What do we really know about cancer risks at doses pertinent to CT scans?

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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?

<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>
</tr>
<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 18F-FDG PET</td>
<td>Bladder</td>
<td>18</td>
</tr>
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</table>
Why are we particularly interested in CT?

Frequency of CT scans per year in the US

The key organ-dose ranges of relevance for CT

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

Estimating the radiation-induced cancer risks from CT exams

- Risk estimation based A-bomb survivor data and CT organ doses
- Direct epidemiology on people who received CT scans
Understanding CT Risks
AAPM 2016
David J Brenner, Columbia University

**Atomic bomb survivor locations by dose**

Brown dots: Individuals exposed to between 5 and 100 mGy (~25,000)

Douple et al 2011

**RERF solid-cancer low-dose trend tests**

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<tr>
<th>Cancer Mortality</th>
<th>&gt;0 to 0.1 Gy</th>
<th>P=0.04</th>
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Cancer Mortality

• >0 to 0.1 Gy P=0.04
• >0 to 0.15 Gy P=0.006

Cancer Incidence

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Risk estimates based on organ doses and A-bomb survivor data - 2001

RERF solid-cancer low-dose trend tests

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The 2012 UK CT Study

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

- 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)
The 2013 Australian CT Study

Cancer risk in 680 000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians

The 2013 Australian CT Study

Incidence rate ratios for all cancers

Potential Biases 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
Reverse causation: The effect of increasing lag time

The 2013 Australian CT Study

To study potential confounding....

- We are evaluating the risk of colorectal cancer in relation to abdominopelvic CT in adults scanned at Columbia University Medical Center
- Electronic records for patients without previous cancer diagnoses who got CT scans from 1994-2013, and were followed for >2 years
- 70,000 patients had 200,000 CTs
- Followup analysis lag of 1 year to eliminate CTs related to cancer diagnosis
- Median follow-up time 6 years
- We classified reasons for CTs into 12 broad categories and estimated the association between each category and colorectal cancer risk

Hazard ratios for patients who had a CT scan for a given reason vs. patients who had a CT scan for any reason

Abdominal-pelvic CT and colon cancer
The UK CT Study
Absolute risk estimates

- Pearce et al estimated absolute risks of about 1 in 10,000 per head CT scan, both for leukemia and for brain tumors
- How does this compare with lifetime risk estimates based on organ doses and A-bomb survivor data?

UK CT study: Absolute risks vs. A-bomb based estimates

<table>
<thead>
<tr>
<th></th>
<th>UK CT study (10 yrs follow-up)</th>
<th>UK CT study (corrected to lifetime follow-up)</th>
<th>A-bomb estimates, (corrected to lifetime follow-up)</th>
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<tr>
<td>Leukemia</td>
<td>1 in 10,000</td>
<td>1 in 7,500</td>
<td>1 in 10,000</td>
</tr>
<tr>
<td>Brain tumor</td>
<td>1 in 10,000</td>
<td>1 in 1,000</td>
<td>1 in 2,000</td>
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For a pediatric head CT scan, done around 1995

Based on Pearce et al 2012
Based on Brenner et al 2001

The pediatric CT Epi Studies:
Pretty important events in our field

- We have now passed a watershed in the field and it is now not very plausible to suggest that CT risks are "too low to be detectable and may be non-existent" (AAPM 2011)
Do CT risk estimates "cause some patients to refuse medical imaging ... placing them at substantial risk" (AAPM 2011)?

- **Boutis et al. (2013):**
  - 742 parents of child in ED with head injury were given appropriate risk information
  - Zero refused a recommended CT scan

- **Larsen et al. (2007):**
  - 100 parents of child recommended for CT were given appropriate risk information
  - Zero refused a recommended CT scan

- **Gebhard et al. (2015):**
  - 120 parents of child recommended for fluoroscopy were given appropriate risk information
  - Zero refused recommended fluoroscopy exam

Should we be primarily concerned about children and young adults?

Most CT scans are given in middle age

**Age distribution of CT scans, US, 2007**

From: Berrington de Gonzalez et al 2009
Conclusions

I: Are individual CT radiation risks real?

- Almost certainly
- But the risks are small

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 is really about the population exposure from the roughly 25% of CT scans (~20 million CTs / yr) that may not be clinically warranted.