Patients with over 100 mSv doses: Experience from large scale studies to assess the magnitude

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

What we knew before we started

- Scattered reports of patients with high cumulative doses from recurrent CTs
- Mostly based on multiplying number of CTs with typical dose
- Several studies in specific disease conditions e.g. Crohn's disease, Cardiac, End-stage kidney disease, EVAR...
- CT technology has been improving continuously with focus on dose reduction

A check on PubMed for the number of papers on CT dose optimization in 2019 shows three to five papers every week.

Normalized to “radiology” publications

"radiation dose" AND "computed tomography"

Incomplete list

2001-2005
International Action Plan (IAEA)
Cancer risk from CT scan
First skin injury from CT and DSA combined

2006-2010

2011-2015
Choosing Wisely

2016-
Several regional and national campaigns

2016-

Incomplete list
General feeling on CT doses

- Patient doses have gone down substantially for a defined level of information
- There are continuous efforts and momentum has been astounding
- CT cannot be considered a high dose imaging modality

Patient doses have gone down substantially for a defined level of information. There are continuous efforts and momentum has been astounding. CT cannot be considered a high dose imaging modality.

Most organizations

- Negative information gets highlighted in public domain
- This is a significant positive movement in professional domain

Common perception

- With current technology, difficult to imagine that patients with 100 mSv+ are in number worth thinking much (100 mGy organ dose).
- If there are, they are likely confined to specialized hospitals with specialized patients, not a common occurrence.
- They may be the patients who are mostly older in age and with malignant or disease with lower life expectancy.

Hey!!!! Hold on
May be we had not looked at something!

What we did not know?

- What really is the magnitude of patients in high dose group of 100 mSv+?
- Are there reasonable number of patients in this group in lower age brackets of 0-10, 11-20, 21-30, 31-40... yrs.?
- How many % with and without malignancy?
- If there are sizeable, is it because of lack of optimization and justification?

What we did?

- Started with a single major hospital
- Only when the data was such that it needed further studies, extended to wide scale


<table>
<thead>
<tr>
<th>Institute</th>
<th>Duration (Years &amp; months)</th>
<th>Number of Hospitals</th>
<th>Number of CT scanners</th>
<th>Total number of patients undergoing CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A in USA</td>
<td>5 yrs</td>
<td>5 sites</td>
<td>19</td>
<td>267,013</td>
</tr>
<tr>
<td>B in USA</td>
<td>2 yrs 7 m</td>
<td>16 sites</td>
<td>35</td>
<td>430,049</td>
</tr>
<tr>
<td>National data Europe</td>
<td>5 yrs</td>
<td>70</td>
<td>108</td>
<td>807,526</td>
</tr>
<tr>
<td>D in USA</td>
<td>1 yr 1 m</td>
<td>252</td>
<td>326</td>
<td>999,997</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>324</td>
<td>488</td>
<td>2,504,585</td>
</tr>
</tbody>
</table>
Patients with 100 mSv+

- 0.64% to 3.4% with average of 1.33%
- Roughly 1% and that means 1 in every 100 patients who undergoes CT exam
- ONLY from recurrent CT exams

Reference, Table 2 in:

Typical arguments
1. Patients may be over 50 years of age with a significantly lower probability of radiation effects
2. CT scans may not be optimized
3. CT scans may not be clinically justified.

Data on cohort with cumulative effective dose (CED) ≥ 100 mSv

<table>
<thead>
<tr>
<th>Institution</th>
<th>Total number of patients with CED ≥ 100 mSv (%)</th>
<th>Minimum CED mSv</th>
<th>Median CED mSv</th>
<th>Maximum 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>A</td>
<td>8,952 (3.4%)</td>
<td>1185</td>
<td>146.9</td>
<td>21</td>
<td>19</td>
<td>109</td>
</tr>
<tr>
<td>B</td>
<td>5888 (1.4%)</td>
<td>785.7</td>
<td>129.9</td>
<td>12</td>
<td>11</td>
<td>57</td>
</tr>
<tr>
<td>C</td>
<td>12,198 (3.0%)</td>
<td>864.7</td>
<td>130.7</td>
<td>6.3</td>
<td>6</td>
<td>67</td>
</tr>
<tr>
<td>D</td>
<td>6,369 (0.64%)</td>
<td>800.3</td>
<td>125.5</td>
<td>7</td>
<td>6</td>
<td>89</td>
</tr>
</tbody>
</table>

Institution Minimum days needed for a patient to get 100 mSv

<table>
<thead>
<tr>
<th>Institution</th>
<th>Minimum days needed for a patient to get 100 mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
</tr>
</tbody>
</table>
Nearly 20% (13.4 to 28%) are ≤ 50 years. About 1 in 5 ≤ 50 years.


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 angio 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>A</td>
<td>254 (75%)</td>
<td>772 (89%)</td>
<td>561 (84%)</td>
<td>476 (70%)</td>
<td>204 (38%)</td>
</tr>
<tr>
<td>D</td>
<td>336</td>
<td>903</td>
<td>600</td>
<td>615</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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

Important points

- We are NOT saying that CT was used in these patients without justification or optimization (at least for the MGH part)
- Perhaps this may be the first time when imaging appropriateness in such patients was seriously studied
- Can anyone think of a time in last century when there was a similar situation?

Even though CT is one of the safest imaging modalities, and its contribution to patient benefit is unquestionable, it seems that we have a real point for patients who need recurrent imaging.

Remember: This is what we felt.
Sorry. No chance to sit back and relax, but need to act further.

Do you agree that there is need for contributions by Medical Physicists, Industry, and Users?


CT is still not a low-dose imaging modality

M. Kachelrieß, M. M. Rehani


Is it possible to kill the radiation risk issue in computed tomography?

More powerful X-ray tubes, thicker prefilters, in a filter changer
Use of tunable tube voltage settings
AGC not only to include mA modulation but also kV and filter thickness modulation
Adaptive bow-tie filters
Photon counting detector technology
Deep learning

Future

There will be a need to include the concept of cumulative dose in Standards and regulations

We foresee that with industry acting, 100 mSv+ will become a thing of the past at least in CT
With the concept of Cumulative Dose

Total dose to patient will include not only from CT, but NM, interventional and imaging dose from RT

Holistic approach of patient protection

Protection of individual patient

“Whatever you do will be insignificant, but it is very important that you do it”

To myself I am only a child playing on the beach, while vast oceans of truth lie undiscovered before me.

—Isaac Newton

Thank You

mrehani@mgh.harvard.edu
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