Radiation Burden in Cardiac Imaging

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Cardiac Imaging  
(ionizing radiation)

- Nuclear Imaging

- Cardiac Catheterization procedures (diagnostic & intervention)

- Cardiac CT
Cardiac Imaging

• Nuclear Imaging
  (Nuclear radiations)

• Cardiac Catheterization procedures (X rays)

• Cardiac CT (X rays)
Learning Objectives

• To learn about levels of radiation doses to patient in cardiac imaging examinations
• To understand radiation burden of cardiac imaging vis a vis overall radiological exposure to patients
• To become familiar with safety implications for individual patient radiation burden
Variability in exposure across different centers in coronary angiography

mean fluoroscopy time, frame number and dose-area product (DAP) in six European centers (600 procedures, third-quartile values)

5.6-13.6 mSv

Neofotistou, European Radiology 2003
Variability in exposure across different centers in coronary angiography
dose-area product (KAP) in seven centers (Chile, Italy, Spain, Uruguay, USA, 2265 procedures)
Variability in exposure across different centers in coronary angioplasty

Mean fluoroscopy time, frame number and dose-area product (DAP) in six European centers (600 procedures, third-quartile values)

9-21 mSv

Neofotistou, European Radiology 2003
Variability in exposure across different centers in coronary angioplasty
dose-area product (KAP) in seven centers (Chile, Italy, Spain, Uruguay, USA, 1844 procedures)

13-34 mSv

Balter, Medical Physics 2008
Doses are **NOT** patient doses

These are doses to phantom (typical patient)
Dose & Risk in perspective

• **Nuclear Imaging**
  – Activity administered
  – Distribution in many tissues
  – Effective dose (carcinogenic risk)
  – Absence of evidence of tissue reactions

• **Cardiac Catheterization**
  – Tissues in chest region
  – Dominant consideration tissue reaction (CAK, skin dose)
  – Stochastic risk (KAP, effective dose)

• **Cardiac CT**
  – Stochastic risk (DLP, effective dose)
Learning Objectives

• To learn about levels of radiation doses to patient in cardiac imaging examinations
• To understand radiation burden of cardiac imaging vis a vis overall radiological exposure to patients
• To become familiar with safety implications for individual patient radiation burden
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Effective Dose mSv</th>
<th>Increased Risk of Cancer</th>
<th>Equivalent Period of Natural Background</th>
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<tbody>
<tr>
<td>No Dose</td>
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<td></td>
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<tr>
<td>MRI</td>
<td>Not defined/applicable</td>
<td>Not known</td>
<td>Not equivalent</td>
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<td>Ultrasound</td>
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<tr>
<td>Low Dose</td>
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<tr>
<td>Chest X ray</td>
<td>&lt;0.1</td>
<td>One in a million</td>
<td>Few days</td>
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<tr>
<td>Extremities</td>
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<td>Intermediate Dose</td>
<td>1 - 5</td>
<td>1 in 10,000</td>
<td>Few months to a few years</td>
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<tr>
<td>IVP</td>
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<tr>
<td>Lumbar spine</td>
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<td></td>
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<tr>
<td>Abdomen</td>
<td></td>
<td></td>
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<tr>
<td>CT head and neck</td>
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<tr>
<td>Higher doses</td>
<td></td>
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<tr>
<td>Chest or abdomen CT</td>
<td>5 - 20</td>
<td>1 in 2,000</td>
<td>Few years to several years</td>
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<td>Nuclear cardiogram</td>
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<td></td>
</tr>
<tr>
<td>Cardiac angiogram</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Barium enema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural background</td>
<td>2.4</td>
<td>1 in 5,000</td>
<td>-</td>
</tr>
</tbody>
</table>
Einstein et al. JAMA 15 Nov. 2010

• Studied >1,000 cardiac patients
• Over a 20-year period for each patient
• Almost a third received more than 100 mSv much of which was attributable to SPECT MPI
• SPECT MPI is the test with the highest radiation burden -- accounting for 22% of the cumulative effective dose from all medical sources

• SPECT MPI volume in US increased from fewer than 3 million procedures annually in 1990 to more than 9.3 million in 2002.
UNSCEAR

- Nuclear medicine (medical) (12 %)
- Computed tomography (medical) (24 %)
- Space (background) (5 %)
- Internal (background) (5 %)
- Terrestrial (background) (3 %)
- Radon & thoron (background) (37 %)
- Industrial (<0.1 %)
- Occupational (<0.1 %)
- Consumer (2 %)
- Conventional radiography / fluoroscopy (medical) (5 %)
- Interventional fluoroscopy (medical) (7 %)
USA

