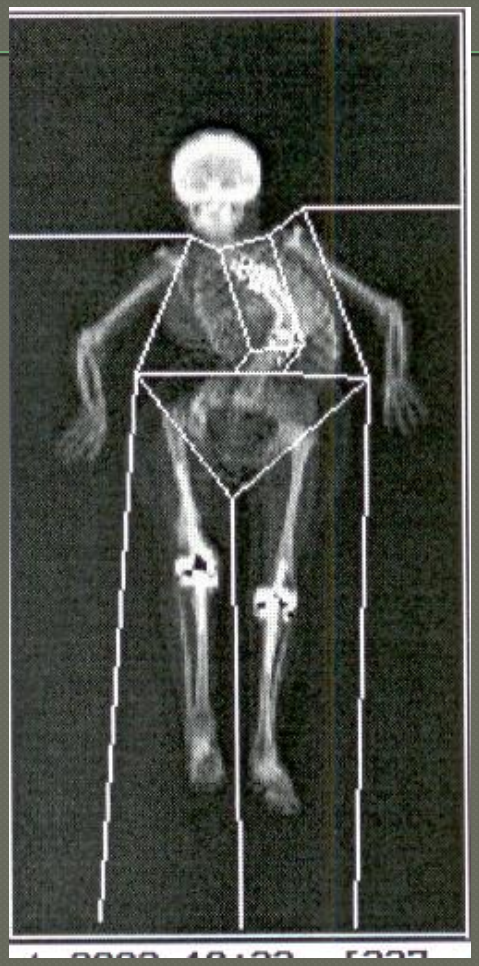

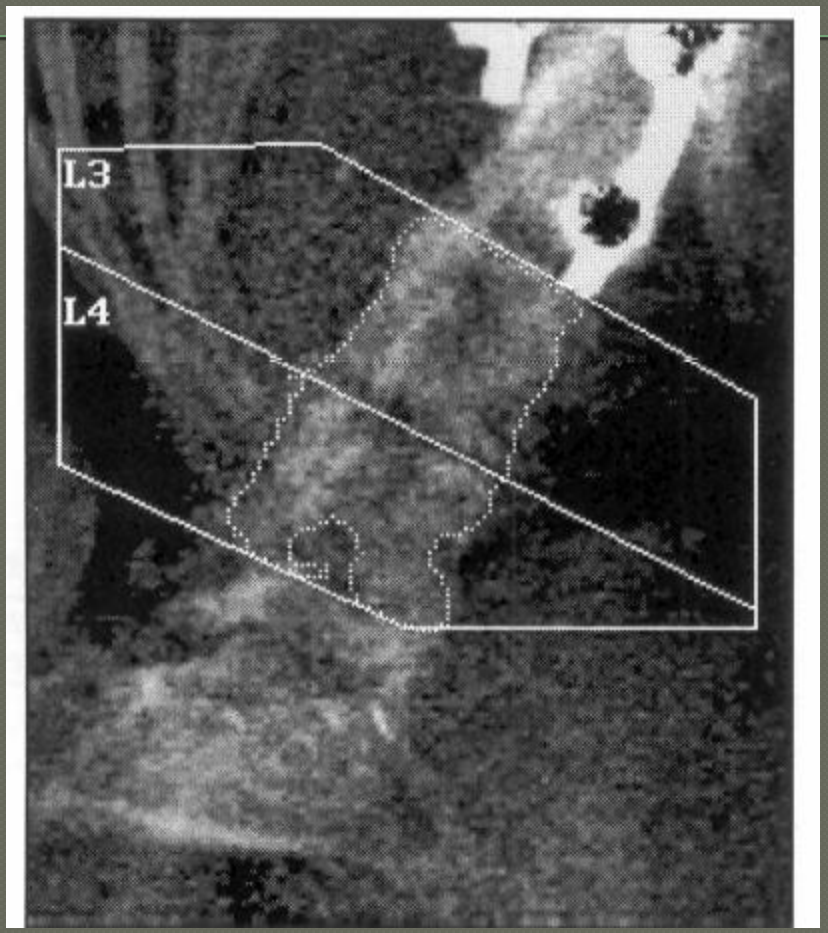
L3
L4

Conclusions?

