# The Challenges Presented in Clinical Practice in Wales:

## *Safe Practice in DXA Scanning & Interpretation*


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*Senior Lecturer & DXA Service Lead,*

*Welsh Institute of Chiropractic,*

*University of South Wales*

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*Cardiff & Vale UHB*

# Today's Objectives

- How safe is our practice?
  - Clinical Governance
  - Training
  - Considerations for those who scan, create or interpret technical reports

# The DXA Service at the Welsh Institute of Chiropractic (WIOC)

# Advice

University of South Wales
Prifysgol De Cymru

GIG CYMRU NHS WALES
Bwrdd Iechyd Prifysgol Caerdydd a'r Fro
Cardiff and Vale University Health Board

GIG CYMRU NHS WALES
Bwrdd Iechyd Prifysgol Cwm Taf University Health Board

National Osteoporosis Society

Vertec

# Personnel

- IRMER
  - Practitioner
  - Operator
- Reporting
- Clinical governance

# Personnel

- IRMER
  - Practitioner
    *Professor David Byfield, Head of Clinical Services at WIOC*
  - Operator
    *Angela Sims, Senior Lecturer & Cardiac Physiologist*
  - RPS
    *Angela Sims, Senior Lecturer & Cardiac Physiologist*
- Reporting
  *Angela Sims, Senior Lecturer & Cardiac Physiologist*
- Clinical Governance
  *Professor Mike Stone*

# Training

University of South Wales
Prifysgol De Cymru

## Vertec

In-House Training

THE SOCIETY OF RADIOGRAPHERS

RPS Training

## UNIVERSITY of DERBY

PGCert Bone Densitometry Reporting

- DXA Reporting for clinicians

- Advancing practice
- Assessment, prevention and management of falls (theory)
- Principles of service improvement in the workplace
- Theoretical considerations in the diagnosis and management of osteoporosis
- Work-based negotiated

https://www.derby.ac.uk/postgraduate/radiography-courses/bone-densitometry-reporting-pg-cert/ (03/04/2019)

## Royal Osteoporosis Society

National Training Scheme for Bone Densitometry

- Understand the use of DXA in identifying osteoporosis
- Evaluate X-rays effectively
- Pass on detailed reports to clinicians to inform decisions around treatment

https://theros.org.uk/healthcare-professionals/courses-and-cpd/national-training-scheme-for-bone-densitometry/ (03/04/2019)

University of South Wales
Prifysgol De Cymru

# Accreditation

- Application Process
  - Application Form
  - Policies & Procedures
  - Patient Information
  - Referral Forms
  - Site Inspection

Arolygiaeth Gofal Iechyd Cymru
Healthcare Inspectorate Wales

# Current Service

- Short waiting list (1-2 weeks)
- £100, including written report
- Rapid report turnaround (1-5 days)
- Referrals
  - WIOC clinic
  - Private H/C clinics
  - Primary care
  - Secondary/tertiary care
- Research
  - Sport Wales
  - Simbec
  - Velindre
  - USW
- Future

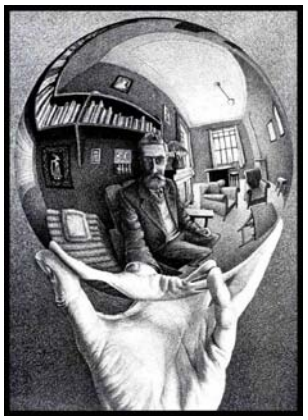
# Maintaining a Safe, Robust Service

- Clinical Governance
  *Prof Mike Stone (clinical)*
  *Rebecca Pettit (technical)*
  *Audit*

- Maintaining current knowledge
  *WOAG Meetings*
  *NOS/ROS conference*

- IRMER/IRR
  *Regular updates*
  *RPA/MPE inspections*

- Reflection



M C Escher, c1925

# SOURCES OF ERROR

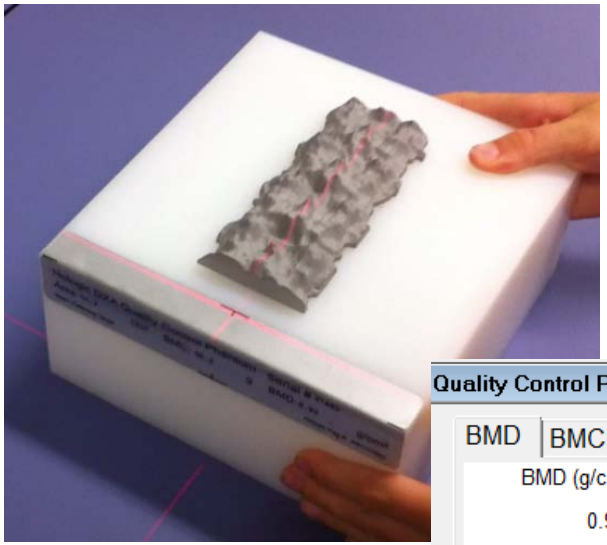
# Sources of Error

- The instrument
- The patient – avoidable and unavoidable
- The operator
- The report

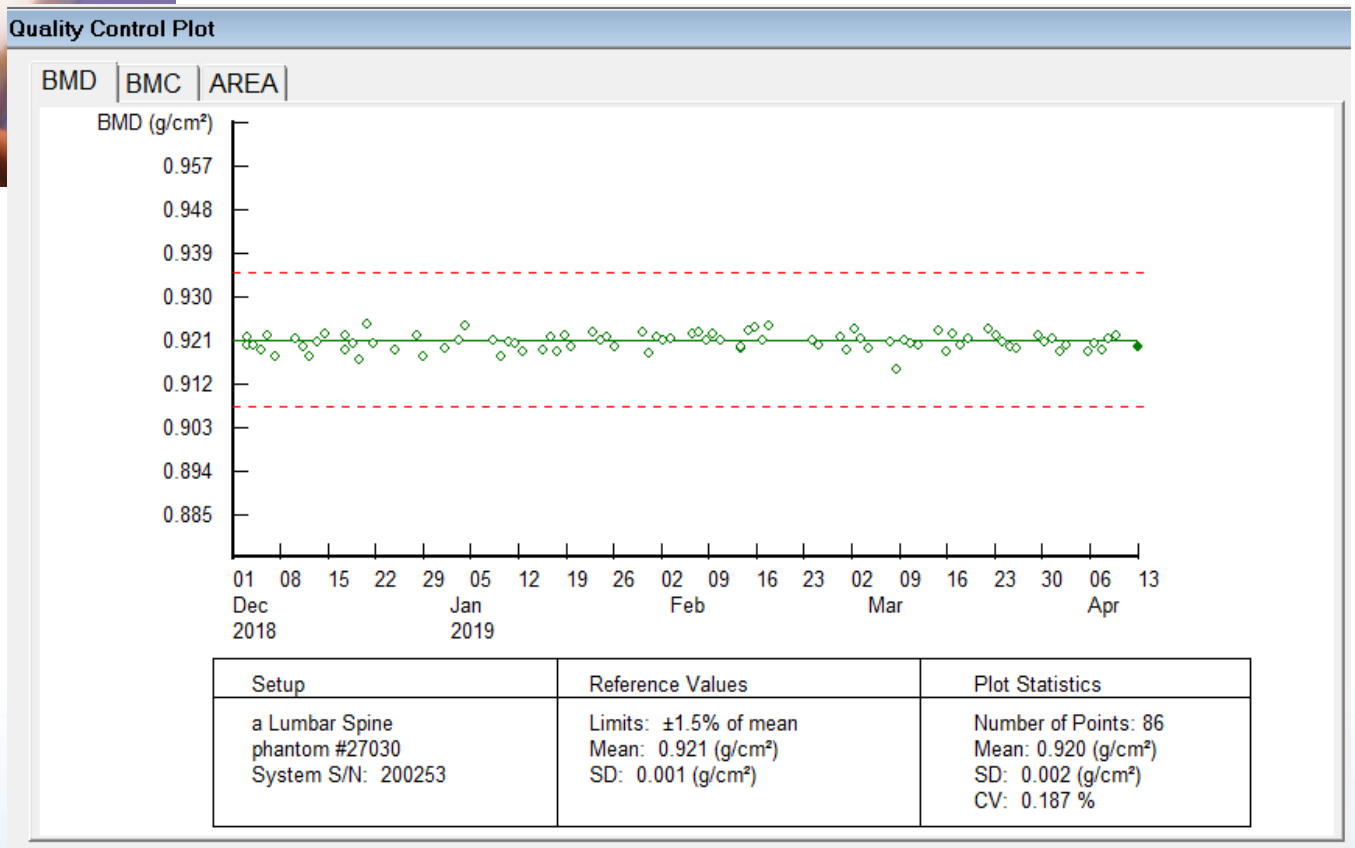
# The Instrument – Bone Densitometer

- Calibration and Quality Control
- Image processing algorithms
- Reference data
- Malfunctions

# Calibration and Quality Control



Quality Control
Spine Phantom




Quality Control
BMD Plot

# Calibration and Quality Control

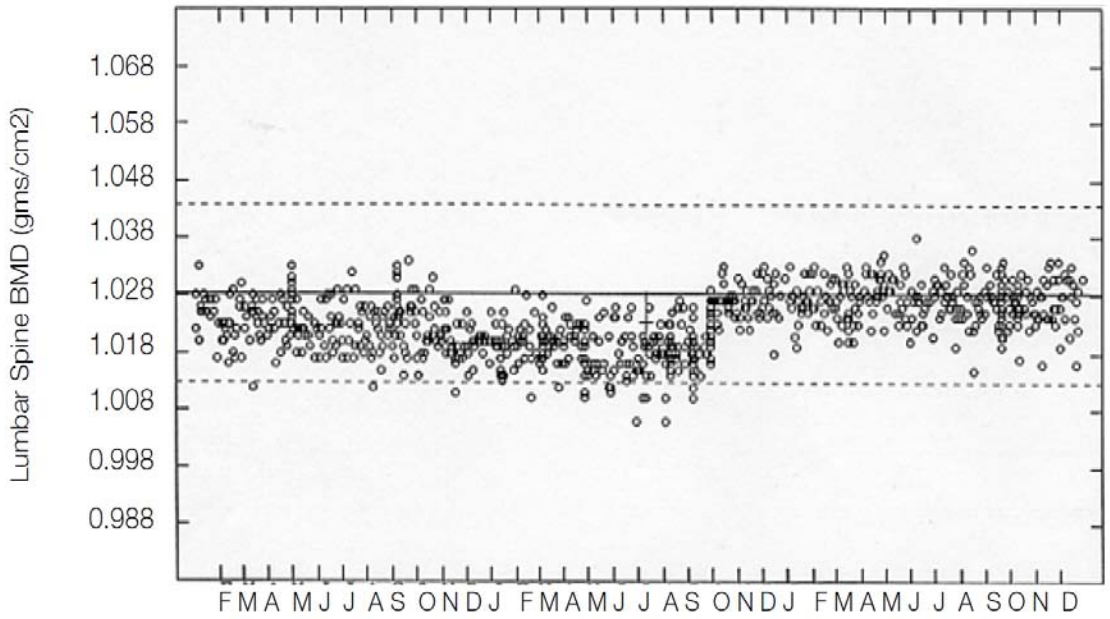
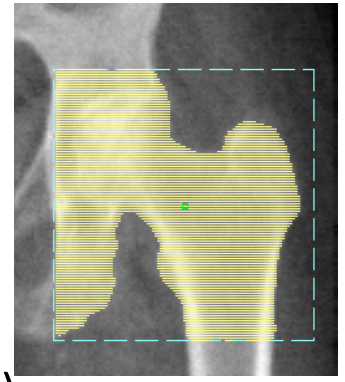



**Figure 1: A gradual drift in a quality assurance history, which was a result of a slow oil leak.**

Knapp et al. Osteoporosis Review 2014; Vol 22: No1: P 1-6

# Image processing algorithms



$$\text{Bone Mineral Density (BMD) (g/cm}^2\text{)} = \frac{\text{Bone Mineral Content (BMC) (g)}}{\text{Area of bone (cm}^2\text{)}}$$

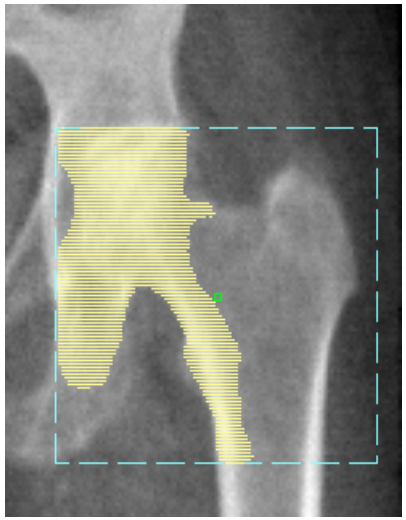
Edge detection image processing algorithm identifies bone using predetermined thresholds, and creating a “bone map” identifying the bone region in the acquired image.

