AAPM 2014

From dose to risk: an uncertain predicament or an ethical mandate?

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Disclosures

• Research grant: NIH R01 EB001838
• Research grant: General Electric
• Research grant: Siemens Medical
• Research grant: Carestream Health

Acknowledgement
Outline

- How to understand risk associated with medical imaging in the context of medical physics:
  - 7 formative questions
- Organ dose in the context of other dose metrics

Imaging quality and safety

- Quality: Imaging provides a clinical benefit
  - Diagnostic information
  - Image quality: Universally-appreciated
  - Enhancement dependent on illusive criteria
- Safety: Imaging involves a level of “cost”
  - Monetary cost
  - Information excess
  - Radiation cost

Increase in Radiation Exposure from Medical Imaging
1. Is the increase in the number of imaging exams bad?

- No necessarily so, provided that the exams render the needed medical information
- If benefit > risk, more exams means more benefit!

2. Are low-levels of radiation dose harmful?

Figure 1: Figure with data in below. 4th year (FY14) to be mostly flat.

—and citation text—

Diagnostic X-rays and risk of childhood leukemia

Mortality and cancer incidence following occupational radiation exposure: third analysis of the National Registry for Radiation Workers
2. Are low-levels of radiation dose harmful?

- Limited epidemiological data
- High degree of uncertainty in risk estimates
- No-threshold model questioned
  - AAPM, HPS, IOMP statements (<50 mSv => ???)
- Yet:
  - Applying reference diagnostic levels
  - 50% of AAPM talks speak to dose
  - ALARA: As low as reasonably achievable

*We got to sort out our passive/aggressive attitude towards radiation risk*

3. If the benefit >> risk, do we need to worry about risk?

- Yes!
- *Primum non nocere,* "first, do no harm"
- We are healthcare providers bound by an ethical obligation
- In the face of risk we are obligated to minimize the likelihood of harm no matter how big the benefit

4. If the risk is uncertain, do we need to worry about risk?

- Yes!
- Uncertainty ≠ absence
- *Primum non nocere,* "first, do no harm"
- We are healthcare providers bound by an ethical obligation
- In the face of uncertainty we are morally bound to take the safest path
5. Is there such thing as individual risk?

- Yes
- Risk is a statistical construct, likelihood estimated for a population, but ascribed to an individual
- Risk: Inherently uncertain for the individual yet that is what the risk is

6. Is risk additive?

- Yes!
- Even wo repair mechanisms, twice the dose means twice the likelihood of harm, whether the doses are at the same time or 5 years apart
- Counting cumulative or incremental dose for individual exam is up for debate

7. What about the exams when benefit is uncertain?

- Clearly indicated exams informing an explicit course of treatment
  - Benefit >> Risk
  - Ascertain and use the needed dose for the diagnostic task at hand, and not more
- Softly-indicated exams when individual benefit is not guaranteed
  - Benefit? Risk?
  - Is the added perceived risk justified for the sake of potential benefit?
### Dose metrology syntax

<table>
<thead>
<tr>
<th>Metric</th>
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<tbody>
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<td>CTDI</td>
<td>Radiation output of a CT system in a standard sized phantom</td>
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<td>Weighted sum of organ/tissue equivalent dose for radiation sensitive organs ignoring patient specific factors</td>
</tr>
<tr>
<td>Risk index</td>
<td>Weighted sum of organ/tissue equivalent risk for radiation sensitive organs, accounting for age, gender, anatomy</td>
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Samei, Ped Rad, in press, 2014

### Metric Measure-able Modality Generic Scanner Model and Factors Patient Size Patient Radiation Patient Age Patient Gender Patient average burden

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### Organ dose: WHY?

- The only dose metric that
  - Accounts for specific patient attributes
  - Is an actual physical quantity (measureable)
  - Can be compared across modalities
  - Can be a solid basis for any risk estimation
- **Caveat:** Non-scalar metric of radiation burden
Conclusions

• The increased use of imaging exams is a positive trend, not a negative one
• Existence of benefit and uncertainty does not negate the moral obligation for risk mitigation
• Imaging optimization requires individualized metrics of radiation burden
• Organ dose is the most meaningful metric of radiation burden with the caveat of the need for scalarization

Thank you!
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#### CTDI dose

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<tbody>
<tr>
<td></td>
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<tr>
<td>32 cm</td>
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<table>
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Organ dose: HOW?

• Precise estimation possible only if we overcome 4 challenges
  1. Knowing/modeling patient anatomy
  2. Modeling CT acquisition process
  3. Knowledge of irradiation condition
  4. Integration into clinical operation

XCAT Virtual Patient Models

Segars et al. 4D XCAT phantom for multimodality imaging research. Medical Physics, vol. 37 (9), 2010

150+ models thus far, building towards 400
Population Representation

Imaging Simulation

Example Dose Distributions

Patient Specific Dose Calculator iPhone App

Sahbaee, Samei, MP; In press, 2014