The use of cumulative effective dose – an educational debate:
In support of cumulative dose

Madan Rehani, PhD
mrehani@mgh.harvard.edu
madan.rehani@gmail.com

What we are sure of
Is there anyone who does not think that medical imaging is IMMENSELY USEFUL?

If I am prescribed a CT scan by the doctor, I will not think a bit about the radiation risk.
True, but...
We are not among those in whom cumulative dose is of concern

Why cumulative doses?

• Not talking about doses in a single or double digits of mSv or mGy but in 3 or even 4 digits of mSv or mGy to an individual patient.
• There was never a time in history when such a situation was encountered (Unprecedented era).
• A couple of years ago: Lower single digit of mSv dose or at the most 10-20 mSv.

Organ doses and cancer risk assessment in patients exposed to high doses from recurrent CT exams
Sobhan Bezwadi1,2, Fatemeh Mir1, Madan M. Rehani1

Cohort CED ≥ 100 mSv

• Mean dose for each organ >100 mGy.
• Organ doses higher than 200 mGy for stomach and liver,
• 100-200 mGy for nine organs (lungs, breasts, colon, red bone, marrow, urinary bladder, esophagus, testicles, ovaries, and skin).
Organ doses in cohort with CED ≥ 100 mSv

- 0 to 3000 mGy to some of the important organs like
  - Breast (38% >100 mGy)
  - Heart (89% >100 mGy)
  - Lungs (89% >100 mGy)
  - Eye (31% 100-5900 mGy)
  - Brain (24% with 100-4400 mGy)
  - Colon (83% above 100 mGy)

Such patients with high doses may only be a few

From published papers (324 hospitals, 2.5 million patients)

- Likely a quarter of a million every year in USA with CED ≥ 100 mSv from CTs alone
- Not rare (definition of rare by NIH/NCI).
- 0.03% getting 100 mSv+ in a single day
- 4% with CED ≥ 100 mSv from FGI
- Triple rate with hybrid imaging
- Total dose not yet known

Take-home Points

1. If studies on cumulative dose were not done, we will not know the magnitude of doses involved
2. Miss millions of patients with such doses

The patients with such doses are those with malignant disease who get mega quantity of radiation dose in any way. So why worry.

Fact

- Medical physicists are employed to optimally impart max radiation dose to tumor, and avoid dose to normal issues
- Industry spends Billions of $-machines to minimize radiation dose to normal issues
Take-home Points

1. If studies on cumulative dose were not done, we will not know the magnitude of doses involved
2. Miss millions of patients with such doses
3. Myth that cancer patients get high doses in any way. We need to recognize the role of medical physicists.

Let us look at data: of these patients with high cumulative doses

Optimized or not?

Let us look at data: of these patients with high cumulative doses

Optimized or not?

Justify each exam first and then Optimize the exam

Patient safety is achieved


Median DLP values in mGy.cm

<table>
<thead>
<tr>
<th>Institution</th>
<th>CT Chest without contrast</th>
<th>CT Head/brain without contrast</th>
<th>CT abdomen/pelvis without contrast</th>
<th>CT abdomen/pelvis with contrast</th>
<th>CT Chest angiography heart with and without contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>American College of Radiology Dose Index Registry</td>
<td>339</td>
<td>869</td>
<td>669</td>
<td>682</td>
<td>541</td>
</tr>
<tr>
<td>MGH</td>
<td>254 (75%)</td>
<td>772 (89%)</td>
<td>561 (84%)</td>
<td>476 (70%)</td>
<td>204 (38%)</td>
</tr>
</tbody>
</table>

38 to 89% of national benchmark, i.e. 11 to 62% below

AUC METHODOLOGY

ACR Appropriateness criteria and others societies criteria are built into the system
Despite use of the BEST system available today for CDS with latest appropriateness criteria from ACR and optimization through ACR DIR

<table>
<thead>
<tr>
<th>Institution</th>
<th>Total number of patients with CED≥100 mSv (no.)</th>
<th>Total number of patients with CED≥100 mSv (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGH</td>
<td>8,892 (3.4%)</td>
<td></td>
</tr>
<tr>
<td>Orlando</td>
<td>5,898 (1.4%)</td>
<td></td>
</tr>
<tr>
<td>Slovakia</td>
<td>12,358 (0.4%)</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>6,260 (0.04%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>33,407 (1.33%)</td>
<td></td>
</tr>
</tbody>
</table>

Can our current day system of justification stop this from getting doubled in 10 years?