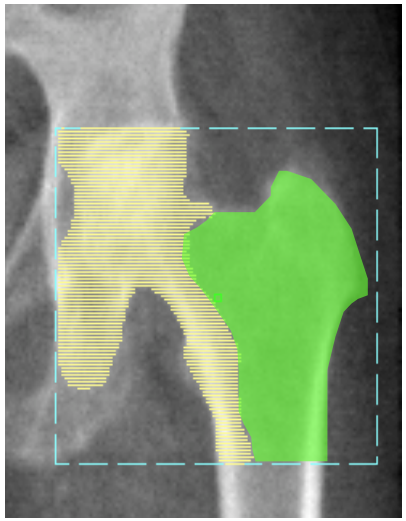
DXA Operator can change the area of bone identified by manually adjusting the bone map.

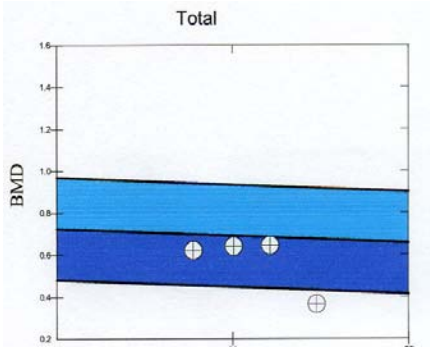
Adjusting the bone map can either increase or decrease the area of bone identified and so can alter the BMD significantly.

Once the result is produced, it is not possible to tell what adjustments to the bone map have been made.

# Manual Filling in of Bone Map on Hip Scan



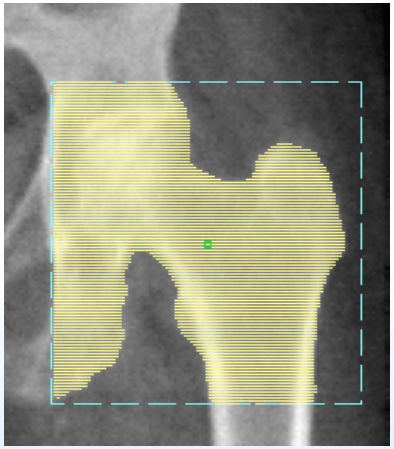


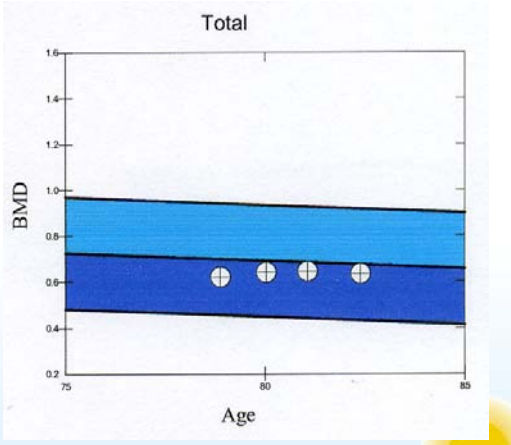



82-year-old woman on treatment. Scan comparison using automatic analysis failed to identify the bone in a large area of the hip. Operator painted in the missing bone total hip BMD appeared to decrease by 43% compared with the previous scan(spine BMD decreased by only 2%)

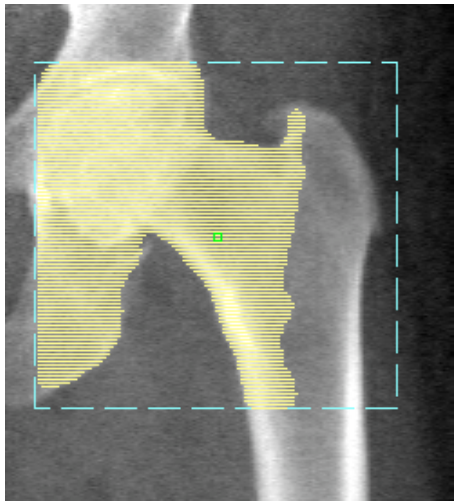
# Automatic Filling in of Bone Map on Hip Scan

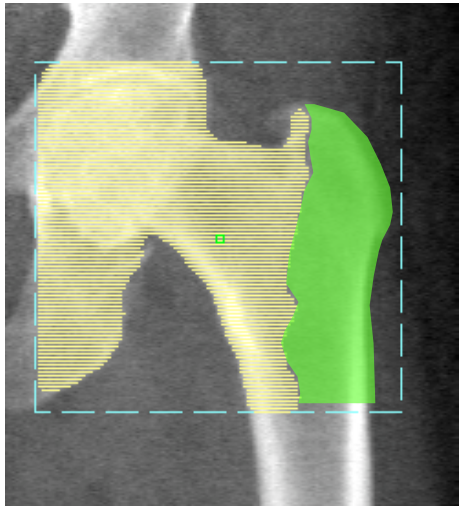
Upper border of the analysis box was raised, system software correctly identified the bone without the need for painting in. Total hip BMD was found to have decreased by only 1.5%.

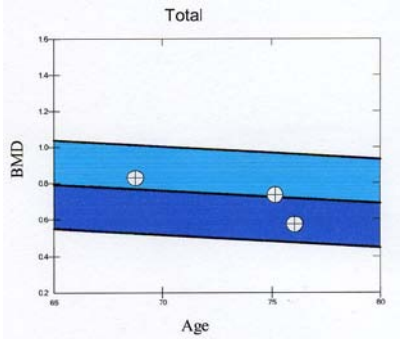




# Manual Filling in of Bone Map on Hip Scan



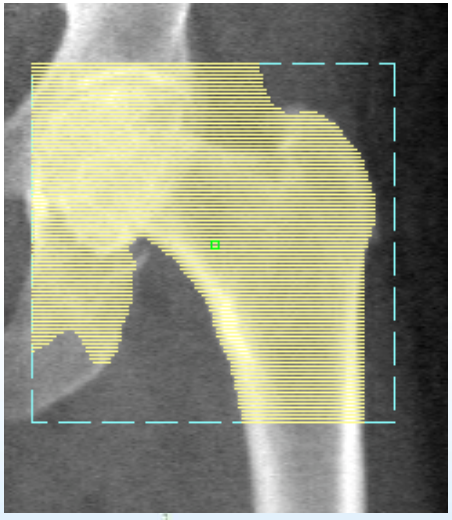


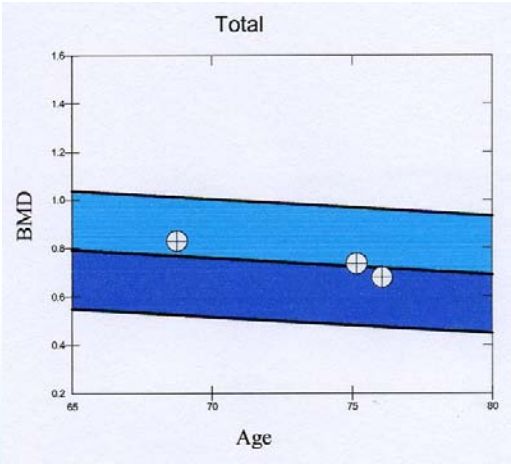



76-year-old female had a follow-up hip scan where automatic analysis using the scan comparison software failed to properly identify all the bone . When the missing bone was painted in total hip BMD appeared to decrease by 22% compared with the previous scan.

## Bone Map determined using Low Density Software

In this case raising the upper border of the analysis box failed to solve the problem. When the scan was re-analysed without scan comparison the analysis defaulted to auto low density but now a large area of soft tissue above the femoral neck was included in the bone ROI. When this was painted out total hip BMD appeared to decrease by 8%.





# Sources of error

- The instrument
- The patient – avoidable and unavoidable
- The operator
- The report

# The patient

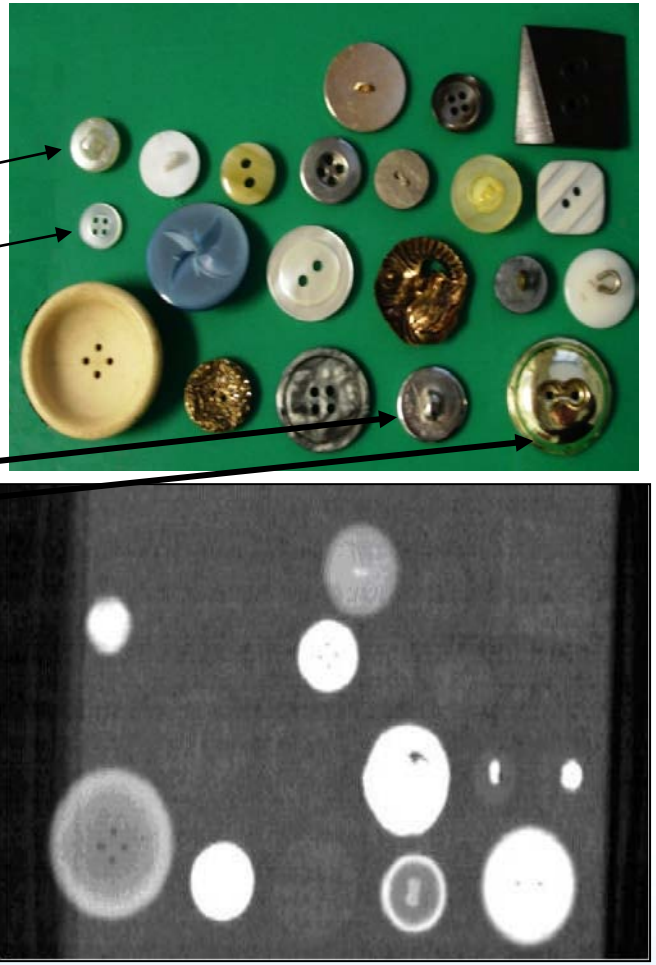
- Clothing and other external artefacts
- Internal Artefacts
- Recent investigations
- Clinical conditions
- Positioning

# Clothing and other external artefacts

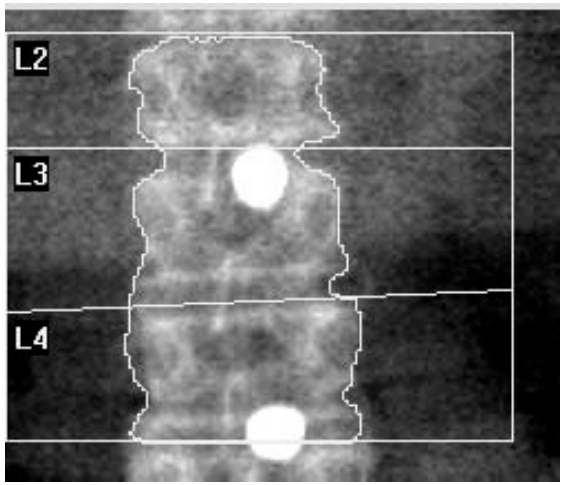
Pearl

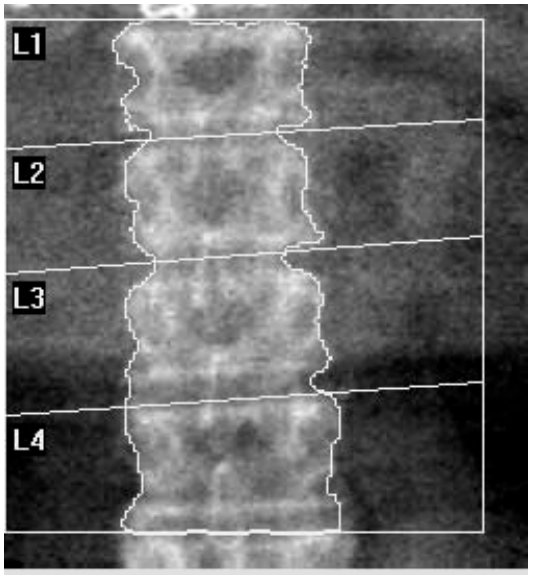
Plastic

Metal coated



# Clothing and other external artefacts



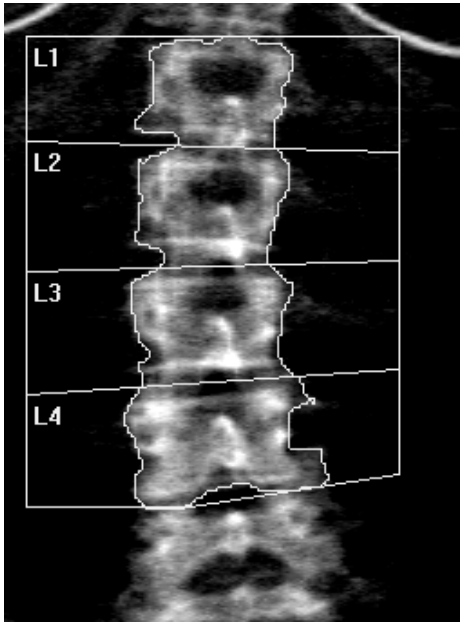

| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| L2 | 0.621 | -3.7 | -0.9 |
| L3 | 0.878 | -1.9 | 1.1 |
| L4 | 1.029 | -0.3 | 2.8 |