• More nuclear cardiology procedures are performed in the USA than in the rest of the world combined

• Cardiac studies accounted for 85% of the nuclear medicine exposure (NCRP, 2009).
Learning Objectives

• To learn about levels of radiation doses to patient in cardiac imaging examinations
• To understand radiation burden of cardiac imaging vis a vis overall radiological exposure to patients
• To become familiar with safety implications for individual patient radiation burden
Patient A

Underwent at age of 25

• Cardiac imaging (Tc-99m) on x.y.2001
  • Dose $\approx 10 \text{ mSv}$
• Coronary angiography a.b.2003$\approx 7 \text{ mSv}$
• Cardiac CT thrice 2005-2008 $\approx 5 \times 3 \approx 15 \text{ mSv}$

Total dose 32 mSv till 32 years of age
Effective dose:

– Age and sex averaged.

– It should not be used retrospectively to determine individual risk.

• Individual risk is best evaluated by determining the mean doses to all radiosensitive tissues of the individual and combining these with age-, sex-, and organ-specific risk coefficients.
2007 recommendations

Tissue weighting factor for breast increased from 0.05 to 0.12 (2.4 times, by 140%) and for gonads decreased from 0.2 to 0.08, by $\approx 60\%$

Remainder tissues (new 0.12, old 0.05 using a new additive system)
### TABLE 2 Lifetime risks of cancer incidence by organ, age and sex for a composite Euro-American population (% per Gy)

<table>
<thead>
<tr>
<th>Organ</th>
<th>Age at exposure (y)</th>
<th>0-9</th>
<th>10-19</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
<th>80-89</th>
<th>90-99</th>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Lung</td>
<td></td>
<td>0.65</td>
<td>0.69</td>
<td>0.73</td>
<td>0.78</td>
<td>0.80</td>
<td>0.76</td>
<td>0.61</td>
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<td>0.93</td>
<td>0.73</td>
<td>0.57</td>
<td>0.43</td>
<td>0.31</td>
<td>0.20</td>
<td>0.12</td>
<td>0.06</td>
<td>0.02</td>
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<td>Colon</td>
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<td>1.49</td>
<td>1.22</td>
<td>0.98</td>
<td>0.79</td>
<td>0.60</td>
<td>0.43</td>
<td>0.25</td>
<td>0.12</td>
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<td>RBM</td>
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<td>0.49</td>
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<td>0.18</td>
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<td></td>
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<tr>
<td></td>
<td><strong>Males</strong></td>
<td>9.98</td>
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<td>6.22</td>
<td>5.12</td>
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<td>3.27</td>
<td>2.23</td>
<td>1.32</td>
<td>0.55</td>
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**Females**

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<td>1.58</td>
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<td>1.78</td>
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<td>0.39</td>
<td>0.32</td>
<td>0.24</td>
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<td><strong>All cancers</strong></td>
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<td>1.83</td>
<td>0.70</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Breast Dose

- CT coronary angiography = 50-80 mGy
Patient A

Underwent at age of 25

- Cardiac imaging (Tc-99m) on x.y.2001
  - Breast dose $\approx 5\text{-}10\text{ mGy}$
- Coronary angiography a.b.2003: Breast dose $\approx 30\text{ mGy}$
- Cardiac CT thrice 2005-2008 $\approx 40\times 3 \approx 120\text{ mGy}$

Total dose to breast 160 mGy till 32 years of age
Patient B

Underwent at age 41 (2001)

- Chest radiograph (PA) in 2001 ≈ 0.02 mSv
- CXR in 2005 ≈ 0.02 mSv
- Knee radiograph in 2011 ≈ 0.01 mSv
- CT of LS in 2012 ≈ 8 mSv
- Total of ≈ 8.05 mSv till 52 yrs age
Easily Understandable Points

• With existing knowledge Patient B should hardly have worry about radiation effect

• Patient A
  – There is need for concern
  – Stronger justification: Retrospective and prospective
  – Particular attention to optimization
Editorial

Rising Rates of Cardiac Procedures in United States and Canada. Too much of a Good Thing?

John Z. Ayanian, MD, MPP

If new tests and treatments are used indiscriminately, their impact may be minimal for many patients, deleterious for some patients, and costly for the society.

Circulation 2006; 113: 333-335
Editorial

Rising Rates of Cardiac Procedures in United States and Canada.
Too much of a Good Thing?

If new tests and treatments are used indiscriminately, their impact may be minimal for many patients, deleterious for some patients, and costly for the society.