Take-home Points

1. If studies on cumulative dose were not done, we will not know the magnitude of doses involved
2. Miss millions of patients with such doses
3. Myth that cancer patients get high doses in any way. Role of medical physicists
4. Despite use of the BEST system for imaging appropriateness and optimization, thousands of patients with 3-digit doses

Probability of receiving a high cumulative radiation dose and primary clinical indication of CT examinations: a 5-year observational cohort study

Cumulative effective dose from recurrent CT examinations in Europe: proposal for clinical guidance based on an ESR Eurosafe Imaging survey

Which patients are prone to undergo disproportionate recurrent CT Imaging and should we worry?

Medical Physicists think that it is controversial subject. What do radiation effects scientists think?

IOMP-ICRP Webinar: Are radiation risks below 100 mGy for example through recurrent CT procedures of real concern for radiological protection?

We cannot sum doses received at different times to get cumulative dose

Two aspects (MP, other scientists)
Most estimates of dose-risk relationships are free of substantial bias. The results directly support the existence of excess risks associated with low doses for solid cancers and leukemia, with a magnitude consistent with estimates derived from the Life Span Study.

Confounding and selection bias

Sources of dose errors

Study power, lost of follow-up and outcome uncertainty

Model misspecification

Eligible studies

22 studies published since the BEIR VII report in 2006

Providing risk estimates and confidence intervals for the dose-response for cumulative radiation dose

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Providing risk estimates and confidence intervals for the dose-response for cumulative radiation dose

Radiation effects below 100 mGy of acute or protracted

1. There is evidence for radiation risks <100 mGy

2. Not only for acute exposure but protracted also

3. At the moment summing of doses at different times is the only way as no correction factors are available

4. Need to press for research to establish gap correction factors
Take-home Points

1. If studies on cumulative dose were not done, we will not know the magnitude of doses involved.
2. Miss millions of patients with such doses.
3. Myth that cancer patients get high doses in any way. Role of medical physicists.
4. Despite use of the BEST system for imaging appropriateness and optimization, thousands of patients with 3-digit doses with sizable number with long life expectancy.
5. We should press for research to establish gap correction factors, till that time cumulative dose is the way.

Medical Physicist

- I will ask myself if I am making day-to-day decisions for ordering of exams for patients?
- How much teaching medical physicists do to ordering clinicians?
- How much interactions we have with clinicians on issue of ordering an exam [Remember, every single day nearly quarter of a million CTs are ordered in the US]
- Am I stepping out of my boundary and elevating myself as a King or God?
- This is an area where our role is to provide information on dose, potential risk and principles of radiation protection.

Radiation dose

- One of the most important tools for MP
- Can we do without it?
- Risk-benefit or benefit-risk is fundamental aspect
- Can one say that do not worry about cumulative aspects of contrast agent, chemotherapeutic drugs, scheduled drugs
- How can we say about cumulative radiation dose

Stochastic risks
**Take-home Points**

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2. Miss millions of patients with such doses
3. Myth that cancer patients get high doses in any way. Role of medical physicists
4. Despite use of the BEST system for imaging appropriateness and optimization, thousands of patients with 3-digit doses with sizable number with long life expectancy
5. We should press for research to establish gap correction factors, till that time cumulative dose is the way
6. Risk-benefit is the fundamental principle, not just benefit alone (Clinician part?)

**Long survival diseases**

- Crohn’s disease
- Heart disease
- Trauma
- Many cancers are curable
  - Prostate
  - Testicular
  - Thyroid
  - breast
  - melanoma
Cumulative dose data has been available via thousands of “dose management systems” installed in US and Europe for many years, without any evidence suggesting information on cumulative doses prevents necessary clinical imaging.

