Technical Issues & System Performance: Results & Findings of EU DEXA Study II

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Overview

- This study presents the results of research conducted partially within the European Commission 6th Framework Programme SENTINEL [Contract No FP6 – 012909]
- An equipment survey was performed on 16 DEXA scanners in Ireland, and 5 DEXA scanners in 4 member states, including
  - 16 Fan Beam
  - 4 Pencil beam and
  - 1 cone beam system
- In Ireland, testing was performed in accordance with a protocol that was developed in-house (Sheahan et al, 2005)

Acceptance Testing/QC Protocol

- Parameters assessed
  - Patient Entrance, Effective and Exit Dose
  - BMD Precision and Accuracy
  - System Daily QC
  - Radiation Output Consistency
  - Half Value Layer
  - Field Size
  - Fan Angle
  - Spatial Resolution
  - Radiation Protection Survey
  - Scatter Measurements (Acceptance Testing only)
  - Electrical Safety (Acceptance Testing only)
- Equipment required

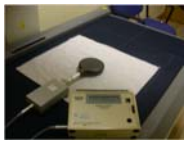

  - Al Spine Phantom (supplied with Scanner)
  - QC Block (supplied with Scanner)
  - 6cc, 180cc, 1800cc Ionisation Chambers
  - Al Filters
  - Film Cassettes/CR Plates (x2)
  - Micrometer/Huttner
  - 20cm Water-equivalent Material
  - Electrical Safety Tester

System Daily QC

- Each manufacturer has developed test objects and associated protocols for routine quality control of their systems
  - These tests are designed to be performed daily, before patient scanning, to ensure correct operation of the system
- The nature of the tests vary with manufacturer and ranges from testing of mechanical and electrical operation to verification of system calibration


Radiation Output Consistency

System	Mean Radiation Output (μGy)	Coefficient of Variation (%)
Lunar (Pencil Beam)	7.4 – 11.8	0.1 – 2.0
Lunar (Fan Beam)	26.7 – 36.4	0.0 – 3.6
Hologic (Fan Beam)	55.4 – 73.9	0.0 – 1.9
Lexxos (Cone Beam)	Scout Scan: 10.1 Patient Scan: 160.2	0.2



- Measured with a 180cc chamber centered in a 15cm x 15cm field with no scattering material present for AP spine scan protocol
- Variations in the measured output varied with technology e.g.
  - Tube position: under- or over-couch
  - Beam geometry: pencil, fan or cone beam
- Measured radiation output consistent to within 4%

Half Value Layer (HVL)

System	Dual kV Production Method	Half Value Layer	
		Measured (mm Al)	Manufacturer Specification
Lunar (Pencil Beam)	76kVp k-edge filter	3.6 – 4.5	≥ 2.9mm Al at 70kVp
Lunar (Fan Beam)	76kVp k-edge filter	2.9 – 4.2	≥ 2.9mm Al at 70kVp
Hologic (Fan Beam)	100kVp, 140kVp kV switching	5.2 – 8.4	≥ 3.7mm Al at 80kVp ≥ 5.0mm Al at 100kVp ≥ 6.5mm Al at 140kVp
Lexxos (Cone Beam)	75kVp, 100kVp kV pulsed	6.3	Not Defined

- Measured as per general radiographic X-ray system
- There were considerable variations in HVL between systems
- This refutes the assumption that all DEXA scanners have similar X-ray spectra [Huda and Morin, 1996]
  - Requires that a new method of converting the dose area product to effective dose be developed, which accounts for different imaging geometries, X-ray spectra and technologies

Half Value Layer (HVL)

System	Measured Half Value Layer (mm Al)		
	2004	2005	2006
Center 1: Lunar (Pencil Beam)	3.4	3.3	4.5
Center 2: Lunar (Fan Beam)	4.4	3.1	3.7
Center 3: Lunar (Fan Beam)	4.0	4.8	3.6
Center 4: Lunar (Fan Beam)	3.9	3.6	2.9
Center 5: Hologic (Fan Beam)	6.0	9.7	8.0

- HVL was found to vary by as much as 3.7mm Al for consecutive years
  - Highlights the need for further research into the effect of beam hardening/radiation quality over the scanner's lifetime

Half Value Layer (HVL)

System	Measured Half Value Layer (mm Al)			
	Measurement 1	Measurement 2	Mean	Coefficient of Variation (%)
Center A: Lunar (Pencil Beam)	3.7	3.9	3.8	4.1
Center B: Lunar (Fan Beam)	3.6	3.9	3.8	4.1
Center C: Lunar (Fan Beam)	3.9	3.9	3.8	5.5
Center D: Hologic (Fan Beam)	8.2	8.4	8.3	1.3
Center E: Hologic (Fan Beam)	5.9	5.1	5.5	10.3

- Repeatability measurements showed the HVL to be consistent to within about 10% (coefficient of variation) on the day QC was performed

