Radiation Burden in Cardiology

A quick tour!
David Sutton
Contents

- Radiation Doses to Staff
  - Doses to the eye
- Radiation Doses to Patients
  - Nuclear Cardiology
  - CCTA
  - Cardiac x-ray procedures
Guiding Principles

- Justification
- Limitation
- Optimisation
Justification of a practice

- Justification means that any exposure produces sufficient benefit to offset the radiation harm that it might cause.
Optimisation of protection

- Optimisation includes the criterion: doses should be “as low as reasonably practicable” assuming image quality is adequate for diagnostic purposes.

- Optimisation means that minimum risk and maximum benefits should be achieved.
Radiation Dose to Staff & Patients

- Reprise
  - Stochastic Effects – Linear no threshold.
  - Deterministic Effects – Threshold
What is the scientific basis for radiation standards for protection at low levels of ionising radiation (<0.1 Sv) where there are considerable uncertainties in the epidemiological data?

**LNT : The dilemma for radiation protection.**
## Deterministic Thresholds – Revised!!!

<table>
<thead>
<tr>
<th>Exposed tissue</th>
<th>Net Effect</th>
<th>Absorbed dose (Gy)</th>
<th>Time for effect to develop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>Initial Erythema</td>
<td>2</td>
<td>2-24 hours</td>
</tr>
<tr>
<td></td>
<td>Erythema</td>
<td>3-6</td>
<td>1-4 weeks</td>
</tr>
<tr>
<td></td>
<td>Temporary epilation (hair loss)</td>
<td>3-4</td>
<td>2-3 weeks</td>
</tr>
<tr>
<td>Lens of eye</td>
<td>Cataract</td>
<td>0.5</td>
<td>Several years</td>
</tr>
</tbody>
</table>
Eye Doses-Background

- New evidence suggests that the eye is more susceptible to radiation than previously thought.
- Some of the evidence from is Cath Labs
- Consequent reduction in recommended dose limit to the lens of the eye.
- Limits have reduced from 150 mSv per year to 20 mSv per year.
Impact in Cardiology

- Several studies have shown that the new limit can be exceeded in the Cath Lab quite easily if protective measures not used.
- Risk of radiation-induced cataracts after working for several years without proper protection.
Cardiology – Dundee data - Angiography

- Eye to KAP ratio of 3 $\mu$Gy/Gy.cm$^2$.
- Average dose per procedure of 110$\mu$Gy (no protection)
- *Dundee cardiologists may exceed the proposed dose limit if they perform > 15 procedures a month*
Eye doses in Cardiology

Principi 2015

eye dose mSv

No of procedures per year

Vanhavere et al 2011

eye dose mSv

No of procedures per year
Cause of Cardiologist Dose

- Provided you don’t stand in the primary beam, scattered radiation will be the major cause of staff doses in interventional cardiology.
- There are different amounts of scatter in different directions but there is nowhere where there is no scattered radiation.
Reducing Cardiologist Dose

- Anything that affects patient dose affects the amount of scattered radiation.
- The amount of scattered radiation depends on the field size, volume of patient irradiated and the quality of the primary beam.
- Scattered radiation has a strong angular dependence.
- The bigger the patient dose, the bigger the cardiologist dose.
Factors affecting staff dose
Positioning - ISL
Access

Relative dose rates 1

Interventional cardiology

Radial access

Femoral access
Move away from the source

Dose 1

1/4

Distance 1m

Distance 2m
Orientation

– Stay away from the tube side
Dose to Cardiologist PCTA 1 Stent 30°

- Head: 200 µGy
- Body: 400 µGy
- Legs: 360 µGy
- X-ray tube: 120 µGy
- Image receptor may provide additional protection for head on this side
- Head: 40 µGy
- Body: 120 µGy
- Legs: 320 µGy
- Legs of operator should be protected by screen attached to couch

Additional protection for head essential in this position
PPE

- Personal protective equipment in the form of lead/rubber aprons, thyroid collars, lead rubber gloves and leaded glasses are examples of the use of shielding.
Ceiling & Table Shielding

- Ceiling mounted shields reduce doses to the head and body of staff who need to remain close to the patient during procedures.

