International Radiation Protection Association
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Madrid, Spain - May 23-28, 2004

Refresher Course
Radiation Protection in Cardiac and Interventional Procedures
C. Reek
Overview

• Introduction and Background
• Regulations
• Dose
• Patient Dose Reduction-Factors
• Special Cases
• Limitation of Staff Dose
• Good Practice
• Recommendations
Sources of Radiation

![Radiation Exposure Chart]

- **Radon**: 47%
- **Thoron**: 4%
- **Gamma Rays**: 14%
- **Medical**: 12%
- **Other**: 1%
- **Food and Drink**: 12%
- **Cosmic**: 10%

*Average Person 2.5 mSv*
November 8th 1895

Wilhelm Conrad Röntgen
• 23rd January 1896
• Public lecture on X rays
• Hand of von Kolliker
First British Radiographs

- 25th January 1896
- BMJ Alan Campbell Swinton
British Medical Journal 18\textsuperscript{th} April 1896

- First published report of the dangers of X rays
1921

- Deaths attributed to X rays
- No regulations prior to 1928
### Stochastic (Random) Effects

<table>
<thead>
<tr>
<th>Event</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking 10 cigarettes/day</td>
<td>1 in 200</td>
</tr>
<tr>
<td>Natural causes (40 yr old)</td>
<td>1 in 850</td>
</tr>
<tr>
<td>Accidents on road</td>
<td>1 in 9500</td>
</tr>
<tr>
<td>Accidents at work</td>
<td>1 in 43,500</td>
</tr>
<tr>
<td>Cancer from radiation exposure of 1 mSv</td>
<td>1 in 25,000</td>
</tr>
<tr>
<td>Majority of NHS staff (&lt;0.3mSv/yr)</td>
<td>1 in 83,333</td>
</tr>
</tbody>
</table>
## Deterministic Effects

<table>
<thead>
<tr>
<th>Injury</th>
<th>Threshold Dose to Skin</th>
<th>Mins fluoro 0.02Gy/min</th>
<th>Mins fluoro 0.2Gy/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient erythema</td>
<td>2</td>
<td>100</td>
<td>&lt;&lt;1</td>
</tr>
<tr>
<td>Permanent epilation</td>
<td>7</td>
<td>350</td>
<td>35</td>
</tr>
<tr>
<td>Dry desquamation</td>
<td>14</td>
<td>700</td>
<td>70</td>
</tr>
<tr>
<td>Dermal necrosis</td>
<td>18</td>
<td>900</td>
<td>90</td>
</tr>
<tr>
<td>Telangiectasia</td>
<td>10</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>Cataract</td>
<td>&gt;5</td>
<td>&gt;250 to eye</td>
<td>&gt;25 to eye</td>
</tr>
</tbody>
</table>
Development of Interventional Cardiology

1929
First documented human cardiac catheterisation
Eberswald, Germany
Dr Werner Forssman

1958
Diagnostic coronary angiogram
Dr Mason Sones
Development of Interventional Radiology

1964
Transluminal angioplasty
Dr Charles Dotter

1967
Judkins technique
Dr. Melvin Judkins
Development of Interventional Cardiology

**1974**

First peripheral balloon angioplasty
Dr Andreas Gruentzig

**1977**

First cath lab PTCA on awake patient
Development of Interventional Cardiology

1980
Use of angioplasty in evolving myocardial infarct
Dr Geoffrey Hartzler

1987
First use of coronary stents in human
Embolisation: detachable balloon occlusion

- Transplant post-biopsy

9.9 x 24.6 mm det. balloon
Regulations

- **Ionising Radiation Regulations 1999**
  - relate to public and staff safety

- **Ionising Radiation (Medical Exposure) Regulations IR(ME)R 2000**
  - govern the fate of patients undergoing a medical exposure
Regulations

• Duties of all bodies- employer, practitioner, operator and referrer
• ALARA/ ALARP principle
• Training
• Diagnostic Reference Levels (DRLs)
• Local Rules-policies, procedures, protocols
• Other Bodies eg NRPB, ICRP, ACC, BCIS, European Commission’s Radiation Protection Research Program
Dose Definitions

• Gray - energy absorbed per unit mass (in diagnostic = KERMA, energy transferred)

• Sievert - equivalent dose = absorbed dose x radiation weighting factor

• Effective dose – equivalent dose in each organ and tissue x tissue weighting factor and summed over whole body
Dose Definitions

• DAP - dose area product (Gycm²)
  incident dose x area of X ray field

• Entrance skin dose – absorbed dose in the skin
  at a given location on the patient (Gy)
## Annual Dose Limits

<table>
<thead>
<tr>
<th></th>
<th>Classified Staff</th>
<th>Unclassified / trainees</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
<td>20 mSv</td>
<td>6 mSv</td>
<td>1 mSV</td>
</tr>
<tr>
<td>Eyes</td>
<td>150 mSv</td>
<td>50 mSv</td>
<td>15 mSv</td>
</tr>
<tr>
<td>Organs</td>
<td>500 mSv</td>
<td>150 mSv</td>
<td>50 mSv</td>
</tr>
<tr>
<td>Fetus</td>
<td>1 mSv</td>
<td>1 mSv</td>
<td></td>
</tr>
</tbody>
</table>
Monitoring

Ensure

- Film badges and TLDs are easily available
- Results of monitoring are available to all
- Reminders to wear them are in appropriate places
## Dose to patient

