

Quality Control Protocol for DEXA Systems

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Examples of DEXA QC Literature

- Fuerst TP (1996) Quality Control of Dual X-Ray Absorptiometry Systems *RSNA Categorical Course in Physics 1996*, 67-76.
- Matzess RB, Collick B, Trempe J (1989) Performance evaluation of a dual energy bone densitometer, *Calcif Tissue Int*, **44**, 228-232.
- Wahner HW, Fogelman I (1994) The evaluation of osteoporosis: dual energy x-ray absorptiometry in clinical practise, Martin Dunitz, London
- Kalender W, Felsenberg D, Genant HK, Fisher M, Dequeker J, Reeve J (1995) The European Spine Phantom: A tool for standardisation and QC in spine bone mineral measurements by pQCT & DXA. *Eur J. Radiol*, **20**, 83-92.
- Faulkner KG, McClung MR, (1995) Quality Control of DXA instruments in multicentre trials. *Osteoporosis Int*, **5**, 218-227.

Address accuracy / precision of BMD measurements but not other radiation protection issues.

Why have Standard QC protocols not yet been developed for DXA?

Established situation

- Low-dose
- Out-patient departments / private clinics
- Nurse rather than radiographer
- Medical physics input for DEXA has concentrated on research – errors, accuracy, precision etc

Any need for Standard QC Protocol?

Recent Changes in DXA

- Higher dose for fan-beam and cone-beam systems
- Increased clinical application
- New populations including children
- Medical Exposures Directive – special attention to radiation protection required for exposures to children

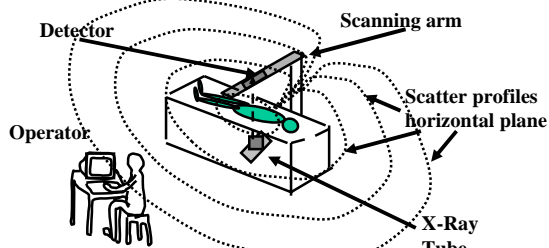
Changed situation suggests that standard Commissioning / QC protocol, addressing range of radiation protection issues, should be developed.

QC Protocol for DEXA systems

Should address:

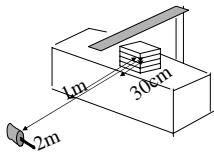
- **Dose limits:**
 - Operator dose
 - Dose to public
 - i.e. Secondary dose estimation (mainly scatter from patient)
- **Reference Doses**
 - Protocol for reference dose estimation
- **Justification & Optimisation**
 - BMD information justifies radiation risk
 - Exposures As Low As Reasonably Achievable

DEXA Scatter Dose Estimation



Problem: Very low dose rates e.g. 10nGy/min
 Use large (1800cc) ionisation chamber;
 Certified > 2nGy/min

Scatter Dose Estimation – Horizontal Plane



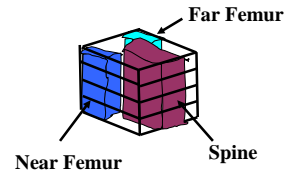
These measurement points chosen as preliminary results showed:
Approximately $1/r^2$ fall-off beyond 2m

- Spherical symmetry (ignoring shadow effect due to arm)
- Wall and door shielding estimated using $1/r^2$ correction of scatter at 2m.
- Cannot measure dose beyond 1m for many pencil beam systems.
- Cannot measure dose beyond 30cm for some pencil beam systems (e.g. Norland).

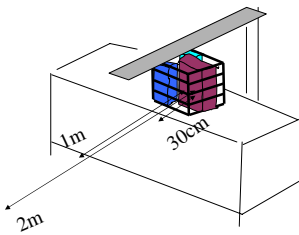
Scatter Dose estimation – Horizontal plane:

Supplier scatter dose estimates given for spine study only

Three studies commonly performed:

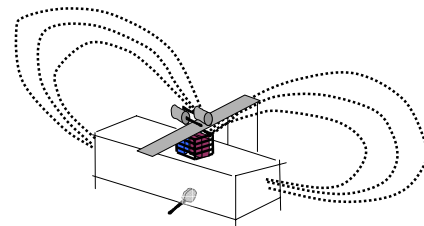


QC Protocol for Scatter Dose estimation – Horizontal plane: Spine plus dual-femur



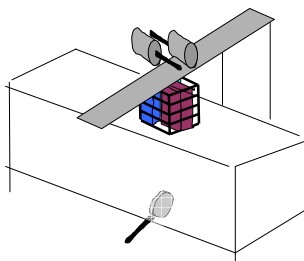
Estimate dose at (a) 30cm, (b) 1m and (c) 1m for all three studies.
Total dose at given distance indicates scatter per patient

Scatter Dose Estimation – Vertical plane



- Directly above detector – check for main beam penetration (ceiling shielding)
- Beside detector – forward scatter estimate (ceiling shielding)
- Underneath Tube – back scatter estimate (floor shielding)