- The legs of cardiologists can receive substantial doses which can be substantially reduced by drapes hung from the table.
Effect of Table Mounted Shielding

Leg dose reduction – up to 30 times!
Ceiling Suspended Shields

Ceiling suspended screens protect the whole head

- Place as close to the image receptor and as low as possible
- Tilt slightly away from operator to protect largest area
- Protection depends on the diligence of operator
Protective eyewear

- Should be worn
  - Where it is not practicable to use ceiling suspended shields
  - With ceiling suspended screens when workloads are high
Dose Reduction

- Suspended lead screen shielding.
  - 2 to 10 /20 reduction for PTCA
- Wrap around glasses.
  - 2 to 6 dose reduction for PTCA
- Access
  - Femoral vs radial 1.2 to 4.8 reduction
Personal dosimetry

- Two personal dosimeters are recommended for cardiac catheterisation laboratories:
  - one outside the lead apron at the collar or shoulder
  - one on the trunk under the apron
- At least one dosimeter, **the collar dosimeter**, should always be worn - ICRP.
- Eye dosimeters, when available and agreement reached on their use.
Patient Radiation Doses
CTCA

- Increasing Numbers
- Increasing concern about Patient Radiation Dose
- Refer to Dr Castellano’s talk yesterday
Acquiring coronary CTA images: gating of acquisition

- two types:
  - prospective
  - retrospective
- different image sets generated
- different radiation burden to patient
CTCA – Retrospective Gating

- Retrospective ECG Gating > 10 mSv per exam
- Applied radiation during entire cardiac cycle – 100% modulation
- Functional information during entire cycle
Retrospective gating

- Images reconstructed from partial projection data set
  - To improve temporal resolution
- Single or multi-segment recon
  - Determines temporal resolution
- Reconstruction window can be adjusted
  - Essential for arrhythmic patients
- **Typical patient dose 10 – 30 mSv**
  - 500 – 1500 CXRs
CTCA – Prospective Gating

- Reduced current allows some visualisation during entire cardiac cycle.
- 4-fold reduction in dose achievable (1.3 to 3.5 mSv) possible using prospective gating for comparable image quality*
- See also iterative reconstruction

*Menke Am Heart J 2013
Prospective Gating

- choice of table motions
  - step-and-shoot
  - slow helical
  - high-pitch helical (Flash)
  - none
- axial images reconstructed from partial projection data sets
- MPRs, VR image sets
- patient dose 1 – 5 mSv
  - 50 – 250 CXRs

Elly Castellano
Nuclear Cardiology
## Doses in Nuclear Cardiology – UK DRLs

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Form</th>
<th>Procedure</th>
<th>Activity</th>
<th>ED</th>
<th>Uterus</th>
</tr>
</thead>
<tbody>
<tr>
<td>99m-TC</td>
<td>Albumin</td>
<td>Blood Pool</td>
<td>800</td>
<td>4.9</td>
<td>3.8</td>
</tr>
<tr>
<td>99m-Tc</td>
<td>Pertechnetate</td>
<td>FP</td>
<td>800</td>
<td>10.4</td>
<td>6.5</td>
</tr>
<tr>
<td>99m-TC</td>
<td>Erythrocytes</td>
<td>MUGA</td>
<td>80</td>
<td>5.6</td>
<td>3.1</td>
</tr>
<tr>
<td>99m-TC</td>
<td>Sestamibi</td>
<td>Myocardium</td>
<td>300</td>
<td>R2.7</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>800 SPECT</td>
<td>S2.4</td>
<td>2.2</td>
</tr>
<tr>
<td>99m-TC</td>
<td>Tetrofosmin</td>
<td>Myocardium</td>
<td>300</td>
<td>R2.4</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>800 SPECT</td>
<td>S2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>123-I</td>
<td>MIBG</td>
<td>SIHH</td>
<td>3+1</td>
<td>4.8</td>
<td>3.7</td>
</tr>
<tr>
<td>201-T1</td>
<td>T1 Chloride</td>
<td>Myocardium</td>
<td>80</td>
<td>11.2</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Worldwide distribution of patient radiation effective doses from myocardial perfusion imaging.

Andrew J. Einstein et al. Eur Heart J 2015;36:1689-1696
## Doses in Nuclear Cardiology

<table>
<thead>
<tr>
<th>Region</th>
<th>Africa</th>
<th>Asia</th>
<th>Europe</th>
<th>Latin America</th>
<th>North America</th>
<th>Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of Labs</td>
<td>12</td>
<td>69</td>
<td>102</td>
<td>36</td>
<td>55</td>
<td>34</td>
</tr>
<tr>
<td>Median ED (mSV)</td>
<td>9.4</td>
<td>11.4</td>
<td>8.8</td>
<td>12.8</td>
<td>12.1</td>
<td>11.5</td>
</tr>
<tr>
<td>QI&gt;6</td>
<td>75%</td>
<td>25%</td>
<td>71%</td>
<td>22%</td>
<td>31%</td>
<td>53%</td>
</tr>
</tbody>
</table>

From Einstein A et al. Eur Heart J 2015;36:1689-1696
Europe

- The mean effective dose from nuclear cardiology is lower and the average quality score is higher than in the RoW.
- There is regional variation in effective dose in relation to the best practice quality score.
- A possible reason for the differences between Europe and the RoW could be the safety culture fostered by actions under the Euratom directives and the implementation of diagnostic reference levels.

