Image Gently Communication

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Disclosure

- Nothing to disclose
Objectives

- Discuss how to communicate radiation dose and risk
- Put dose and risk in a personalized perspective
- Acknowledge uncertainty and cognitive biases
- Emphasize patient care, not patient scare
It’s Not So Easy

- Individual patients should be the focus, not populations
- Imprecision and uncertainty
- Innumeracy and irrational cognitive biases
Radiation Dose and Risk Measures

- Dose and risk
  - Risk = probability of a specified harm
  - Often confused or conflated

- CTDI and DLP apply to phantoms

- Effective dose incorporates cancer risk, but applies to a “reference” person
Who Is This “Reference” Person?

- North American or Western European
- 35 years old
- Hermaphrodite
Effective dose not designed to characterize radiation dose or cancer risk to individuals

Can estimate organ doses and apply mathematical models to calculate cancer risk
Risk of Cancer from Pediatric CT

- Lifetime attributable risk (2 mSv)*
  - Incidence: 1/2700

- Approximate likelihood of drawing the ace of spades twice in a row from a 52-card deck

* Assuming LNT model and BEIR VII preferred estimates for cancer for a 10-year-old
Risk of Cancer from Pediatric CT

- Lifetime attributable risk (2 mSv)*
  - Mortality: 1/4300

- Approximate likelihood that a coin toss will come up heads 12 times in a row

* Assuming LNT model and BEIR VII preferred estimates for cancer for a 10-year-old
Putting Radiation Risk into Perspective

- Background Equivalent Radiation Time (BERT)
- Mortality Risk Comparisons
- Loss of Life Expectancy (LLE)
## Background Equivalent Radiation Time (BERT)

*assuming global average 2.4 mSv/year*

<table>
<thead>
<tr>
<th>Exam</th>
<th>Effective Dose</th>
<th>CXR Equivalents</th>
<th>BERT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CXR</td>
<td>15 µSv</td>
<td>1</td>
<td>2.3 days</td>
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<tr>
<td>Chest CT</td>
<td>2 mSv</td>
<td>133</td>
<td>10 months</td>
</tr>
</tbody>
</table>
Natural Background Radiation Variability

- Average annual effective dose in US is 3 mSv

UNSCEAR 2000
Natural Background Radiation Variability

- Nearly a CXR equivalent of extra radiation every day from living in Finland compared to the Netherlands
Mortality Risk Comparison

- Pediatric CT (2 mSv) 0.023% or 1/4300
- Cycling 0.02% or 1/4400
- Drowning 0.09% or 1/1100
- Motor vehicle accident 1.2% or 1/84

Medical Mortality Risks

- Pediatric CT (2 mSv) 0.023% or 1/4300
- Medical error per hospitalization 0.6% or 1/167
- Preventable adverse event in NICU 4% or 1/25

Overall Mortality Risks

- Heart Disease
- Cancer (naturally occurring)
- Stroke
- Chronic lower respiratory disease
- Accidents (unintentional injuries)
- Diabetes
- Alzheimers
- Influenza and Pneumonia

- Car accident
  - Radiation from Radon
  - Pedestrian accident
  - Arsenic in drinking water
    - Radiation from Abdominal CT
    - Radiation from Head CT
  - Radiation from Natural Background

Fletcher Abdominal Imaging 2012
Pediatric CT (2 mSv)
Activity Equivalent Mortality Risks

- Riding 23,000 miles in a car
- Flying 700 flights in United States on commercial airliner
- Smoking 350 cigarettes
- Being a 50-year-old male for 6 weeks
Loss of Life Expectancy (LLE)

- It’s not just if, but when that matters
- Since everyone ultimately dies, how much lifespan is lost is more meaningful than how many deaths are caused
Loss of Life Expectancy (LLE) from Pediatric Imaging

- 1.4 minutes/µSv or 0.95 days/mSv for infant
- 21 minutes for CXR (15 µSv)
- 2 days for chest CT (2 mSv)
Radiation-induced cancer mortality risk from biennial chest CT (2 mSv) from 0-17 years of age
- 0.2%, if life expectancy of 80 years (normal)
- 0.08%, if life expectancy of 50 years (CF patient)

LLE due to radiation from biennial chest CT is 10-20 days
- < 0.2% of the LLE (30 years) from CF
Uncertainty of Cancer Risk Estimates

- Measured dose (~15% error)
- Effective dose in Sieverts (~40% error)
- Cancer risk to “model” patient (~300% error)
- Cancer risk to individual (~500% error)

**Systematic error:**
- Organ properties
- Organ geometry
- Statistical models (e.g., Monte Carlo)

**Systematic error:**
- Uncertainty of data from cancer studies
- LNT extrapolation

**Patient variability:**
- Age
- Gender
- Body mass
- Genetic factors

Durand J Am Coll Radiol 2012
Personalization of Radiation Risk

- Need to account for latency of cancer induction and mortality of inherent disease
- Need to recognize uncertainty in models and estimates
- Need to distinguish population risk from individual risk
Communication

- Informed decision-making is the goal
- Providing information alone is not communication
- Information + comprehension = communication
- Communication does not ensure a rational decision
Risk MisPerception