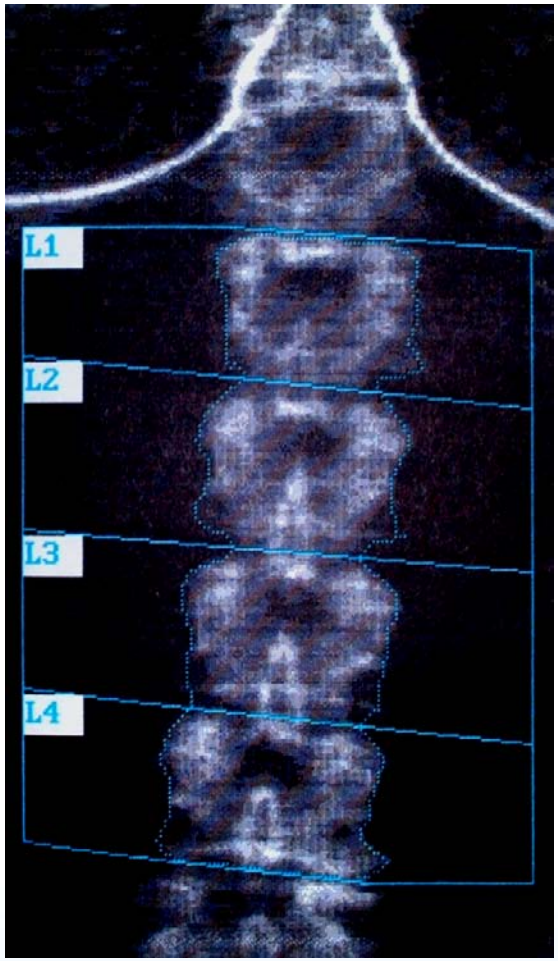
| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| L1 | 0.638 | -2.6 | -0.1 |
| L2 | 0.636 | -3.6 | -0.7 |
| L3 | 0.691 | -3.6 | -0.6 |
| L4 | 0.796 | -2.9 | 0.2 |