Lindner et al. Eur J Nuc Med Mol Im 2016 43 718-728
The eight best practices – Dr Vitola.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Reduction mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Avoid thallium stress. ≤70 years</td>
<td>2.54</td>
</tr>
<tr>
<td>2)</td>
<td>Avoid dual isotope. &lt;70 years</td>
<td>5.42</td>
</tr>
<tr>
<td>3)</td>
<td>Avoid too much technetium</td>
<td>3.12</td>
</tr>
<tr>
<td>4)</td>
<td>Avoid too much thallium</td>
<td>1.05</td>
</tr>
<tr>
<td>5)</td>
<td>Perform stress only imaging</td>
<td>2.28</td>
</tr>
<tr>
<td>6)</td>
<td>Use camera based dose reduction strategies</td>
<td>1.23</td>
</tr>
<tr>
<td>7)</td>
<td>Use weight based administration for technetium</td>
<td>0.84</td>
</tr>
<tr>
<td>8)</td>
<td>Avoid ‘shine through artefacts’</td>
<td>None</td>
</tr>
</tbody>
</table>

From Einstein A et al. Eur Heart J 2015;36:1689-1696
Patient Doses – Coronary x-ray procedures

- UK- Coronary Angio 4 mSv (typical)
  - Literature 2-20 mSv
- UK - PTCA 10 -25 mSv depending on complexity
- Compare to
  - ~ 10mSv for Nuclear Cardiology
  - CXR ~ 0.015 – 0.02 mSv
  - CT – Chest Abdomen Pelvis ~ 20 mSv
Deterministic effects
A trip to the Dentist - 1897

- A few days after being photographed, the skin of the young woman’s face, shoulder and left arm blistered and peeled off. One ear swelled to three times normal size and has no hearing. Also, large patches of Miss McDonald’s hair fell out.
  - Dominion Dental Journal 1897
Factors affecting patient dose in fluoroscopy

- Beam on time
- Filtration
- Patient size
- Tube current / kV
- Source skin distance
- Intensifier to skin distance
- Use of Grid
- Collimation
- Image Magnification
Positioning
Reference Air Kerma (RAK)

- Dose quantity displayed on units
- Called cumulative air kerma or total skin dose
- Measured in centre of X-ray field
- Measured at Interventional Reference Point (IEC,60601-2-43, 2000)
- ~15 cm in front of iso-centre

Source: ICRP
Monitor dose during procedure

- Radiation dose factors
  - Reference air kerma (RAK)
  - Kerma-area product (KAP)
  - Fluoroscopy time
  - No. of cine runs and frames

- As dose increases operator should consider possibilities for controlling skin dose by limiting cine, decreasing dose rates, changing gantry angle, etc.
Interventional Cardiology procedures

- Set a Radiation Dose Level as trigger
- Suggested values for the trigger level are
  - a skin dose of 3 Gy
  - a reference air kerma level of 5 Gy, or
  - a kerma-area product of 200-500 Gy cm² (set locally, as depends on field size and so procedure)
- Advise patient of risk of skin injury
- Contact by telephone after about 30 days to ensure skin injury not missed
- Record radiation dose data in patient’s notes
Our implementation

3. If during a procedure the caution level ($\text{CAK} = 2000 \text{ mGy}$) is reached the Radiographer must ensure the operator (Cardiologist) is made aware. This action should be recorded in the comments box on CRIS. The operator should consider at this point whether it may be possible to vary the entry site / projection angle of the x-rays to avoid one small area of skin receiving the entire dose.

4. If during a procedure the PSD reporting level ($\text{CAK} = 3000 \text{ mGy}$) is reached,

After the procedure, the Radiographer must complete the blue or pink PSD Pack, depending on the dose reached. The blue pack is for patients whose CAK is between $3000 - 5000 \text{ mGy}$ and the pink pack is for patients whose CAK is greater than $5000 \text{ mGy}$.

This includes:

- The Patient Information Leaflet which should be given to the patient by the Radiographer
- The Skin Dose Advice form should be signed by the Cardiologist and must be retained in the patient notes
Thanks for listening.