Circulation 2006; 113: 333-335
Appropriateness of Coronary CTA at the Mayo Clinic

- Not Classifiable: 46%
- Appropriate: 27%
- Uncertain: 10%
- Inappropriate: 17%

Miller JA, JACR 2010;7:105
Inappropriate PCI= 36
Implantable cardioverter-defibrillators in hypertrophic cardiomyopathy: Patient outcomes, rate of appropriate and inappropriate interventions, and complications.

Vriesendorp PA, Schinkel AF, Van Cleemput J, Willems R, Jordaens LJ, Theuns DA, van Slegtenhorst MA, de Ravel TJ, Ten Cate FJ, Michels M.

Department of Cardiology, Thoraxcenter, Erasmus MC, Postbus 2040, Rotterdam, The Netherlands.
Patient and Hospital Characteristics Associated with Inappropriate Percutaneous Coronary Interventions.


Saint Luke's Mid America Heart Institute, Kansas City, Missouri; University of Missouri, Kansas City. Electronic address: pchan@cc-pc.com.

Abstract

OBJECTIVE: To examine whether rates of inappropriate PCI differ by demographic characteristics and insurance status.

BACKGROUND: Prior studies have found that blacks, women and those with public or no health insurance are less likely to undergo percutaneous coronary intervention (PCI). Whether this reflects potential overuse in whites, men, and privately insured patients, in addition to underuse in disadvantaged populations, is unknown.

METHODS: Within the NCDR® CathPCI Registry®, we identified 221,254 non-acute PCIs performed between July 2009 and March 2011. PCI appropriateness was determined using Appropriate Use Criteria (AUC) for coronary revascularization. Multivariable hierarchical regression models evaluated the association between patient demographics and insurance status with AUC-defined inappropriate PCI.

RESULTS: Of 211,254 non-acute PCIs, 25,749 (12.2%) were classified as inappropriate. After multivariable adjustment, men (adjusted OR, 1.08 [95% CI: 1.05-1.11]; P<0.001) and whites (adjusted OR, 1.09 [1.05-1.14]; P<0.001) were more likely to undergo an inappropriate PCI, compared with women and non-whites. Compared with privately insured patients, those with Medicare (adjusted OR, 0.85 [0.83-0.88]), other public insurance (adjusted OR, 0.78 [0.73-0.83]) and no insurance (adjusted OR, 0.56 [0.50-0.61]) were less likely to undergo an inappropriate PCI (P<0.001). Additionally, compared with urban hospitals, those admitted at rural hospitals were less likely to undergo inappropriate PCI, whereas those at suburban hospitals were more likely.

CONCLUSION: For non-acute indications, PCIs categorized as inappropriate were more commonly performed in men, patients of white race, and those with private insurance. Higher rates of PCI in these patient populations may be, in part, due to procedural overuse.
Patient Radiation Burden

Emphasis in past: Optimization

10-60% reduction

Growing realization on inappropriate examinations and interventions

100%
Individual patient exposure tracking
What track?

Tracking of

• Examinations (exposure)
• Dose
OBJECTIVE. The purpose of our study was to review the experience of tracking radiologic procedures and radiation dose for individual patients in terms of impact on justification and optimization.

MATERIALS AND METHODS. Examples were collected at the Hospital for Children

CONCLUSION. Patient-specific justification and optimization becomes possible using the tracking of radiologic procedures and radiation dose of individual patients.
Case Report: 1 (Justification)

- 6 month old boy diagnosed with neuroblastoma of the posterior mediastinum.
- The initial imaging included CT of the thorax as well as abdominal MRI.
- Bone scan performed two weeks later showed increased uptake in the posterior upper ribs on the right.
- Alarmed the oncologist to think of metastases in the ribs and thus a request for new CT scan.
Case Report: 1 (Justification)

• Re-evaluation of the previous CT, showed erosion of the ribs by the tumour, which is a usual phenomenon with this kind of tumour but which was not mentioned in the initial report.

• Thus no further imaging was justified and a new CT scan was avoided
Case Report: 2 (Optimization)

• Boy 16 y, osteosarcoma of the femur.
• Initial imaging: CT of the chest (old scanner in 2008). DLP 475 mGy.cm.
• Follow-up examination in 2009, in another hospital but connected by PACS.
• DLP 221 mGy.cm.
• New scanner DLP 135 mGy.cm. Good image quality despite such low dose values.
Message

Tracking of radiological examinations & dose is useful
We did not study cumulative dose aspect in tracking so far
Radiation Protection today is NOT the same as it was 15 years ago.
Change in mind-set

From compliance with requirements to

It is my responsibility towards patient protection
Thank You

madan.rehani@gmail.com