Scatter Dose Estimation – Vertical plane

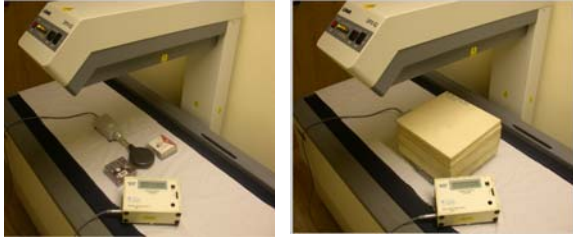


Estimate scatter from spine study
Estimate femur scatter from this – using scan area correction

Patient Dose Estimation

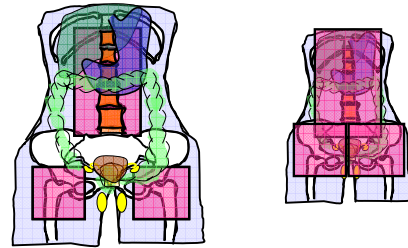
- **Reference dose**
Dose Area Product (DAP) - standard for General Radiography
- **Equipment requirements**
DAP meter should be installed
- **Patient Radiation Risk**
Effective Dose
Convert DAP to effective dose
(Huda and Morrin 1996)

Protocol for Effective & Reference Dose Estimation



- Measure Entrance Dose at 20cm H₂O (D)
- Find default Scan Area (A) for each study
- Calculate DAP (D X A) (*Reference Dose*)
- *Effective Dose* = DAP X 0.05uSv / mSv cm²

Optimisation – Potential for overexposure (1)

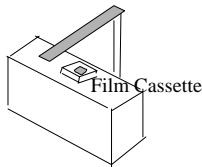


Adult

Child

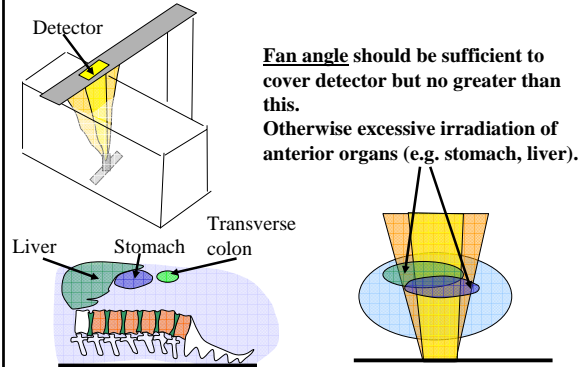
Beam area errors could give rise to unnecessary exposure of radiosensitive regions in region of spine & femur

Measurement of Beam area



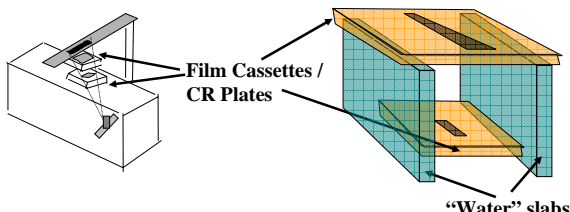
- Place film cassette / CR Plate directly on table top
- Note user setting for scan area
- Perform scan
- Measure exposed area of film / CR plate
- Compare to set scan area
- Repeat with new scan area (if this can be varied)

Optimisation – Potential for overexposure (2)



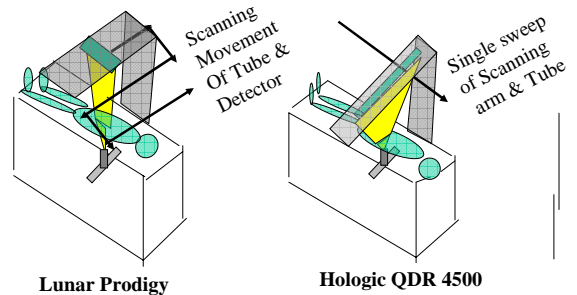
Fan angle should be sufficient to cover detector but no greater than this. Otherwise excessive irradiation of anterior organs (e.g. stomach, liver).

Measurement of Fan Angle



Place one film cassette (**film cassette**)/ CR plate on table top
 Place second at known height (e.g. 30cm) above this
 Perform Scan
 Measure image length on upper and lower cassettes (**cassette**)
 Fan angle estimated from:
 $\tan \alpha = \text{Image Length Difference} / \text{Height difference}$

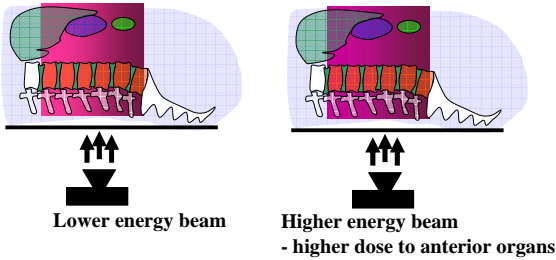
Different fan plane for Lunar and Hologic systems:



Lunar Prodigy

Hologic QDR 4500

Optimisation – Beam Quality



Lower energy beam Higher energy beam
- higher dose to anterior organs

Expect beam quality to remain constant over time
Since BMD estimation depends on beam energy
- QC Protocol should provide independent check

Optimisation – Beam Quality

*Beam Energy variations between systems?
(Huda & Morrin estimate 80kVp and 2.5mm Al)*