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Utility of forearm measurements?
Interpret all BMD with caution

Other patient pathways?

Emergency Admissions Unit (W43)

Dr Ashley Price Dr Soumya Kumble

- 50-60 patients per day admitted
- Variety of conditions
- Indications for DXA / treatment?
- 62 admissions over 3 days Jan 2009
- FRAX tool
- N=21 reassure, N=14 DXA; N=11 Treat
- Need largely unmet at present
- Very early days

Radiology Reports

Dr Geoff Hide; Sister Sharon Abdy

- Spine x-rays may identify vertebral fracture
- Not always followed up by GP
- Indications for DXA / treatment?
- Local audit suggests several per month
- Supported by data from Glasgow
- Pathway to DXA / Treatment unclear

GP Referrals

- Co-ordinated case finding strategy
- Led by single GP practice
- Selected patients offered DXA at FRH
- Technical report produced
- Service level agreement (SLA) in place
- Approx 20 patients per month
- On-going

What's new

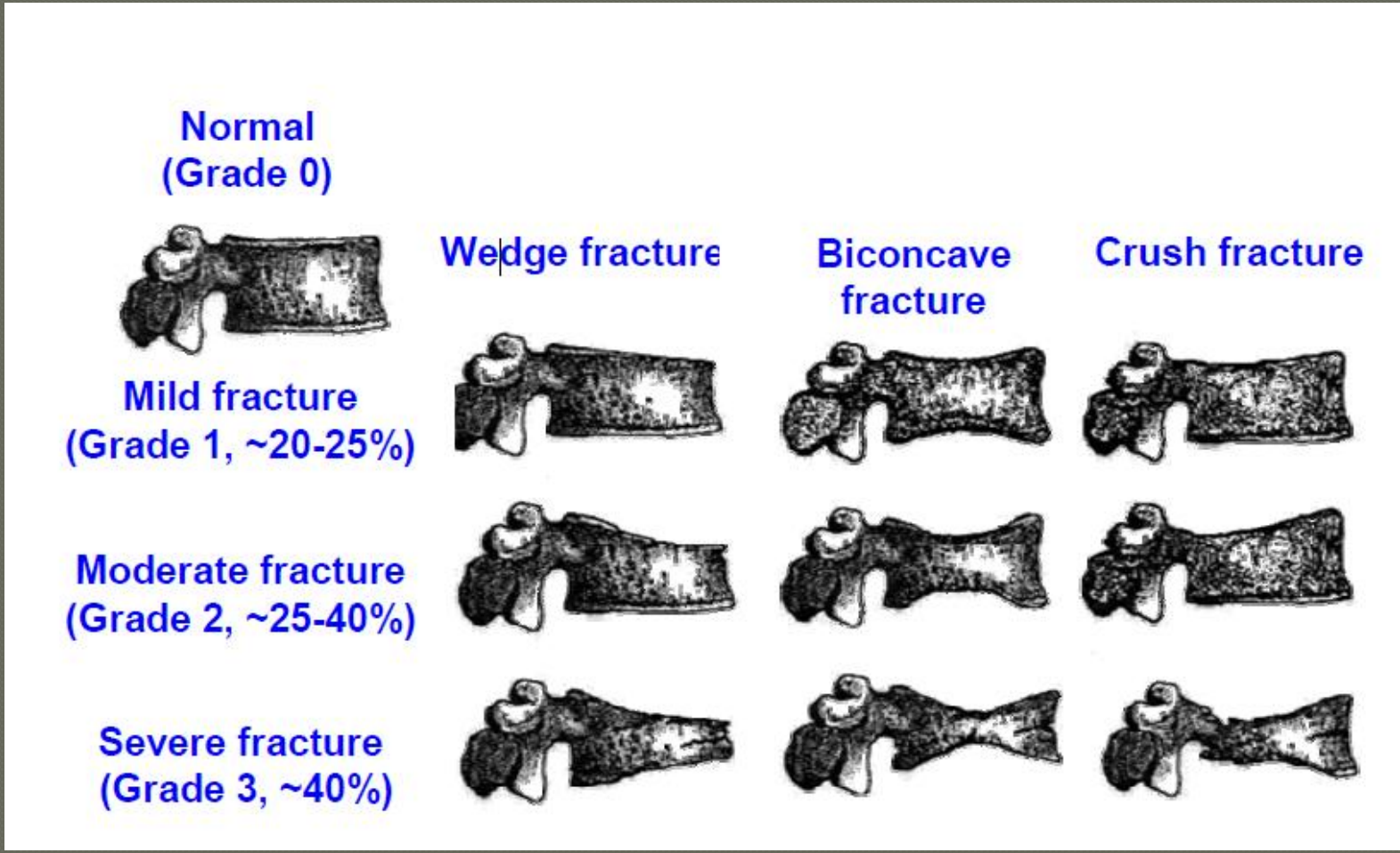
- Vertebral Fracture Assessment
  - Total spine x-ray at same time as BMD
  - Lower dose than conventional spine x-rays
- Electronic requesting (soon)
  - RVI scoliosis assessments now electronic
- Electronic reports (eventually)