<table>
<thead>
<tr>
<th>Procedure</th>
<th>DAP cGycm²</th>
<th>ED mSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary angiography</td>
<td>3040</td>
<td>5.6</td>
</tr>
<tr>
<td>PTCA</td>
<td>3760</td>
<td>6.9</td>
</tr>
<tr>
<td>CA + ad hoc PTCA</td>
<td>5060</td>
<td>9.3</td>
</tr>
<tr>
<td>PTCA + stent</td>
<td>4920</td>
<td>9.0</td>
</tr>
<tr>
<td>CA + ad hoc PTCA + stent</td>
<td>7070</td>
<td>13.0</td>
</tr>
</tbody>
</table>
Diagnostic Reference Levels

- Set for categories of procedures – 20/annum
- At least 100 cases
- DAP (dose area product) or screening time and mAs
- Level set - 90\textsuperscript{th} percentile
- No national DRLs for coronary angiography
- NRPB – proposed 36 Gcm\textsuperscript{2}
- European DIMOND – proposed 45 Gcm\textsuperscript{2}
Dose Reduction - Equipment

- Frame rate selection
- Pulsed fluoroscopy
- Fluoroscopy and image acquisition dose rate selection
- Last image hold
- ‘Replay fluoro’
- Electronic magnification
- Image processing
- Flat panel detectors
Dose reduction - Equipment

- Road map
- Reload facility
- Virtual collimation
- Intelligent filtration
- Dose display

**BUT**
- Most dose reduction features optional
- Improved imaging allows more complex cases
Dose Reduction - Equipment

• Modification of existing equipment
• Equipment maintenance
• Quality assurance
  regular IQ and dose checks
  manufacturer
  medical physicists
Factors affecting exposure
Inspiration
Operational Factors

- Arterial access
- Oblique views
Operational Factors

- Suitable kV and mA
- Centring
- Diaphragms-ROI
- Field size - panning
- Magnification
Appropriate Views

Views should not be prescriptive—depend on patient
Lateral View
Operational

• Stenting strategy
Behavioural

- Table and detector in correct position before screening
- Screening time
- Image acquisition – operator / radiographer?
- Use of equipment features-dose reduction programmes etc
- Prolonged procedures – reduce skin dose
- Operator fatigue
Radiation Awareness

• Regular audit
• Feedback on dose information
  patients
  staff
• High standards of equipment maintenance and quality assurance
• Appropriate theoretical training with annual updates
• Practical training and regular re-assessment
Audit - Operator key

Operator Key

1  2  3  4  5  6  7
8  9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30 31 32 33 34 35
36 37 38 39 40 41 42

TOTAL - REG  TOTAL - ALL
Audit

Left Heart Catheters - January - March 2001 (No. of Cases)
Audit

Left Heart Catheters - January - March 2001 (Ave Dose)
Audit

Left Heart Catheters - January - March 2001 (% Above DRL)
Special Cases-Cardiology

- EPS/RFA
- Brachytherapy
- CT angiography
- Radio-isotopes
- Echocardiography
- Magnetic Resonance Imaging
Electrophysiology
Brachytherapy

- Bifurcation in-stent restenosis
- Two wires
- Cutting balloon final result
- 60mm seed delivery catheter in LAD
- Catheter in diagonal
- 6 month follow up result
CT Angiography

- Anomalous right coronary artery arising from LC sinus
- Occlusion of RCA
Magnetic Resonance Imaging
Special Cases-Radiology

Per-operative arterial rupture

Covered stent deployment
Radiology

- Dose ranges depend on type and site of intervention
- Dose reduction to patient - principles as cardiology
- Tube movements less
- Position of operator more variable
- Use ultrasound guidance where possible
- CT fluoroscopy - decreased operation times
Risk

![Graph showing risk of death per Sievert (Sv) at different ages for females and males.](image)
## Doses

<table>
<thead>
<tr>
<th>Dose from common paediatric procedures</th>
<th>DAP (cGcm²)</th>
<th>ED (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetralogy of Fallot</td>
<td>670</td>
<td>8.4</td>
</tr>
<tr>
<td>Closure of persistent ductus arteriosus</td>
<td>450</td>
<td>3.8</td>
</tr>
</tbody>
</table>
Paediatric Intervention
Limitation of Staff Exposure

• Reduce patient exposure - reduce staff exposure
• Radiation awareness and education
• Dedicated interventional equipment
• Reduce time of exposure
• Use inverse square law
• Use shielding by barrier
Limitation of Staff Dose
Use lead shields
Wear appropriate lead protection

- Lead glasses
- Thyroid shield
- Lead apron – 3.5 - 5mm lead equivalent
- Monitoring
Use mobile barriers

- Lead shield for operator
- Mobile barrier for radiographer
- Other staff appropriately positioned
• Position monitors so that operator looks away from beam
Paediatrics-always a special case
Good Practice 1

- Follow Local Rules, procedures and protocols
- Have all available information about patient eg. previous grafts, echo data etc
- Check patient identity, exposure justification, consent
- Position patient
- Ensure all appropriate staff in room are protected and wearing monitors
- Use all lead shielding
Good Practice 2

- Position table before screening
- Keep mA low-kV high (60-90kV for coronaries)
- X ray tube at max and II at min distance from patient
- Check staff position
- Use dose reduction programmes if possible
- Acquire images on full inspiration where possible
- Collimate to area of interest and choose views carefully
Good Practice 3

- Prolonged procedure-change beam angulation
- Minimise fluoroscopy, high dose rate time, number of acquisitions
- Remember software features to reduce dose eg replay fluoro
- Don’t over use magnification
- Remove grid for small patients
- Check and record screening time and DAP cf DRL
Recommendations

- Dedicated interventional equipment
- Radiation dose reduction packages should be mandatory
- Radiation dose should be displayed on monitors
- Radiation awareness should be promoted by audit and regular feedback
- Local standards-regular review and improvement
- Continuing education-including practical training with annual updates and testing
- Research continued-to develop international standards