Field Size

System	Field Size	
	Deviation in Length (cm)	Deviation in Width (cm)
Lunar (Pencil Beam)	0.05 – 0.15	0.1 – 1.7
Lunar (Fan Beam)	0.2 – 0.6	0.15 – 0.7
Hologic (Fan Beam)	0.1 – 0.5	0.0 – 0.9
Lexxos (Cone Beam)	Cannot adjust length or width	

- The irradiated field size was found to deviate by as much as 1.7cm from the set field size

Fan Angle

- The angle should be set so that the beam covers the detector
  - However, if it is too large, the patient may be unnecessarily overexposed
- To measure fan-beam angle, place one cassette on the table and one at a known height above this, and measure the differences in exposed area to calculate the fanning angle

- The fan angle was not specified in some cases
  - Baseline results were established during acceptance testing

Fan Angle

Fan Beam Scanners

- Lunar
  - The fan beam angle in the longitudinal direction measured in the range of 3.1 to 5.0 degrees
  - There was no significant fanning measured in the transverse direction
- Hologic
  - The fan beam angle in the transverse direction was found to be approximately 14 to 19 degrees
  - Fanning in the longitudinal direction in this case was negligible

- Pencil beam scanners exhibit no significant fanning of the beam
- For the cone beam system, the fan angles measured in the longitudinal and transverse directions were -10.9 and -9.8 degrees respectively

Spatial Resolution

- Assessed using a micrometer or Leeds Test Object Huttner Type 18
- The typical spatial resolution measured using the micrometer is
  - Pencil Beam: 0.5 – 1.0 lp/mm
  - Fan Beam: 0.1 – 1.0 lp/mm
  - Cone Beam: 1.3 lp/mm
- For Lunar fan beam scanners the spatial resolution was found to be better in the transverse direction
  - Longitudinal: ≈ 0.2 lp/mm
  - Transverse: ≈ 0.4 lp/mm

Image Quality

- Advances in vertebral fracture assessment present new challenges for additional image quality measurement
  - Lateral single energy imaging is now available, which offers superior resolution and improved diagnostic sensitivity

Electrical Safety

- Plug-in units
  - Automated electrical safety tester

- Parameters tested
  - Insulation resistance mains
  - Bonding
  - Earth Leakage
  - Enclosure Leakage
- Fixed Systems
  - Bonder
  - Voltmeter
  - IEC Current Measurement Device
- Parameters tested
  - Earth resistance
  - Leakage currents
    - Earth leakage
    - Enclosure leakage
  - Touch voltage

Scattered Radiation and Room Shielding

- Radiation dose to the operator will vary depending on
  - The make and model of DEXA system
  - Patient throughput
  - Distance of operator from patient
  - Use of a radiation barrier or mobile lead screen
- Scattered radiation dose from newer generation systems may exceed the exposure limits for the general public so structural shielding may be required
- Associated with increased patient dose and higher patient throughput is a greater occupational hazard to staff from scatter radiation

Scattered Radiation and Room Shielding

- A standard patient examination consists of AP spine plus dual hip
  - Patient is simulated using 20cm water-equivalent material
- The large scan volume means that the inverse square law does not hold true
  - Scatter is measured at three locations to estimate scatter to walls, doors and operator

Scattered Radiation and Room Shielding

- Scatter is reported here in predicted annual dose at 1m from the scanner for a workload of 20 patients per day
- Scatter is greater for cone and fan beam systems, which is in agreement with the suppliers isodose curves and previous results in literature
- Each facility is assessed on a case by case basis to determine structural and operator shielding requirements

System	Annual Dose (mSv)	Structural Shielding required?
Lunar (Pencil Beam)	0.1	No
Lunar (Fan Beam)	0.5	Yes
Hologic (Fan Beam)	1.0	Yes
Hologic (Fan Beam C-arm)	1.4	Yes
Lexxos (Cone Beam)	1.5	Yes

Radiation Protection Survey

- Facility
  - Equipment licensed by the Radiological Protection Institute of Ireland
  - Radiation warning signs present on all doors
  - Radiation warning light present and functioning outside all doors
  - Illustrated/multi-lingual pregnancy signs on display
  - Appropriate shielding: Mobile lead screen

Radiation Protection Survey

- Equipment
  - Shutter function
  - Visual *Power On* indication
  - Warning Lights: Visual *Exposure On* indication
  - Emergency stop
  - Is in-house QC routinely performed

Operator

  - Who operates the DEXA system: Nurse/Radiographer
  - Does operator wear a personal dosimeter

Summary

- The study illustrates comprehensive acceptance and annual QC testing of DEXA systems
- Timing
  - Acceptance Testing: 1 day
  - Annual QC Testing: ½ day
- Comparative studies will assist in the on-going development of
  - testing guidelines
  - testing frequencies: annually or once every 2 years
  - the establishment of tolerances
  - criteria of acceptability for DEXA X-ray equipment

References

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