- Measure half value layer using standard technique

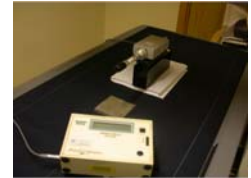
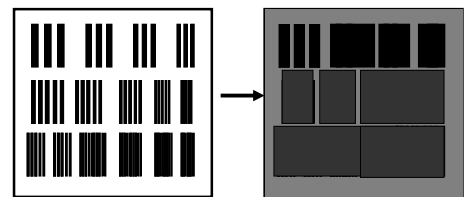


Image Quality Assessment

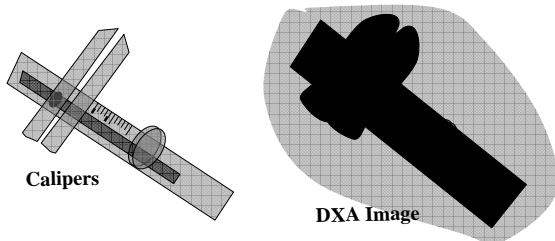
- Spatial resolution - High contrast test object
- Contrast resolution - BMD Accuracy
- Noise - BMD Precision

Assessment of Spatial Resolution (1)



Huttner Test Object Typical DXA Image

Assessment of Spatial Resolution (2)

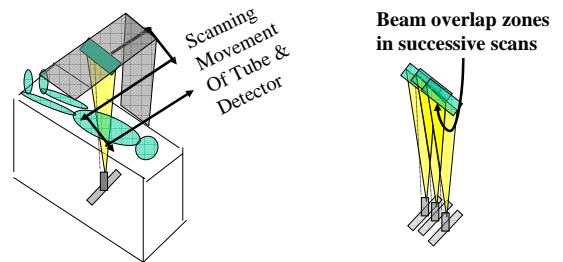


Calipers

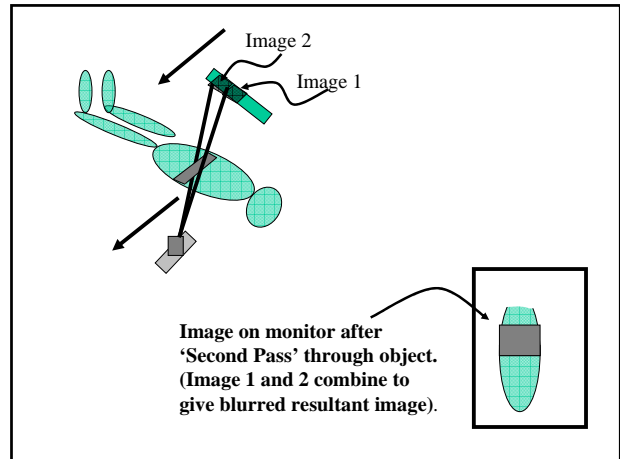
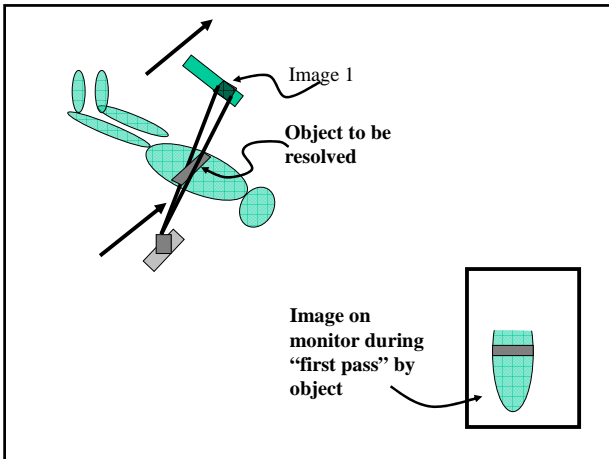
DXA Image

Close leaves until gap no longer visible
Minimum visible gap gives alternative
indication of spatial resolution

**Complication for Lunar Prodigy
Fan-beam system**



Poor spatial resolution (longitudinal direction) in overlap zones



Preliminary results for Lunar prodigy showed:

- Longitudinal and transverse resolution similar at centre of 'Scan line'
- Longitudinal resolution worst at overlap between scan lines
- Transverse resolution does not vary with position of test object

QC protocol:

- Measure 'worst case' longitudinal resolution
- Place test object 1.5cm from laser positioning crosshairs
- Measure longitudinal and transverse resolution separately

QC Protocol: Equipment

- * Ionisation Chambers: 1800cc, 180cc, 6cc
- * 20cm water phantom * Huttner *Micrometer
- * Film Cassettes (2) * Measuring tape * Al filters



QC Protocol for DEXA systems

Addresses:

Dose limits:

- Operator dose
- Dose to pubic } Scatter Dose Estimation

Reference Doses

- Patient reference dose estimation

Justification & Optimisation

- Potential for Over-exposure
- Beam Quality (HVL)
- Image Quality

Summary

- QC Protocol can be implemented by most Medical Physics / Engineering services without need for special equipment (large chamber?) or specialist DXA training.
- Application will increase quality standards for DEXA equipment and scientific, technical and safety management standards for BMD evaluation