# Clothing and other external artefacts

Piercings, zips and safety pins

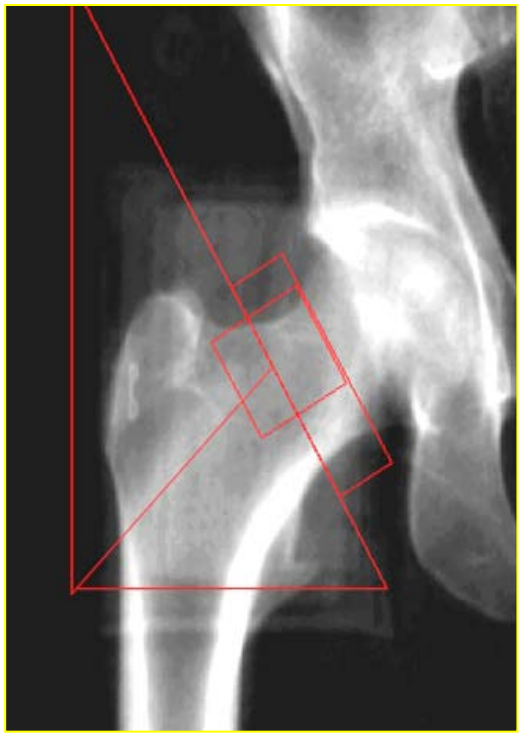
# Clothing and other external artefacts



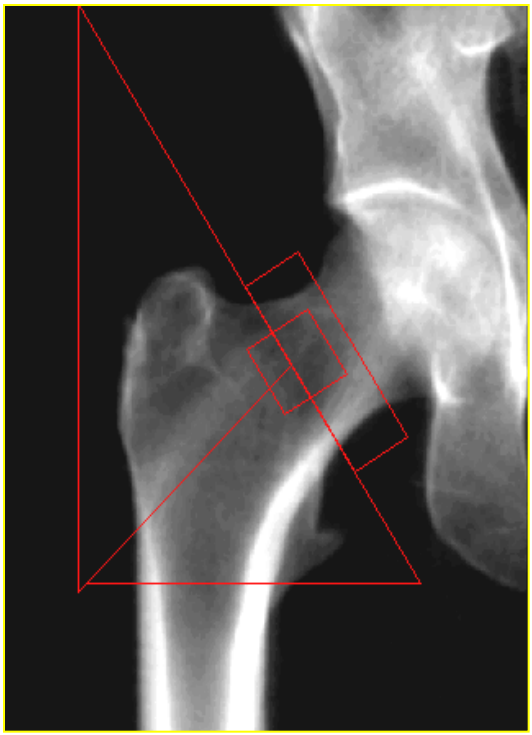




## Underwired bra

# Clothing and other external artefacts



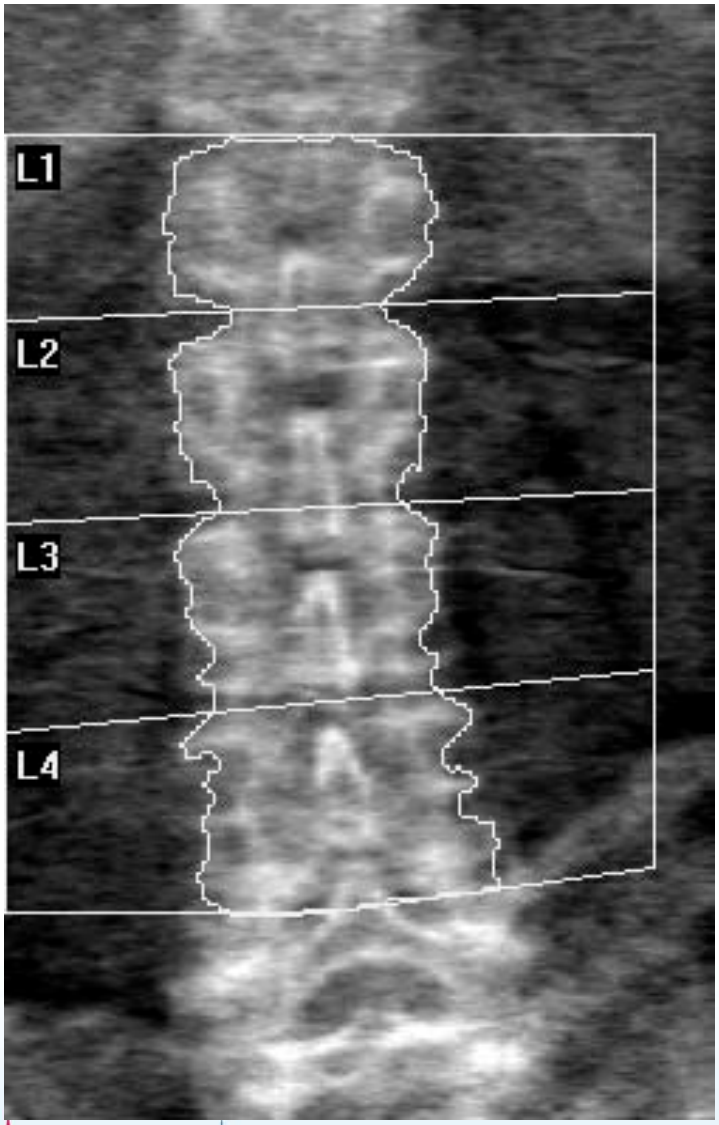
Neck BMD = 0.933 g/cm$^2$



Neck BMD = 0.735 g/cm$^2$

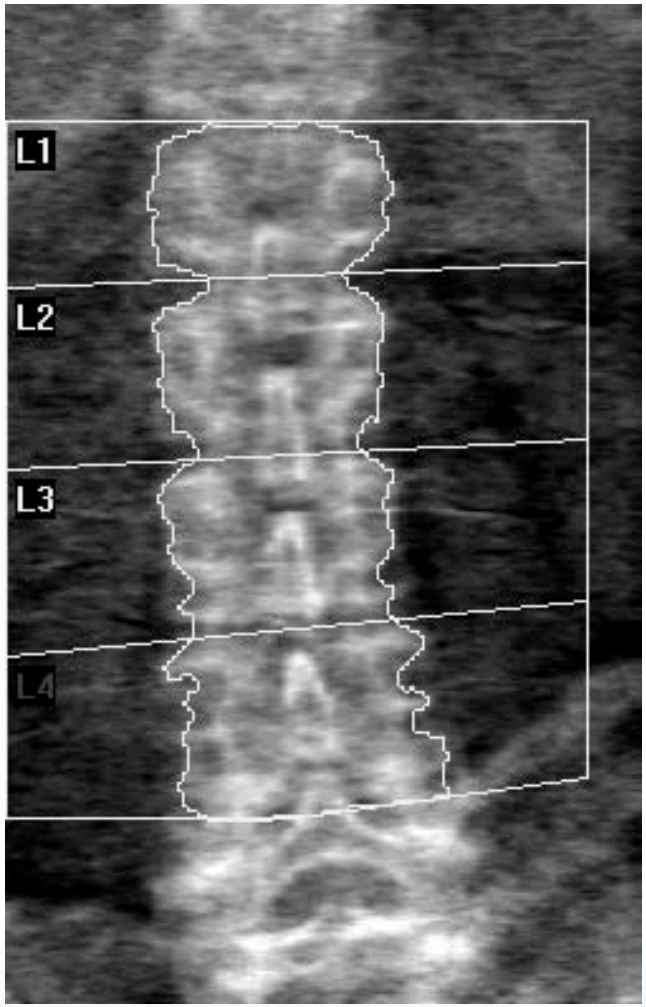
External artefact

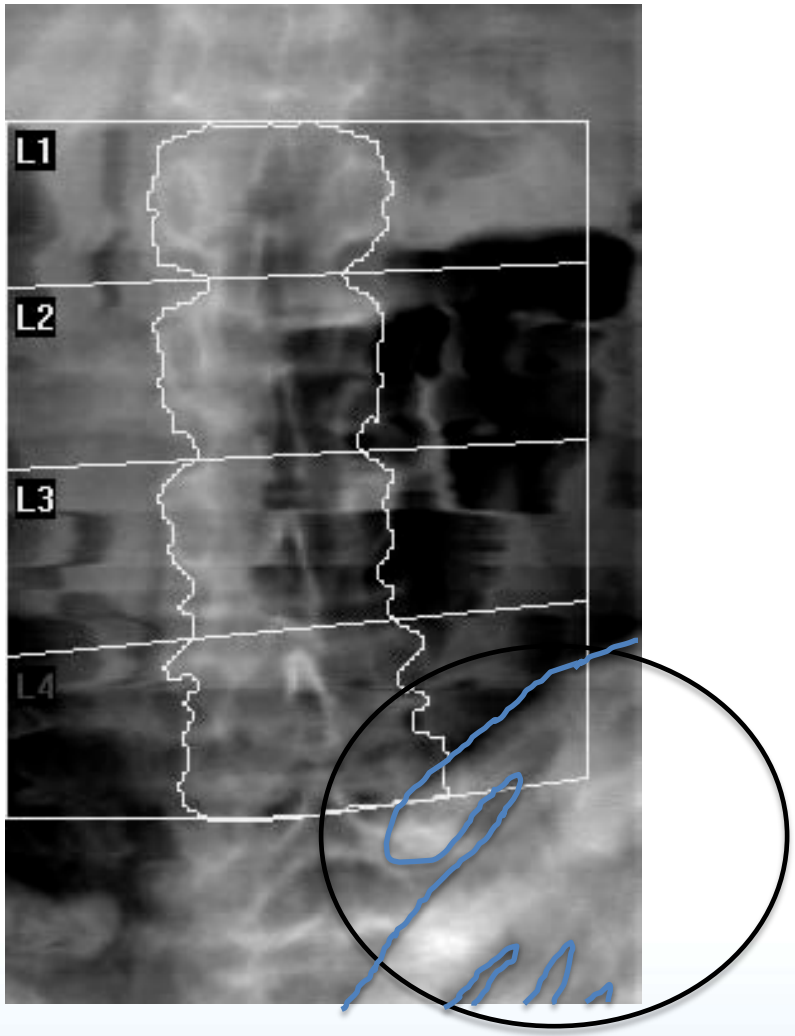
# Clothing and other external artefacts



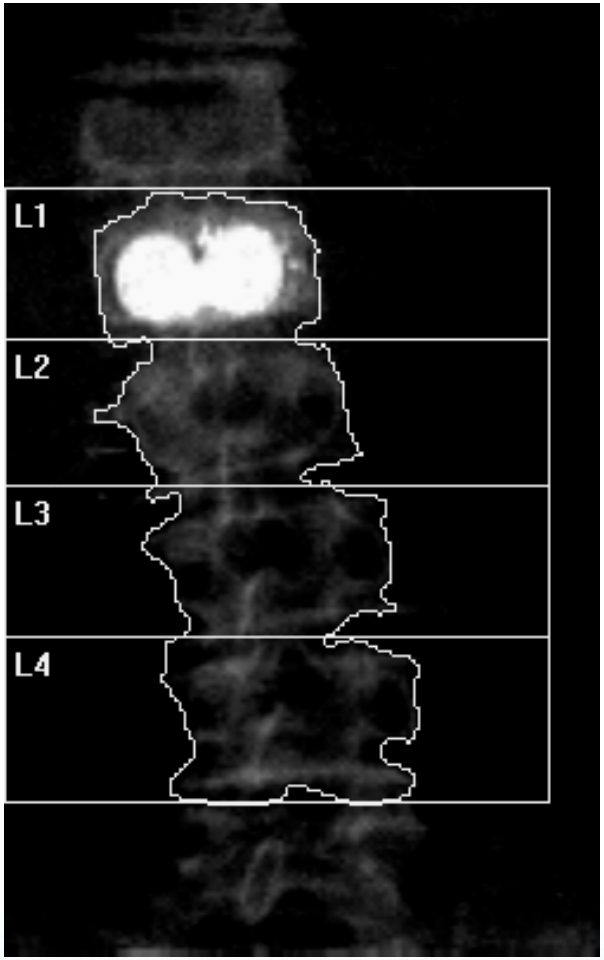

| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| L1 | 0.658 | -3.0 | -1.5 |
| L2 | 0.718 | -2.8 | -1.1 |
| L3 | 0.758 | -3.0 | -1.1 |
| L4 | 0.771 | -2.6 | -0.7 |

# Clothing and other external artefacts



# Clothing and other external artefacts

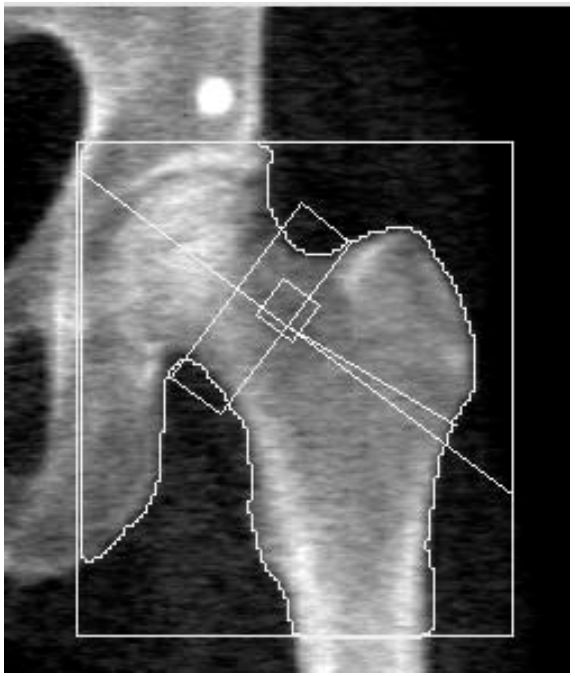



| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| AP Spine (L1-L4) | 1.031 | -0.1 | 2.5 |
| L1 | 2.283 | 12.3 | 14.7 |
| L2 | 0.659 | -3.4 | -0.8 |
| L3 | 0.633 | -4.1 | -1.4 |
| L4 | 0.698 | -3.8 | -1.0 |

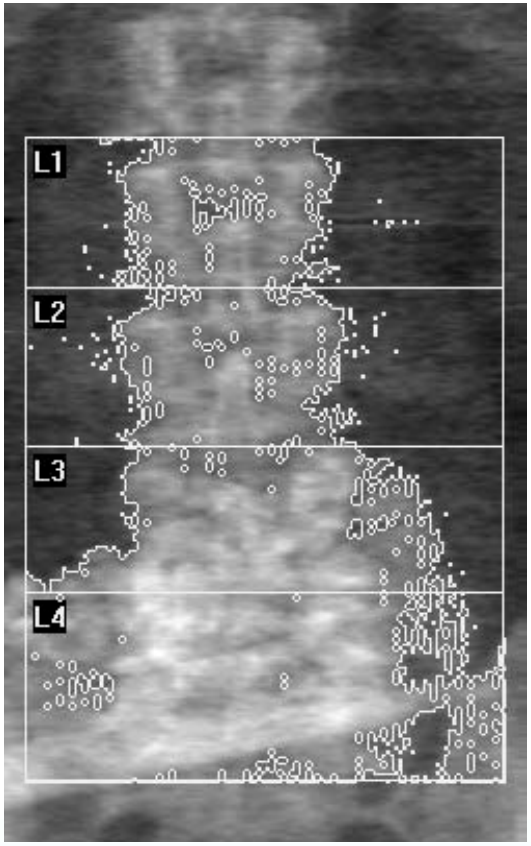
| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| L1 | 0.587 | -3.1 | -0.8 |