On the contrary, experience from Europe shows that it improves the process of justification and optimization: How tracking of radiologic procedures and dose helps: experience from Finland. AJR 2013 200(4):771-5
Conclusions from recent paper

- Overall, total deaths and deaths from specific causes were not elevated in MDs performing Fluoroscopic guided interventions as compared with psychiatrists.

- **Message:** Individual case reports vs analysis of large sample with controls
Avoid misconception

- There is no proposal from ICRP, NCRP and IAEA to introduce dose limit for patients
- There is NO Recommendation to use a defined value of cumulative dose to stop a needed examination


Patient champion

What I can do is

- Cite their research
- Collaborate with them
- Produce joint publications
- Do surveys with them
List of actions where MPs can contribute
• Risk-coefficients, probabilities in age groups and different diseases
• Modeling to assess what % of the high dose group patients are likely to be radio-sensitive
• More than a dozen points on medical physicists can work listed at: https://www.iaea.org/sites/default/files/position_statement_final_endorsed.pdf

What medical physicists can do?
• Brain-storm: How to deal with Elephant in the room
• Identify patient population
  ➢ where radiation risk is of High, moderate or of low importance (end stage disease, age, radiation risks of no significance). It will not be wise to assume that all patients fall in one category of going to die from the disease in any way
  ➢ where there is high probability of higher doses

Concluding remarks
This area needs collaborative work/projects, not just debate (best brains)
Remember: Sizable group of patients with long life expectancy with 3-digit doses despite use of BEST systems of today (Elephant in the room)
We should value our tools the way others do

Thank You
madan.rehani@gmail.com
mrehani@mgh.harvard.edu

Institute Duration Number of Number of Total number of patients undergoing CT
(years & months) Hospitals CT scanners
MGH 5 yrs 5 sites 19 267,013
Orlando 2 yrs 7 m 16 sites 35 430,040
Slovakia 5 yrs 70 108 807,526
National 1 yr 1 m 252 326 999,997
data Hospitals in USA

Total 324 488 2,504,585


<table>
<thead>
<tr>
<th>Institute</th>
<th>Total number of patients with CED≥ 100 mSv (% )</th>
<th>Duration (yrs)</th>
<th>Maximum CED mSv</th>
<th>Median CED mSv</th>
<th>Mean number of CT exams per patient</th>
<th>Median number of CT exams per patient</th>
<th>Maximum number of CT exams in any patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGH</td>
<td>8,952 (3.4%)</td>
<td>5 yrs</td>
<td>1185</td>
<td>146.9</td>
<td>21 19 109</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orlando</td>
<td>586 (1.4%)</td>
<td>31 m</td>
<td>785.7</td>
<td>129.9</td>
<td>12 11 57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slovakia</td>
<td>12,198 (1.5%)</td>
<td>5 yrs</td>
<td>864.7</td>
<td>130.7</td>
<td>6.3 6 67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitals in USA</td>
<td>6,369 (0.64%)</td>
<td>13 m</td>
<td>800.3</td>
<td>125.5</td>
<td>7 6 89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>33,417 (5.37%)</td>
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</table>

Nearly 20% (13.4 to 28%) are ≤ 50 years. About 1 in 5 ≤ 50 years.


Key Points

- Notifications and alerts on patient dose values for computed tomography (CT) and fluoroscopy-guided interventional procedures (PGIP) allow to improve radiation safety and contribute to the avoidance of radiation injuries and unintended and accidental exposures.

- Alerts may be established before the imaging procedures (as in CT) or during and after the procedures as for PGIP.

- Dose management systems should include notifications and alerts and their registry for the hospital quality programmes.


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- Dose management systems should include notifications and alerts and their registry for the hospital quality programmes.
We need to know the different grades of risks such as low, medium, high, very high, critical, and very critical.

Survey among referring clinicians_2

- When asked whether there should be a regulation to limit the number of CT scans that can be prescribed for a single patient in one year, only a small fraction (143, 28%) answered ‘No’, 182 (36%) answered ‘Maybe’ and 166 (33%) answered ‘Yes’. Most respondents (337; 67%) think that radiation risk should form part of the consideration when deciding whether to request a CT exam.