A patient who has already fractured could fracture again…

- fragility fracture (45+)
- no trauma (standing height or less)
- includes vertebral deformity
- independent risk for further fracture
- an indication for treatment without BMD RCP Guidelines 2001

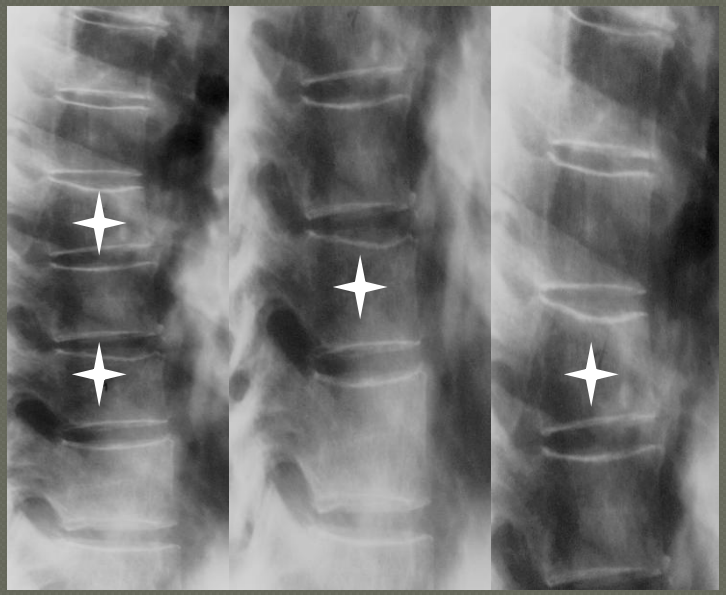
- Pre-existing fracture and low BMD greatly increases risk of future fracture

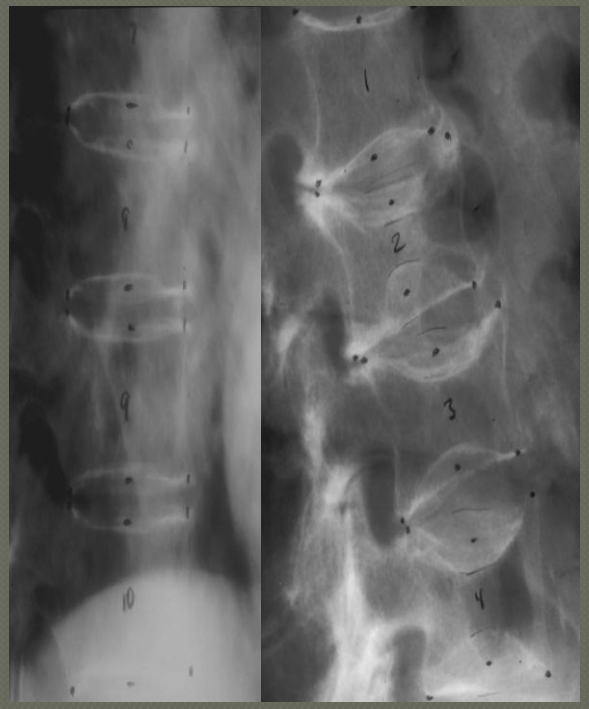
May identify pre-existing fractures by semi-quantitative grading…