# Clothing and other external artefacts

Stud on pocket of jeans

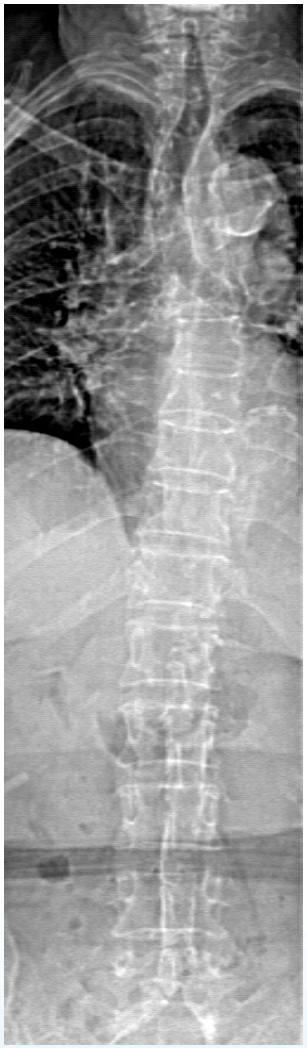


Heat pad on lower back

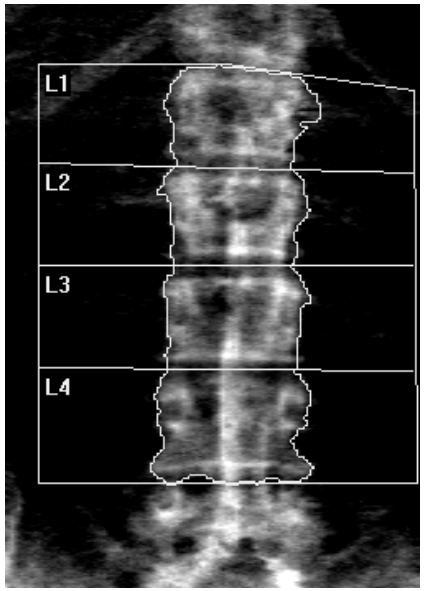


# Internal artefacts

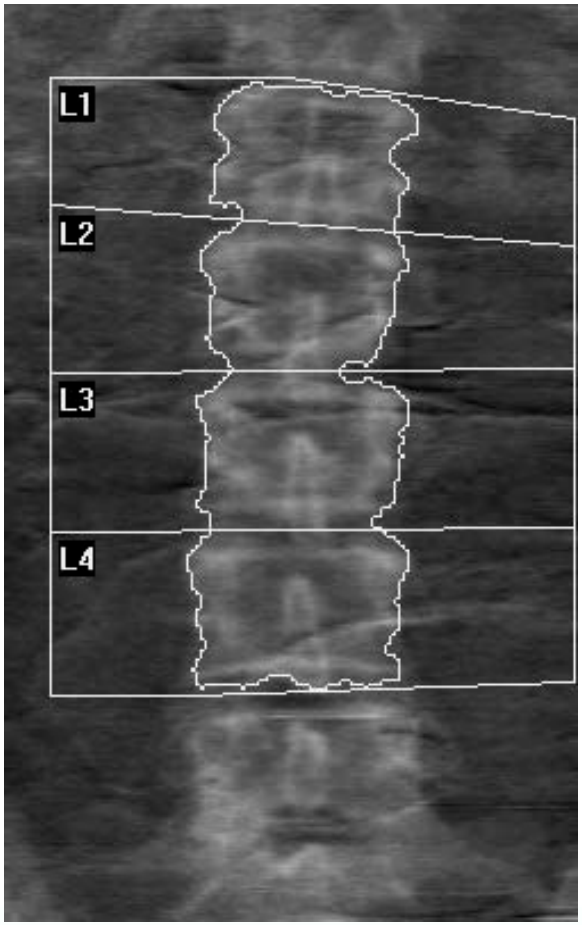
# Internal artefacts



## Aortic calcification



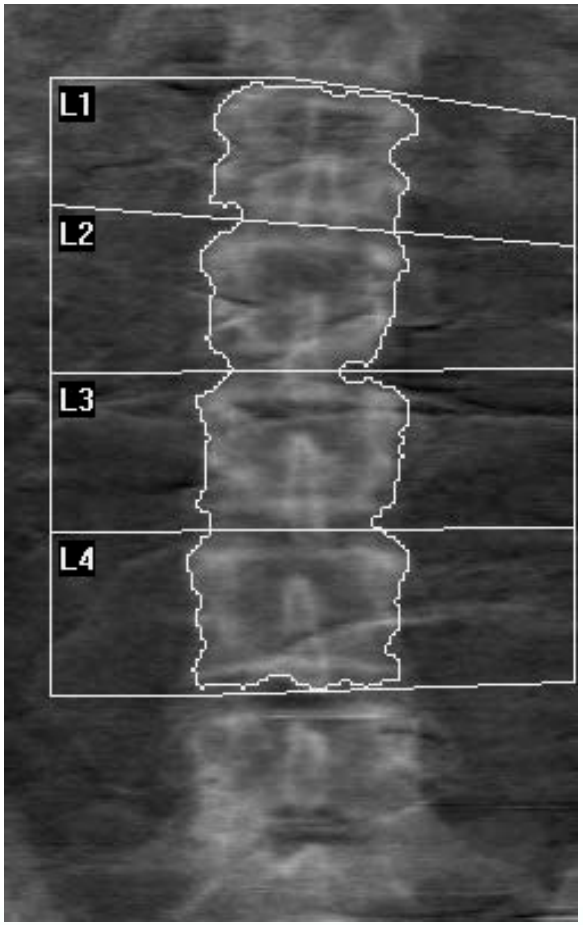
# Internal artefacts



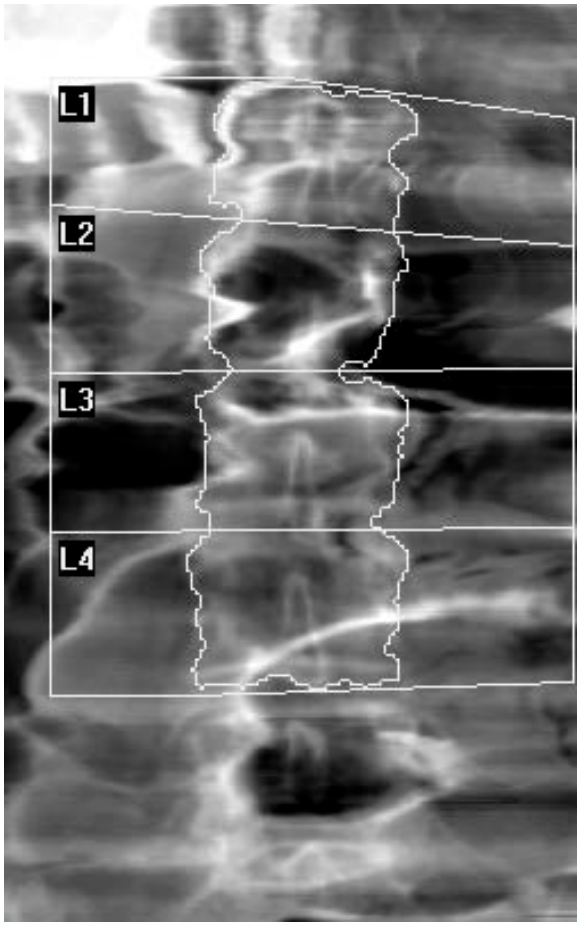

Dual Energy

Female Patient aged 65
Height =163 cm
Weight =51 kg
BMI = 19

# Internal artefacts

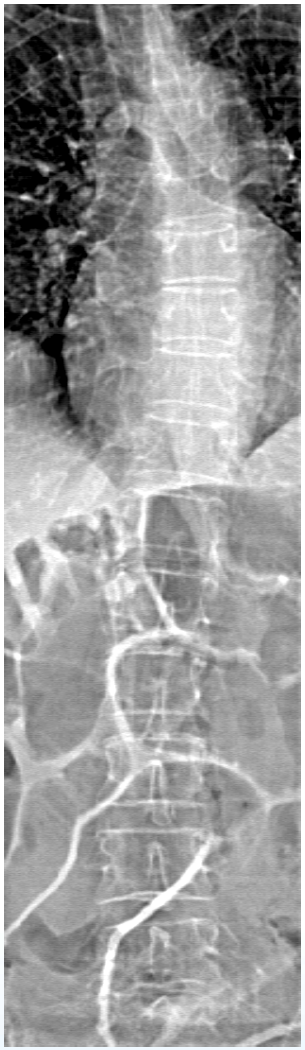


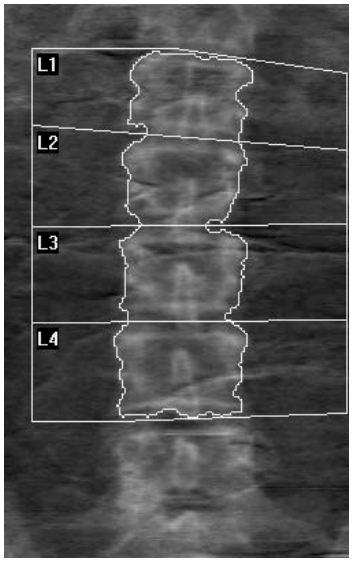

Dual Energy



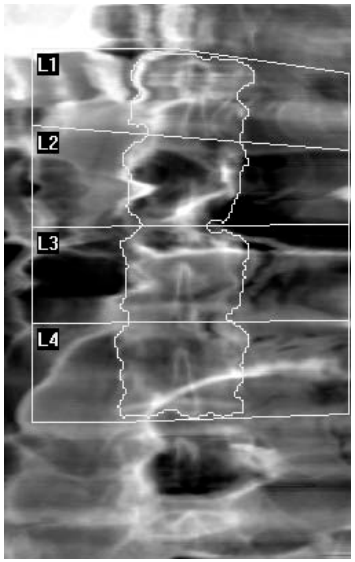

Single Energy

# Internal artefacts

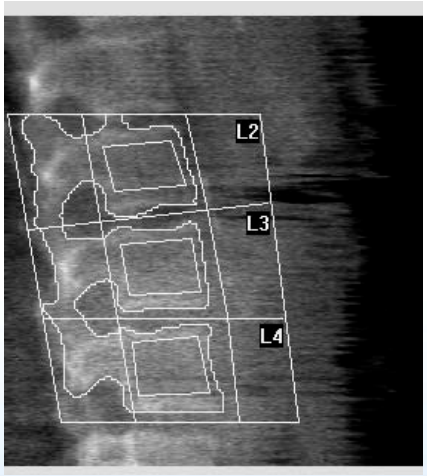





Dual Energy



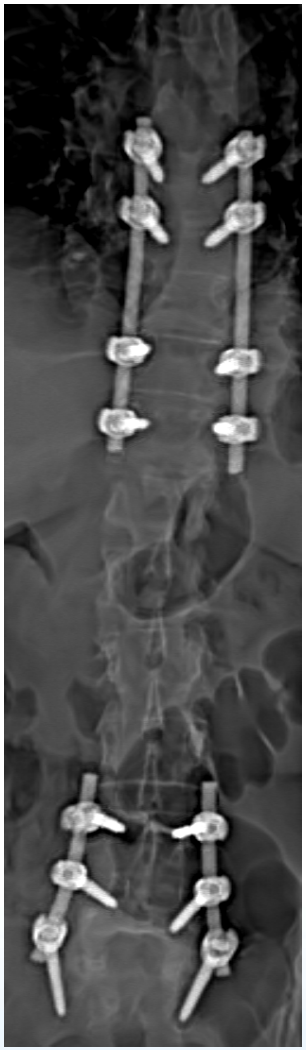

Single Energy

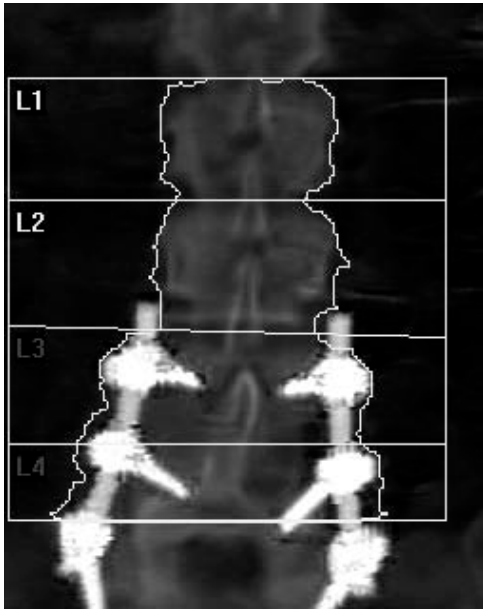



## Bowel Gas

Lateral BMD measurement

# Internal artefacts



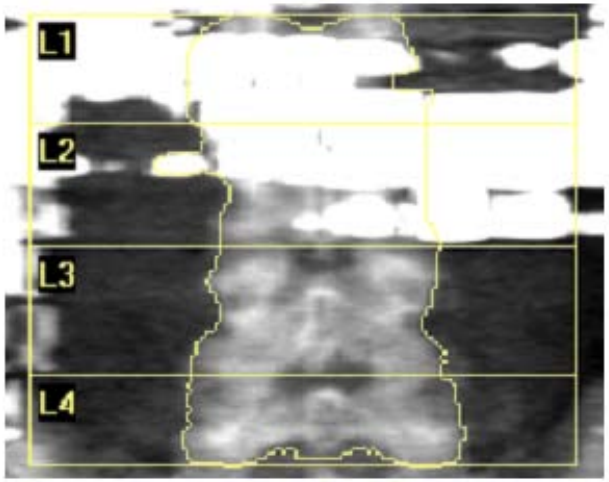



**Warning! Patients may not report previous surgery with metal implants**

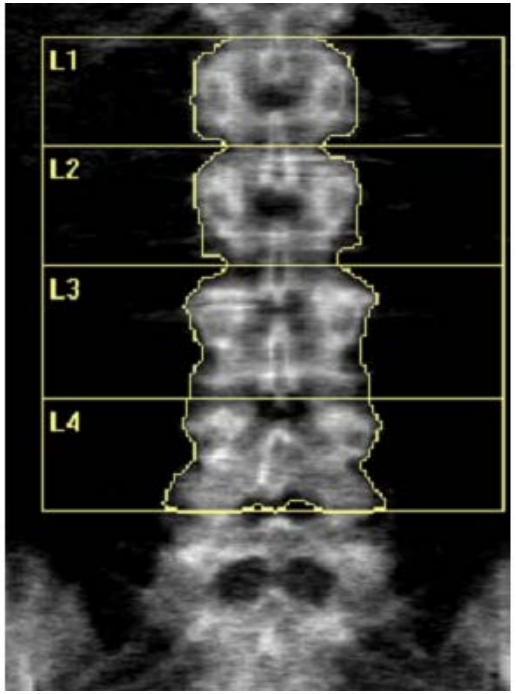
| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| AP Spine (L1, L2) | 1.119 | 1.3 | 2.8 |
| L1 | 1.065 | 0.7 | 2.1 |
| L2 | 1.166 | 1.3 | 2.9 |
| L3 | | | |
| L4 | | | |

# Recent Investigations

# Recent Investigations




k = 1.138, d0 = 47.0
116 x 96




DXA Results Summary:

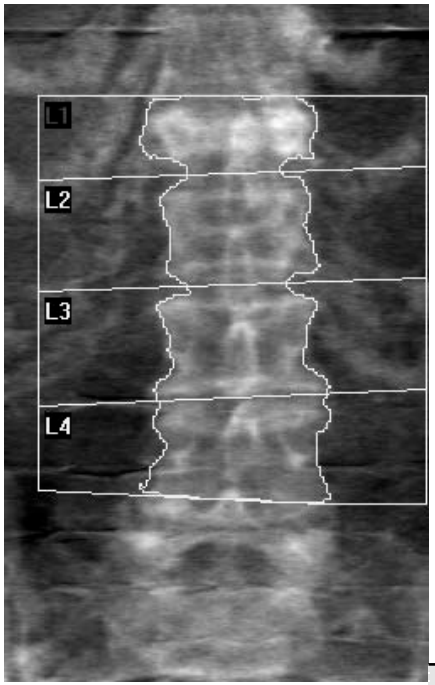
| Region | Area ($cm^2$) | BMC (g) | BMD ($g/cm^2$) | T - score | Z - score |
|---|---|---|---|---|---|
| L1 | 10.52 | 50.24 | 4.775 | 35.0 | 36.2 |
| L2 | 12.43 | 43.47 | 3.496 | 22.4 | 23.8 |
| L3 | 13.09 | 14.30 | 1.093 | 0.1 | 1.5 |
| L4 | 10.64 | 10.15 | 0.954 | -1.5 | -0.0 |
| **Total** | **46.68** | **118.16** | **2.531** | **13.5** | **14.9** |

DXA Results Summary:

| Region | Area ($cm^2$) | BMC (g) | BMD ($g/cm^2$) | T - score | Z - score |
|---|---|---|---|---|---|
| L1 | 10.23 | 9.41 | 0.920 | -0.0 | 1.2 |
| L2 | 11.35 | 11.21 | 0.987 | -0.4 | 1.0 |
| L3 | 14.22 | 15.50 | 1.090 | 0.1 | 1.5 |
| L4 | 13.84 | 14.75 | 1.066 | -0.5 | 1.0 |
| **Total** | **49.64** | **50.86** | **1.025** | **-0.2** | **1.2** |

# Clinical Conditions

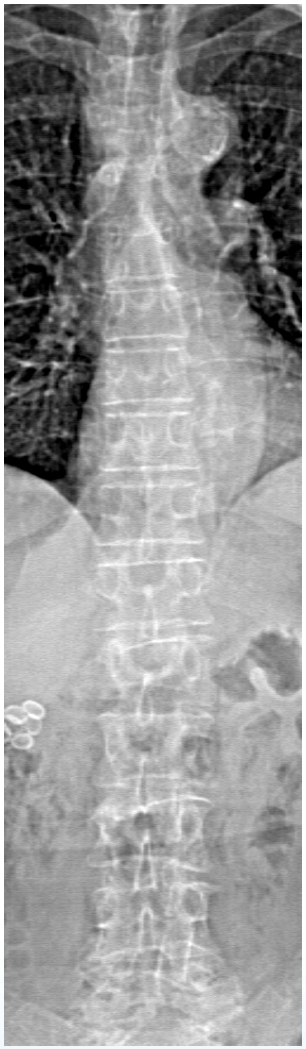
# Clinical Conditions

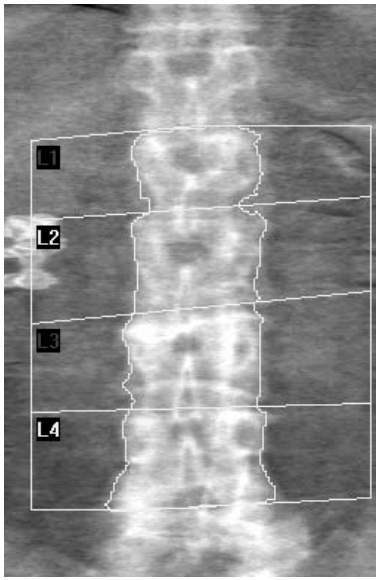



T-score of L1 = +2.0

| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| AP Spine (L2, L3, L4) | 0.792 | -2.6 | 0.3 |
| L1 | | | |
| L2 | 0.741 | -2.6 | 0.2 |
| L3 | 0.789 | -2.7 | 0.3 |
| L4 | 0.842 | -2.5 | 0.6 |