- Risks overestimated or overweighted if...
  - Personified
  - Vivid
  - Unknown or very low
  - Lack of control
  - Effect is delayed
Personalizing Risk Communication

- Be aware of cognitive biases
  - Endowment effect
  - Possibility effect and certainty effect
  - Denominator neglect
  - Framing
Endowment Effect

- Our aversion to risk exceeds our avidity for benefit

- How much would you have to be paid to accept a 1/1000 chance of immediate death? Typical response $50,000

- How much would you pay to eliminate a 1/1000 chance of immediate death? Typical response $200
Possibility Effect and Certainty Effect

- Decision weights are not identical to probabilities
- Almost certain outcomes are underweighted
- Improbable outcomes are overweighted

<table>
<thead>
<tr>
<th>Probability %</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>80</th>
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<tr>
<td>Decision weight</td>
<td>0</td>
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<td>8</td>
<td>13</td>
<td>19</td>
<td>26</td>
<td>42</td>
<td>60</td>
<td>71</td>
<td>79</td>
<td>87</td>
<td>91</td>
<td>100</td>
</tr>
</tbody>
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Kahneman Thinking Fast and Slow 2011
Possibility Effect and Certainty Effect

- Very extreme probabilities are either ignored or greatly overestimated and overweighted
  - Lotteries, insurance, terrorism, vaccines...radiation

- We are insensitive to variations of risk among small probabilities
  - 0.02% is regarded the same as 0.0002%
  - To eliminate worry you must bring the probability to 0

Kahneman Thinking Fast and Slow 2011
Denominator Neglect and Framing

- Low probability events are more heavily weighted when described in relative frequency (how many) than in risk or chance (how likely)

- 0.0002
- 0.02%
- Two hundred children in a group of a million children

Kahneman Thinking Fast and Slow 2011
Denominator Effect Manipulation

CT scans in children linked to cancer later
By Steve Sternberg, USA TODAY

Each year, about 1.6 million children in the USA get CT scans to the head and abdomen — and about 4,500 of those will die later in life of radiation-induced cancer, according to research out today.

What's more, CT or computed tomography scans given to kids are typically calibrated for adults, so children absorb two to six times the radiation needed to produce clear images, a second study shows. These doses are "way bigger than the sorts of doses that people at Three Mile Island were getting," David Brenner of Columbia University says. "Most people got a tenth or a hundredth of the dose of a CT."
Framing Effect

- Outlook is more positive when outcomes are framed in terms of survival than in terms of mortality

Framing Effect

- 1/4,300 mortality
  vs.
  4,299/4,300 survival

- 1 out of 4,300 will be killed
  vs.
  99.98% probability that no one will be killed

Informed Decision Making

- Decisions are often based on irrational thoughts
- Do we have a duty to dispel irrational thoughts?
  - Ethics of beneficence vs. autonomy
- If so, we must influence emotions, not just convey information
Before provision of radiation-induced cancer risk estimate, the proportion of parents willing to proceed with head CT in setting of head trauma was 90%.

After disclosure, willingness decreased to 70%, and 6% would refuse the CT.
A Mind is a Terrible Thing to Waste

Incidental Findings in Children With Blunt Head Trauma Evaluated With Cranial CT Scans
Alexander J. Rogers, Cormac O. Maher, Jeff E. Schunk, Kimberly Quayle, Elizabeth Jacobs, Richard Lichenstein, Elizabeth Powell, Michelle Miskin, Peter Dayan, James F. Holmes and Nathan Kuppermann

- Risk of future CT radiation-induced cancer (1/2,700)
  - Several times lower than likelihood of urgent incidental finding (1/700)
  - Two orders of magnitude lower than likelihood of detecting acute traumatic brain injury (1-8%)
“We must not continue to discuss small hypothetical risks without emphasizing large, well-documented benefits”

““Our goal as imaging professionals is to put this information into perspective”

- Cynthia McCollough
  RSNA 2012
“Predictions of radiation-induced cancers and cancer deaths from imaging procedures should be accompanied by estimates of reductions in patient morbidity, mortality and cost resulting from the same medical imaging procedures”
Gain in Life Expectancy from Imaging

- Increased utilization of CT and MRI improved life expectancy by 7-8 months from 1991-2004 in the U.S.

- Gain in life expectancy of 2 weeks per year from imaging
Summary

- Personal radiation dose and cancer risk may never be known with precision or certainty

- Estimates derived from mathematical models can still be useful for putting risk into perspective

- Medical decisions are influenced not only by what is communicated, but how it is communicated
Final Words of Wisdom

- “Risk is a feeling”

- Need empathy, tolerance of divergent values, and comfort with uncertainty

- Many don’t want information, they want reassurance

- Benefits of imaging far outweigh the risks
Focus on Patient Care, Not Scare
References

**From ‘Image Gently’ to image intelligently: a personalized perspective on diagnostic radiation risk**

R. Paul Guillerman

**OPINION**

Don’t let radiation scare trump patient care: 10 ways you can harm your patients by fear of radiation-induced cancer from diagnostic imaging

Alan S Brody,¹ R Paul Guillerman²

*Thorax* 2014;69:782–784.
Questions ?