Genant et al (1993)

Lateral spine x-rays allow visual grading against the grading chart…

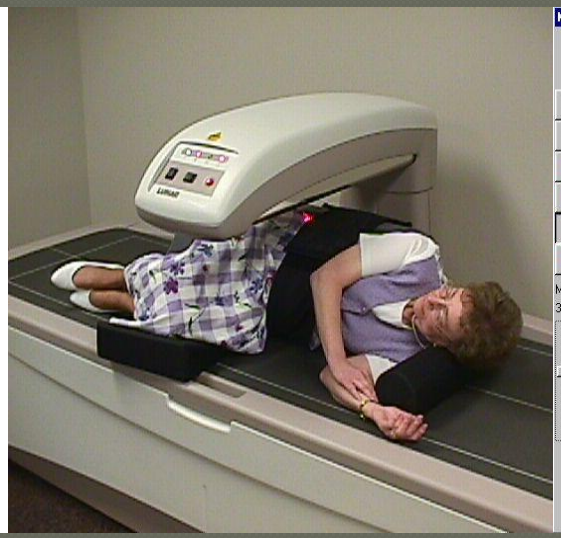


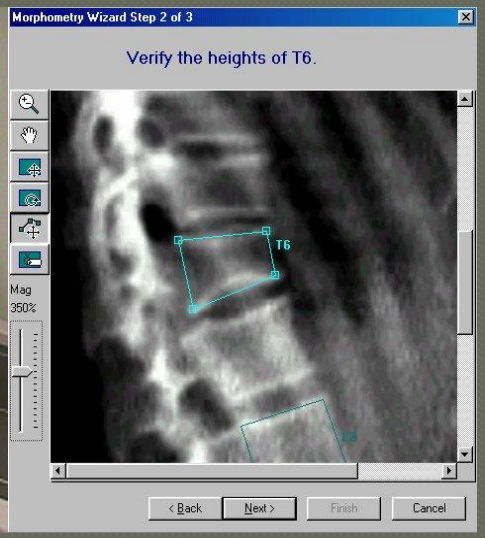


or a quantitative assessment measuring vertebral heights directly

Vertebral Fracture Initiative (2006)

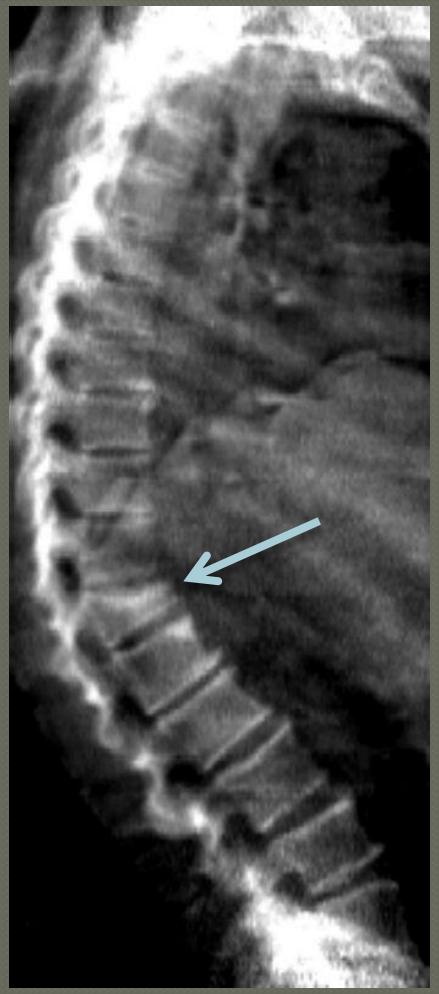
…or we may identify and grade vertebral fractures using DXA





- So BMD and vertebral morphometry together one stop shop!

Advantages of morphometry by DXA



- semi-automated alignment
- semi-automated positioning
- better penetration (100-140kVp)
- single view for whole spine
- dose about 1/50th (0.006mSv)
- Includes BMD assessment
- single or dual energy options
- able to see most vertebra?

Why did the X-ray only take 1 suitcase away on holiday?

It was travelling light!

Thankyou

Any Question?