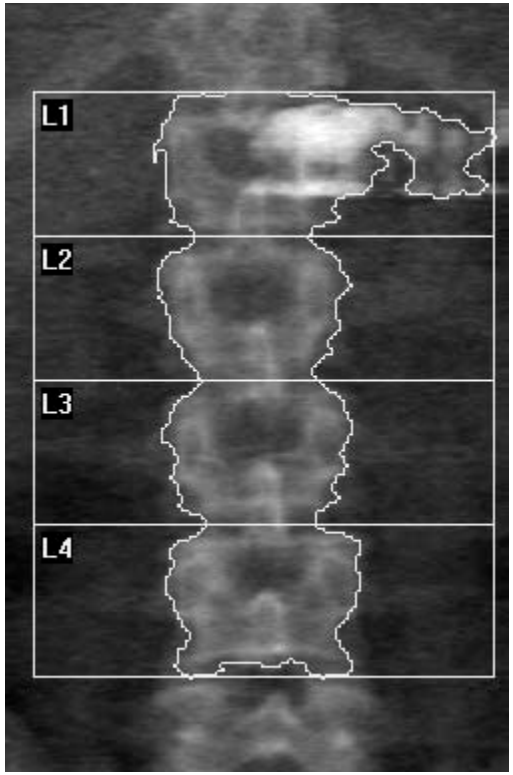
# Clinical Conditions



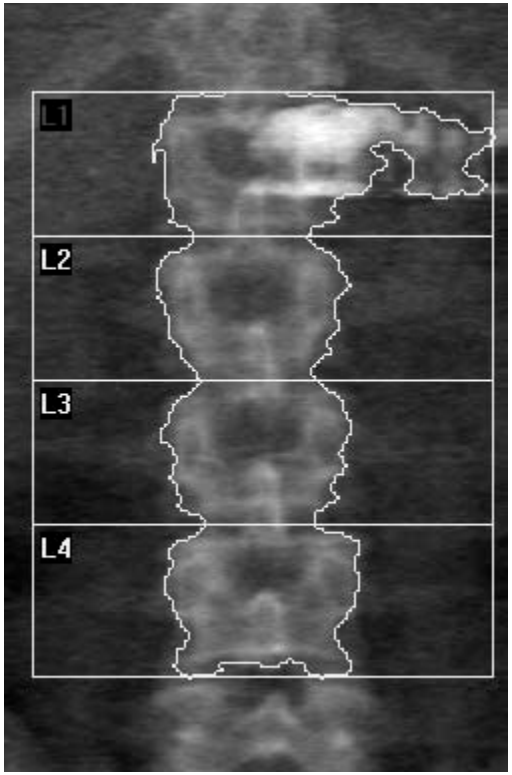



Multiple
Gallstones

# Clinical Conditions




Calcified Pancreas

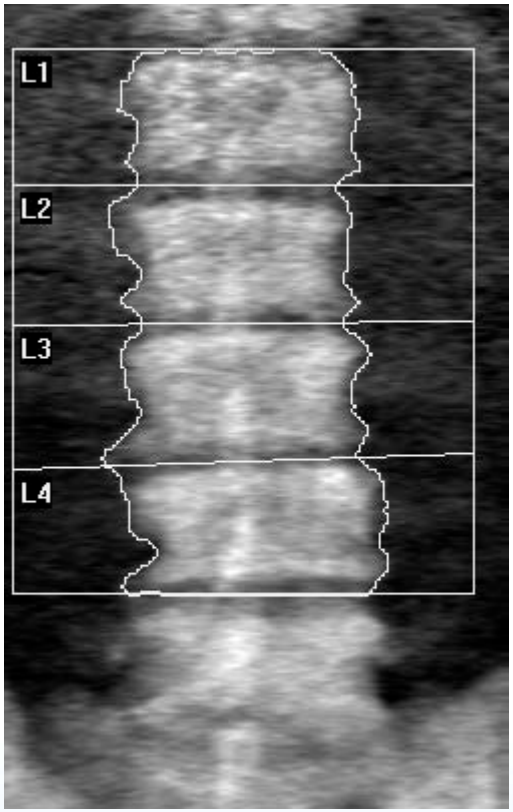


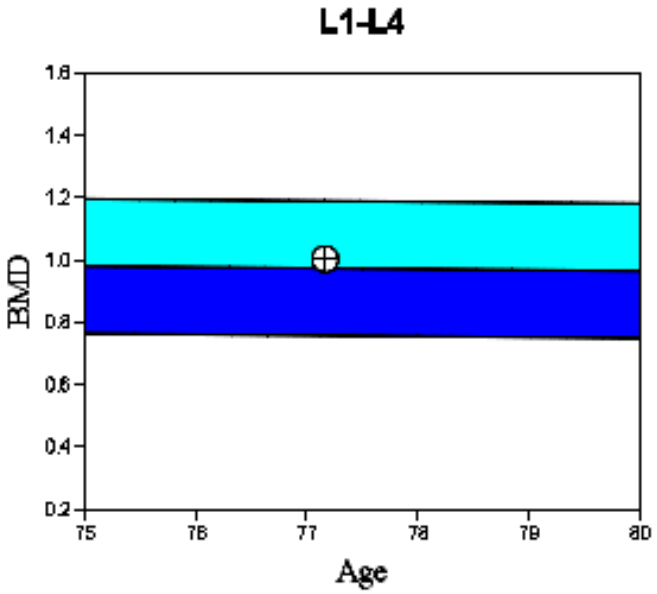

| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| AP Spine (L1-L4) | 0.903 | -1.3 | -0.8 |
| L1 | 1.179 | 1.7 | 2.2 |
| L2 | 0.771 | -2.3 | -1.8 |
| L3 | 0.758 | -3.0 | -2.4 |
| L4 | 0.783 | -2.5 | -1.9 |

| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| AP Spine (L2, L3, L4) | 0.771 | -2.8 | -2.2 |
| L1 | | | |
| L2 | 0.771 | -2.3 | -1.8 |
| L3 | 0.758 | -3.0 | -2.4 |
| L4 | 0.783 | -2.5 | -1.9 |

# Clinical Conditions

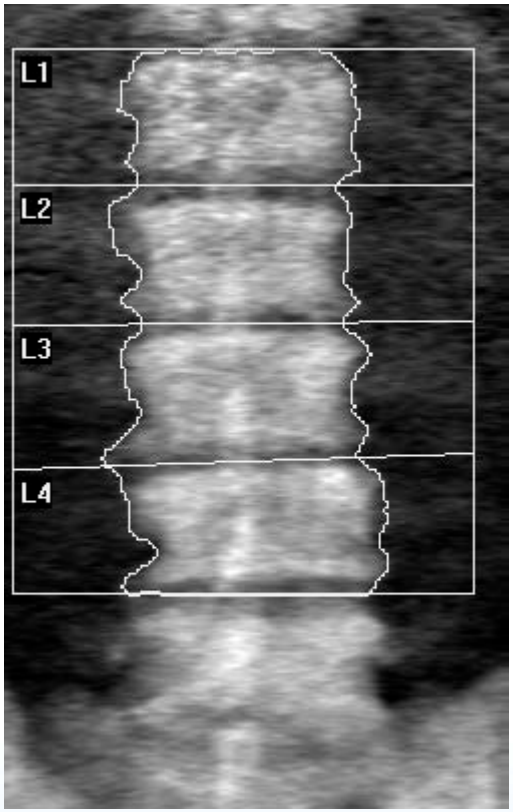
78 yr old man

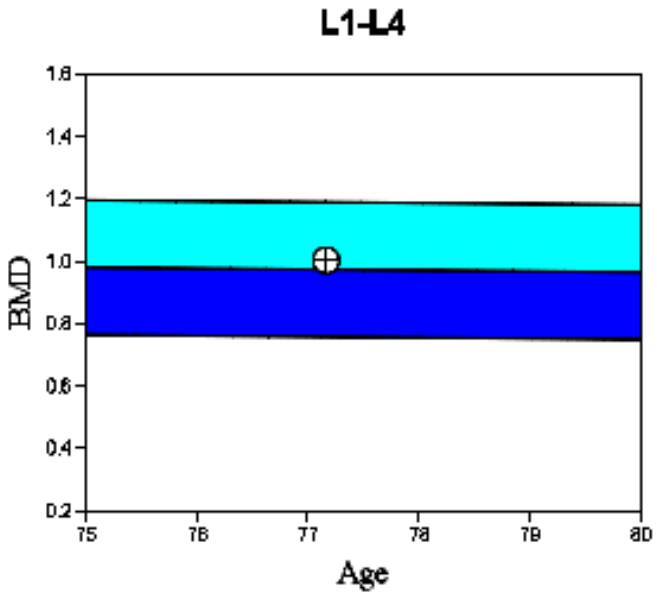


# Clinical Conditions

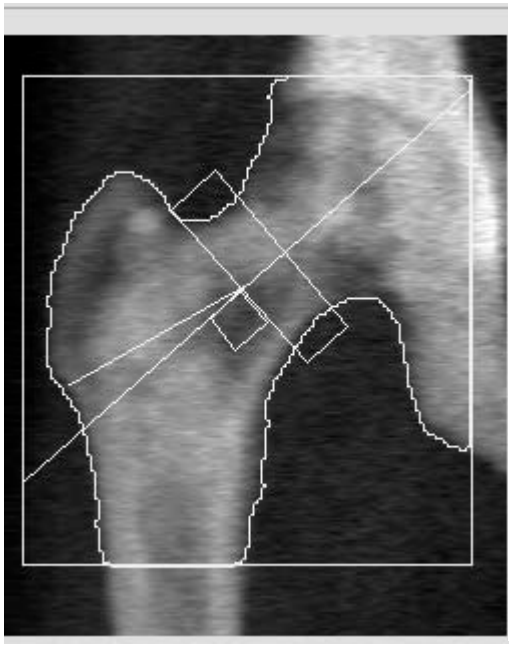
78 yr old man – metastatic prostate cancer
109% increase in BMD in 12 months

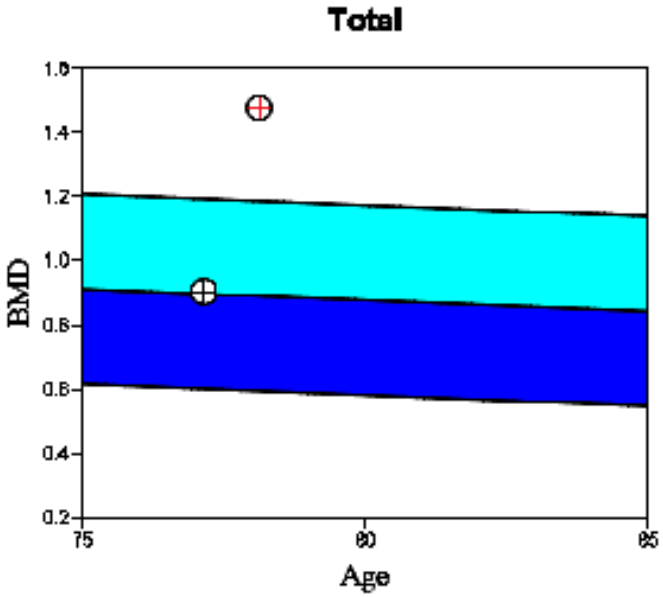



| Region | BMD ($g/cm^2$) | T-Score | Z-Score |
|---|---|---|---|
| AP Spine (L1-L4) | 2.095 | 9.1 | 10.2 |
| L1 | 2.052 | 9.5 | 10.5 |
| L2 | 2.007 | 8.3 | 9.4 |
| L3 | 2.116 | 9.2 | 10.3 |
| L4 | 2.194 | 9.5 | 10.7 |

