Estimating Risks from CT Scans
- in the Context of CT Scan Benefits

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There is no question that CT has revolutionized medical practice

- More effective surgical treatment
- Shorter hospital stays
- Elimination of exploratory surgeries
- Better diagnosis and treatment of cancer
- More efficient treatment after injury
- Better treatment of stroke
- Better treatment of cardiac conditions
Why are we particularly interested in CT?
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<table>
<thead>
<tr>
<th>Examination</th>
<th>Relevant organ</th>
<th>Relevant organ dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental x ray</td>
<td>Brain</td>
<td>0.005</td>
</tr>
<tr>
<td>PA Chest x ray</td>
<td>Lung</td>
<td>0.01</td>
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<tr>
<td>Lateral chest x ray</td>
<td>Lung</td>
<td>0.15</td>
</tr>
<tr>
<td>Screening mammogram</td>
<td>Breast</td>
<td>3</td>
</tr>
<tr>
<td>Adult abdominal CT</td>
<td>Stomach</td>
<td>11</td>
</tr>
<tr>
<td>Adult head CT</td>
<td>Brain</td>
<td>13</td>
</tr>
<tr>
<td>Child abdominal CT</td>
<td>Stomach</td>
<td>10-25</td>
</tr>
<tr>
<td>Child head CT</td>
<td>Brain</td>
<td>20-25</td>
</tr>
<tr>
<td>Adult $^{18}$F-FDG PET</td>
<td>Bladder</td>
<td>18</td>
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</table>
Why are we particularly interested in CT?

Frequency of CT scans per year in the US
Mean individual total radiation dose in the US: 1980 vs. 2011

1980: 3.6 mSv

2011: 7.2 mSv
Average individual dose from medical imaging
USA: 1980 vs. 2011

1980

2011

All medical exams: 0.5 mSv

Other medical exams: 1.9 mSv

CT scans: 2.2 mSv

8 fold increase
The key organ-dose ranges of relevance for CT are

Taking into account

* Machine variability,
* Usage variability,
* Age variability,
* Scans done with and without contrast
* Multiple scans

Relevant organ dose ranges for CT are

5 - 100 mSv for a single series of scans
Brown dots: Individuals exposed to between 5 and 100 mGy (~25,000)
Objective: In light of the rapidly increasing frequency of pediatric CT examinations, the purpose of our study was to assess the lifetime cancer mortality risks attributable to radiation from pediatric CT.

Materials and Methods: Organ doses as a function of age at diagnosis were estimated for common CT examinations, and estimated attributable lifetime cancer mortality risks per unit dose for different organ sites were applied. Standard models that assume a linear extrapolation of risks from intermediate to low doses were applied. On the basis of current observed prevalence of radiation exposure (millisieverts) and organ doses, risk estimates attributable to radiation exposure from a CT in a 1-year-old are 0.016/1000 (abdominal) and 0.006/1000 (head)—orders of magnitude higher than for adults. Although average organ doses were small, CT examinations delivered between 100 and 1500 millisieverts annually to pediatric patients under the age of 15 years, a dose that is above 50% of that expected among cancer survivors attributable to the CT radiation.

Conclusion: The best available risk estimates suggest that pediatric CT is not negligible and may cause additional organ doses greater than adult CT, both because of the increased dose per millisievert and the increased lifetime risk per unit dose. Lower millisievert-second-weighted settings can be used for children without significant loss of information. Although the risk-benefit balance is still reasonably tilted toward benefit, because of the frequency of pediatric CT examinations, it is rapidly increasing. The estimated lifetime attributable risks for children undergoing CT are not negligible and may translate into other sources of radiation exposure in pediatric patients.

Risk estimates based on organ doses and A-bomb survivor data - 2001
Not everyone was convinced...

“I read with dismay the article by Brenner et al. [1] in the February issue. The claim that using CT in the pediatric population results in an increased risk of cancer is unfounded. Their claim is based on the use of “relative risk models” that have never been proven. Moreover, their calculations are based on a setting of 404 mAs for abdominal CT, much more than is now used for adult CT scanning. This figure was taken from a 1989 survey of CT practice in Britain and does not reflect settings that are used in the United States today. This spurious claim of increased cancer risk has been trumpeted by the media and has generated considerable unwarranted anxiety among the parents of our patients.

It is emphasized in the articles by Brenner et al. [2] and Donnelly et al. [3] in the same issue, we should all use the minimum exposure necessary to obtain a diagnostic examination. This is a good reason for children’s imaging to be done by pediatric radiologists.

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Could an epidemiological study of CT risks be performed in the US?
The 2012 UK CT Study

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Mark S Pearce, Jane A Salotti, Mark P Little, Kieran McHugh, Choonsik Lee, Kwang Pyo Kim, Nicola L Howe, Cecile M Ronckers, Preetha Rajaraman, Sir Alan W Craft, Louise Parker, Amy Berrington de González

www.thelancet.com Published online June 7, 2012 DOI:10.1016/S0140-6736(12)60815-0

~10 year follow-up of 175,000 patients who received CT scans in the UK, age <22, between 1985 and 2002
Statistically significant linear associations were seen between brain dose and brain tumor risk ($p<0.0001$), and between bone-marrow dose and leukemia risk ($p=0.01$).
Critiques of the CT Studies

1. **Reverse causation**
   A CT scan is ordered due to symptoms of a cancer which has not yet been detected, but ends up being detected some time later

2. **Confounding by indication**
   A CT scan is ordered due to a condition, e.g., Crohn’s disease, which itself increases cancer risk through radiation-independent or radiation-dependent pathways
### Absolute risks from the UK CT study vs. A-bomb based estimates

**For a pediatric head CT scan, done around 1995**

<table>
<thead>
<tr>
<th></th>
<th>UK CT study (corrected to lifetime follow-up)</th>
<th>A-bomb estimates, (corrected to lifetime follow-up)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leukemia</strong></td>
<td>1 in 7,500</td>
<td>1 in 10,000</td>
</tr>
<tr>
<td><strong>Brain tumor</strong></td>
<td>1 in 1,000</td>
<td>1 in 2,000</td>
</tr>
</tbody>
</table>

Based on Pearce *et al* 2012

Based on Brenner *et al* 2001
What I think we know about risks from CT scans

- We have now passed a watershed in our field where it is no longer reasonable to suggest that CT risks are “too low to be detectable or may be non-existent”
  - We now know (almost) for sure that individual CT risks are small but real

- Because the individual risks are very small, the individual benefits of any clinically-justified CT scan will by far outweigh the individual radiation risks
  - No need for super-accurate benefit-risk analyses for clinically-justified scans

- While individual risks are very small, because the number of CT scans is very large, there will be significant population risks associated with CT
  - This can be minimized by justifying and optimizing every CT scan

- The CT risk issue is not confined to children
  - Because there are far more adult CT scans, the population risks are probably larger for adults than for children
Conclusions I:
Are CT radiation risks real?

- Almost certainly
Conclusions II:
The individual risks are very small

- When a CT scan is clinically warranted, the benefit will by far outweigh any possible individual radiation risk

- (though of course we can and should continue to lower doses per scan)
Conclusions III: Reducing clinically unwarranted CT scans

- The main concern now is really about the population exposure from the roughly $\frac{1}{4}$ of CT scans that may not be clinically warranted.