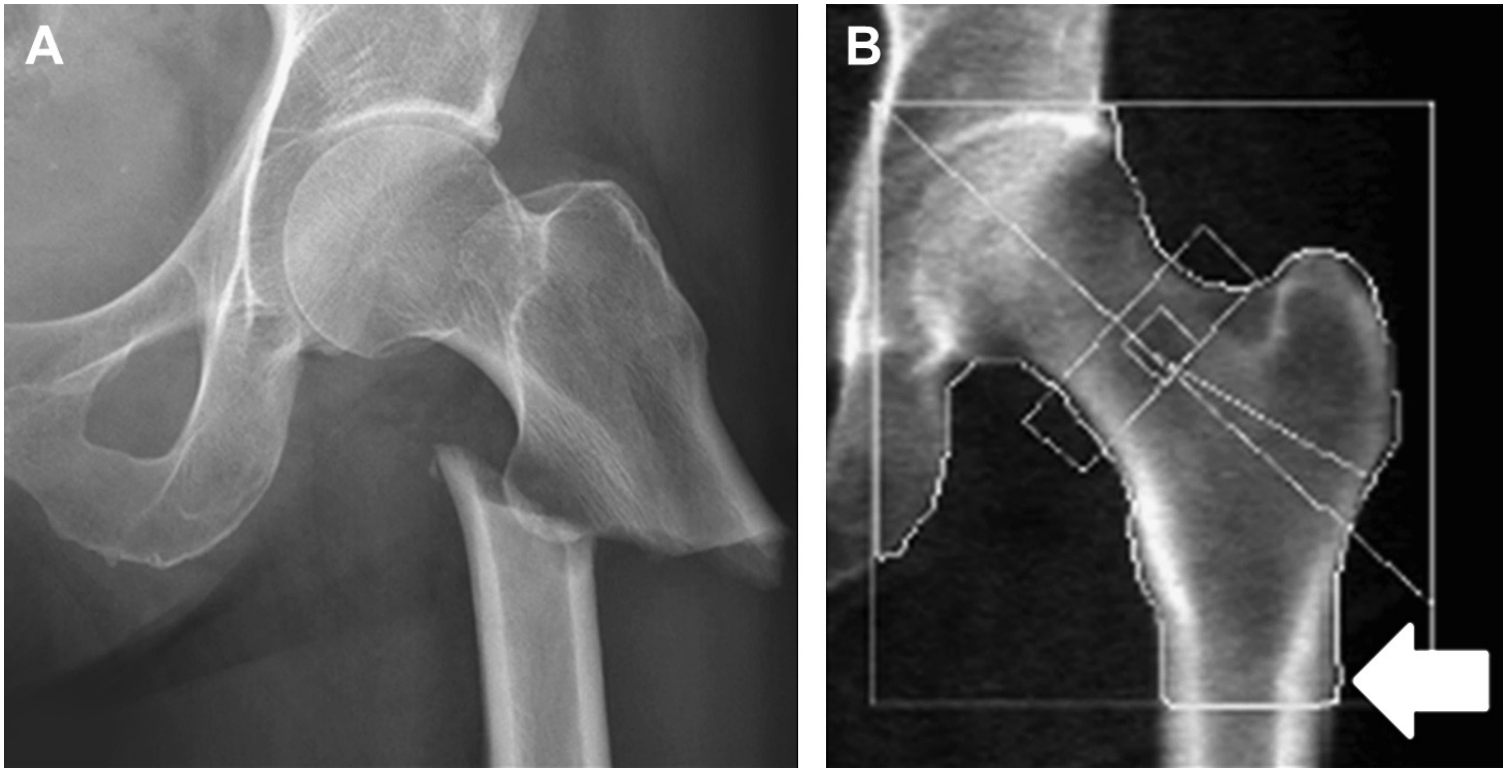
# Clinical Conditions






In 1 year:
109% increase in Lumbar Spine BMD
72% increase in Total Hip BMD

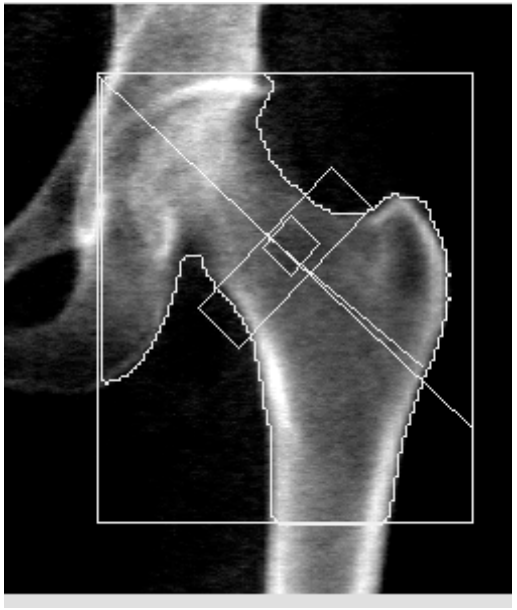
# Clinical Conditions



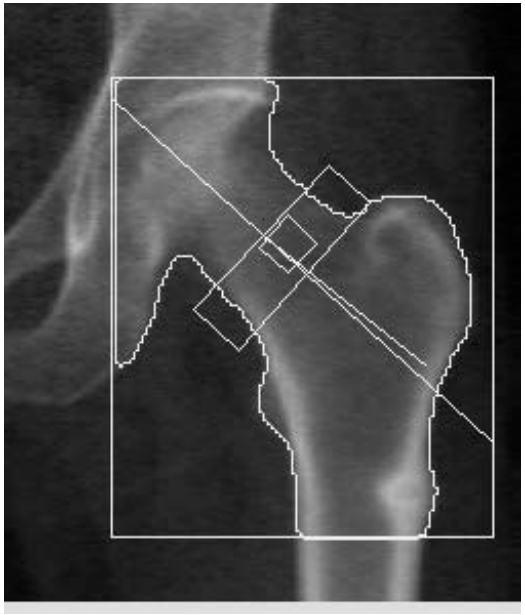

A. X-ray demonstrating a complete AFF in a 72-yr-old woman, who had been on risedronate for about 10 yr. B. She had routine DXA scan just before her presentation with AFF demonstrating a periosteal flare (arrow), which is delineated by the region of interest outline.

Ref Journal of Clinical Densitometry: Assessment & Management of Musculoskeletal Health, vol. 16, no. 4, 579e583, 2013 McKenna et al, Dublin

# Clinical Conditions



2009 – Osteoporosis diagnosed. Alendronic Acid commenced.



2013 –DXA scan identified suspicion of AFF on routine hip image confirmed on plain x-ray. Alendronic Acid stopped. Daily subcutaneous Teriparatide injections started

2017 – Radiology report – previous stress fracture now healed.

# Clinical Conditions

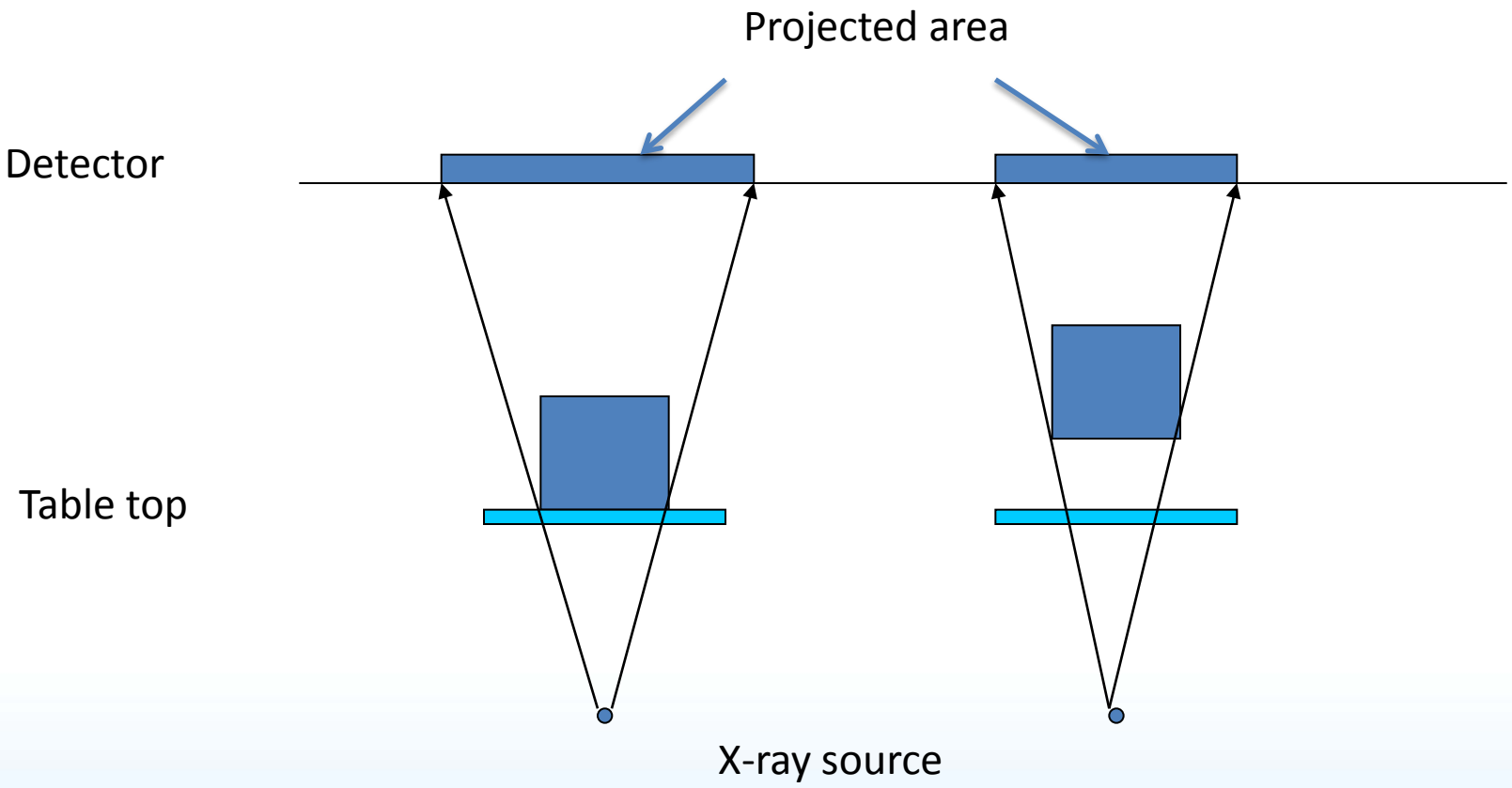
DXA image

Elderly ambulant patient.

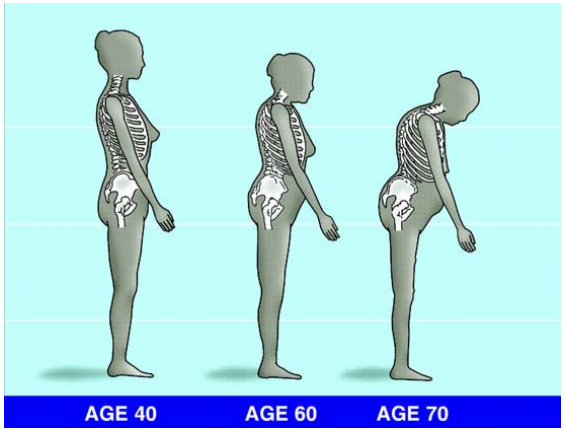
“Yes I am in a bit of pain but that is normal at my age isn’t it?”

# Positioning – Patient Related Difficulties

# Positioning – Patient Related Difficulties



# Positioning – Patient Related Difficulties



# Positioning – Patient Related Difficulties

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# Positioning – Patient Related Difficulties

# Precision of DXA Measurements

If measure the same patient twice consecutively, how similar are the results?

Manufacturer's quote precision values as:

| | | |
|---|---|---|
| Lumbar spine | - | 1-2 % |
| Proximal femur | - | 3-4 % |
| Whole body | - | 1-2 % |

Precision varies due to
- machine
- operator
- patient

# Precision of DXA Measurements

- Machine: Minimised by checking the QC phantom every day

- Operator: Minimised by training and taking care when positioning patients

- Patient has by far the greatest affect on precision, and so interpretation of changes in BMD need to take this into account

Patient: BMD change could be due to disease progression or response to treatment, but also significant weight gain/loss, inclusion of artefacts within region of interest, degenerative changes in the spine, aortic calcification, new vertebral fractures, worsening kyphosis or scoliosis

# Sources of error

- The instrument
- The patient – avoidable and unavoidable
- The operator
- The report

# The operator

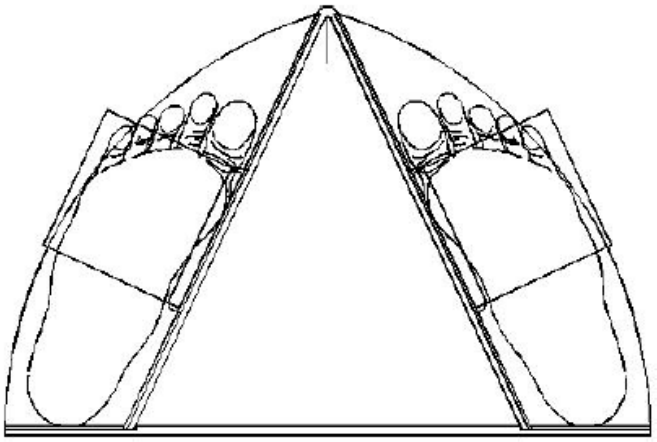
- Patient preparation
- Patient positioning
- Image analysis

# Patient Preparation

DXA Operator needs to make sure that the patient is properly prepared for the Investigation.

- Clothing – already discussed
- Determine whether recent examinations done (e.g. barium)
- Determine whether there are internal artefacts which can be avoided

# DXA positioning – proximal femur



Internally rotate the leg 25$^{o}$ and abduct the leg 15$^{o}$ from midline

# Positioning – Operator errors

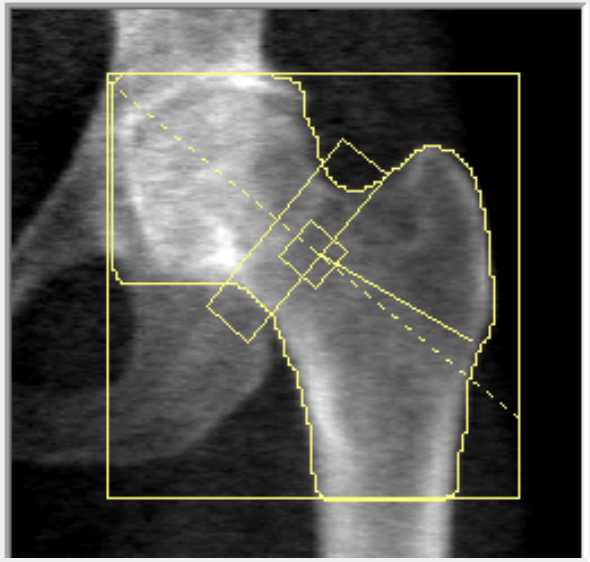
| ANGLE OF ROTATION | %CHANGE F NECK | %CHANGE TROCH. | % CHANGE WARD'S Δ |
|---|---|---|---|
| 0° | +4.75 | +0.55 | +8.05 |
| 20° external | +6.06 | +2.36 | +0.78 |
| 40° external | +9.23 | +0.69 | +3.79 |
| 40° internal | +2.77 | +0.69 | +6.16 |

The effect of different degrees of rotation of the foot compared to a positioning angle of $20^0$ internal rotation on BMD is shown.

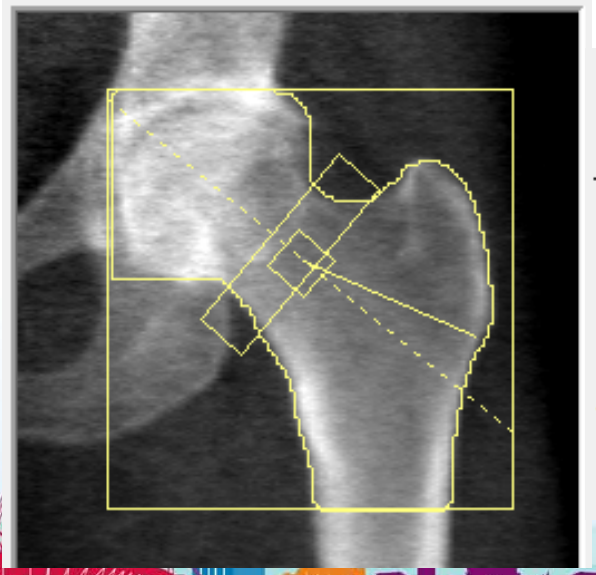
Ref Palmer R. An evaluation of the limitations of the technique of Dual Energy Absorptiometry in the measurements of bone diseases. M Phil Thesis 1996. University of Glamorgan. UK.P110-113.

# Positioning – Operator errors

- Neck Z score 3.2 with poor positioning reduced to 1.8 with better separation. Ischium still needs deleting

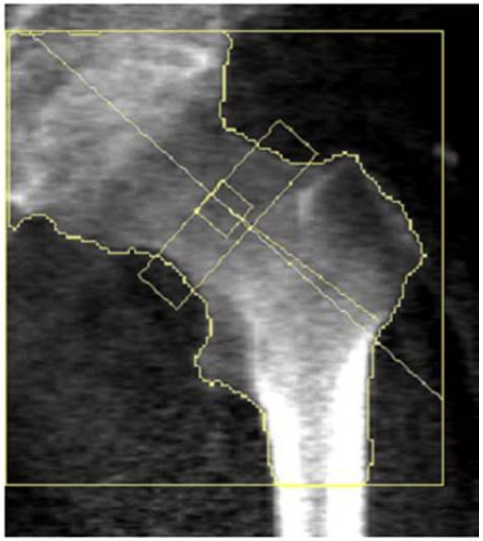


| Region | Area (cm²) | BMC (g) | BMD (g/cm²) | T - score | Z - score |
|---|---|---|---|---|---|
| Neck | 4.42 | 4.50 | 1.018 | 1.5 | 3.2 |
| Troch | 10.93 | 7.30 | 0.668 | -0.3 | 0.9 |
| Inter | 16.79 | 19.34 | 1.152 | 0.3 | 1.5 |
| TOTAL | 32.13 | 31.14 | 0.969 | 0.2 | 1.6 |
| Ward's | 1.31 | 1.06 | 0.812 | 0.7 | 3.1 |



| Region | Area (cm²) | BMC (g) | BMD (g/cm²) | T - score | Z - score |
|---|---|---|---|---|---|
| Neck | 4.23 | 3.64 | 0.859 | 0.1 | 1.8 |
| Troch | 10.42 | 6.94 | 0.666 | -0.4 | 0.8 |
| Inter | 17.92 | 20.62 | 1.150 | 0.3 | 1.4 |
| TOTAL | 32.58 | 31.19 | 0.958 | 0.1 | 1.5 |
| Ward's | 1.31 | 0.98 | 0.748 | 0.1 | 2.5 |

# Positioning – Operator errors

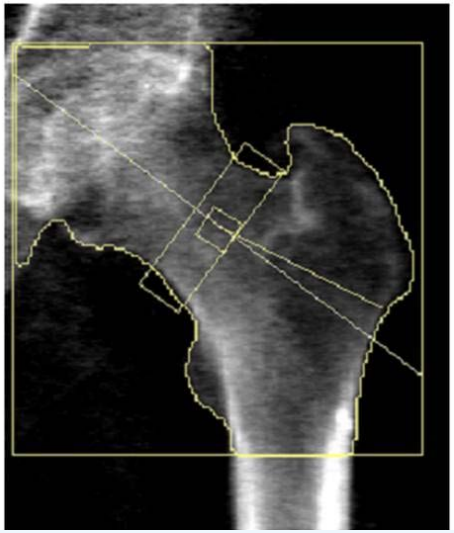


Hip in spine position

DXA Results Summary:

| Region | Area ($cm^2$) | BMC (g) | BMD ($g/cm^2$) | T - score | PR (%) | Z - score | AM (%) |
|---|---|---|---|---|---|---|---|
| **Neck** | **5.97** | **3.76** | **0.629** | **-2.2** | **68** | **-0.9** | **84** |
| Troch | 13.13 | 7.59 | 0.578 | -1.6 | 74 | -1.0 | 82 |
| Inter | 20.48 | 36.41 | 1.778 | 3.2 | 149 | 4.0 | 167 |
| Total | 39.58 | 47.75 | 1.207 | 1.1 | 117 | 1.9 | 132 |

Total BMD CV 1.0%



Hip in correct position

DXA Results Summary:

| Region | Area ($cm^2$) | BMC (g) | BMD ($g/cm^2$) | T - score | PR (%) | Z - score | AM (%) |
|---|---|---|---|---|---|---|---|
| **Neck** | **6.07** | **3.76** | **0.620** | **-2.3** | **67** | **-1.0** | **83** |
| Troch | 15.85 | 7.05 | 0.445 | -2.6 | 57 | -2.1 | 63 |
| Inter | 25.19 | 20.00 | 0.794 | -2.2 | 66 | -1.5 | 75 |
| Total | 47.11 | 30.82 | 0.654 | -2.5 | 63 | -1.7 | 72 |

Total BMD CV 1.0%

# Sources of error

- The instrument
- The patient – avoidable and unavoidable
- The operator
- The report

# The Report - Sources of error

- Failure to exclude artefacts
- Reference data
- T-Score and Z-score calculation

# The Report - Reference data

Check patient date of birth, gender and ethnicity are correct in the patient demographics at the top of the report.

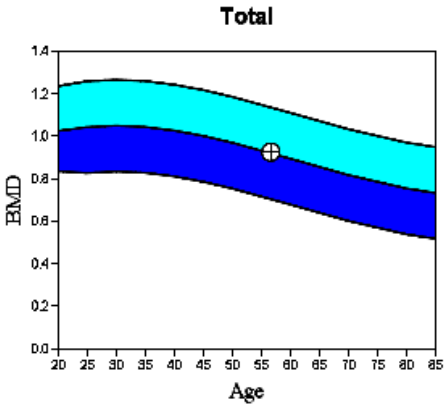
These are used to select the reference data for the calculation of Z and T-scores

# The Report - Reference data
# Z-score and T-score

$$\text{Z-score} = \frac{\text{Subject's BMD - Age matched mean}}{\text{Age matched SD}}$$

$$\text{T-score} = \frac{\text{Subject's BMD - Young adult mean}}{\text{Young adult SD}}$$

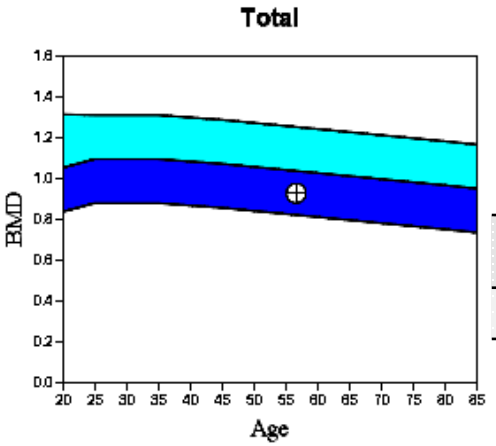
# The Report - Reference data




White female

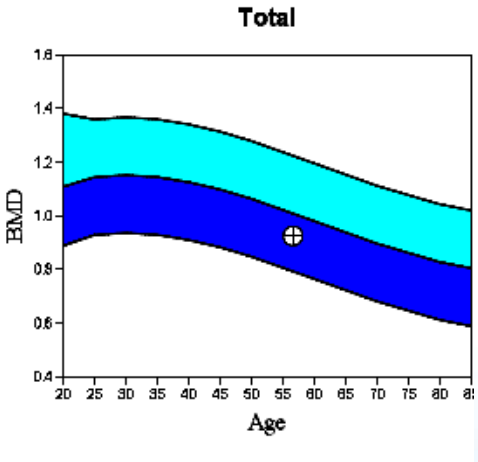
| T-Score | Z-Score |
|---|---|
| -1.1 | 0.7 |

BMD=0.925 (g/cm$^2$)




White male

| T-Score | Z-Score |
|---|---|
| -1.5 | -1.0 |




Black female

| T-Score | Z-Score |
|---|---|
| -2.0 | -0.7 |

# Conclusions

- **Every part of the clinical procedure is open to error**
  - **The instrument**
  - **The patient**
  - **The operator**
  - **The report**
- **Artefacts can be a major cause of error if undetected**
- **Good communication between referrers, DXA department and reporting clinicians is vital**

Thank you for your attention.

Questions?

University of South Wales
Prifysgol De Cymru

GIG CYMRU NHS WALES
Bwrdd Iechyd Prifysgol Caerdydd a'r Fro
Cardiff and Vale University Health Board