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

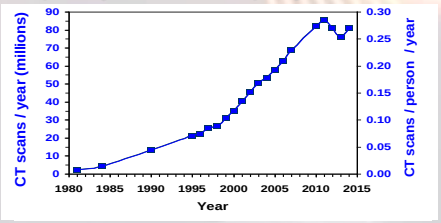
- ✓ *More effective surgical treatment*
- ✓ *Shorter hospital stays*
- ✓ *Elimination of exploratory surgeries*
- ✓ *Better diagnosis and treatment of cancer*
- ✓ *More efficient treatment after injury*
- ✓ *Better treatment of stroke*
- ✓ *Better treatment of cardiac conditions*

Why are we particularly interested in CT?

Examination	Relevant organ	Relevant organ dose (mGy)
Dental x ray	Brain	0.005
PA Chest x ray	Lung	0.01
Lateral chest x ray	Lung	0.15
Screening mammogram	Breast	3
Adult abdominal CT	Stomach	11
Adult head CT	Brain	13
Child abdominal CT	Stomach	10-25
Child head CT	Brain	20-25
Adult ^{18}F-FDG PET	Bladder	18

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**

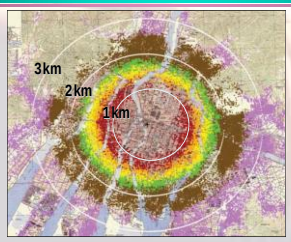
Relevant organ dose ranges for CT are

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**

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

Cancer Mortality

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

Cancer Incidence

- >0 – 0.1 Gy P=0.08
- >0 – 0.15 Gy P=0.01

Courtesy D.L. Preston (2011), based on RERF public dataset DS02can.csv (www.rerf.or.jp)

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


AJR American Journal of Roentgenology

Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT


Let the hype begin

USA TODAY

'Gladiator' wins best drama film

Newsline

CT scans in children linked to cancer later

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

The 2012 UK CT Study

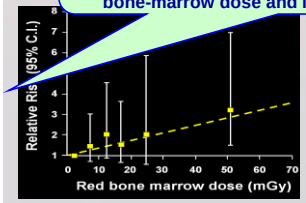
Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

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

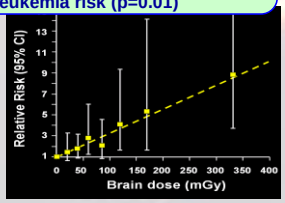
www.thelancet.com Published online June 7, 2012 DOI:10.1016/S0140-6736(12)60815-0

~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 ($p=0.01$)



Leukemia



Brain tumors

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

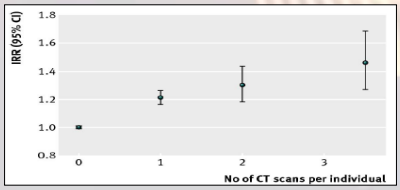
BMJ

John D Mathews *epidemiologist*[1], Anna V Forsythe *research officer*[1], Zoe Brady *medical physicist*[1,2], Martin W Butler *data analyst*[3], Stacy K Goergen *radiologist*[4], Graham B Byrnes *statistician*[5], Graham G Giles *epidemiologist*[6], Anthony B Wallace *medical physicist*[7], Philip R Anderson *epidemiologist*[8,9], Tenniel A Guiver *data analyst*[6], Paul McGale *statistician*[10], Timothy M Cain *radiologist*[11], James G Dowty *research fellow*[1], Adrian C Bickerstaffe *computer scientist*[1], Sarah C Darby *statistician*[10]

~10 year follow-up of 680,000 patients who received CT scans in Australia, age <19, between 1985 and 2005, cancers studied

The 2013 Australian CT Study

Incidence rate ratios for all cancers



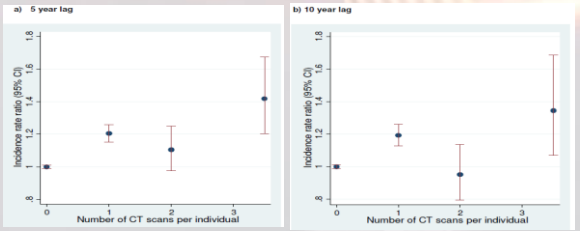
1 year lag period

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

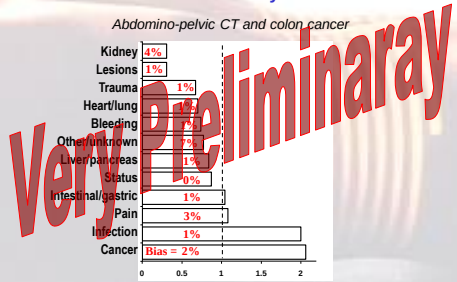


To study potential confounding…..

- 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

Abdomino-pelvic CT and colon cancer



Very Preliminaray

The UK CT Study
Absolute risk estimates

- Pearce *at 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

For a pediatric head CT scan, done around 1995

	UK CT study (10 yrs follow-up)	*UK CT study (corrected to lifetime follow-up)*	*A-bomb estimates, (corrected to lifetime follow-up)*
Leukemia	1 in 10,000	1 in 7,500	1 in 10,000
Brain tumor	1 in 10,000	1 in 1,000	1 in 2,000
	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)*

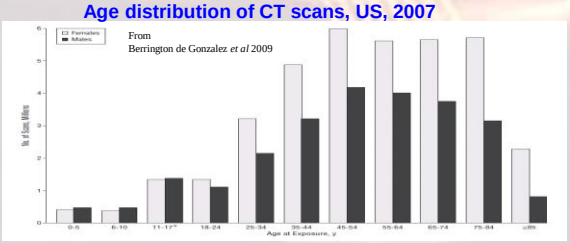
Do CT risk estimates "cause some patients to refuse medical imaging … placing them at substantial risk" (AAPM 2011)?

- 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 fluroscopy 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



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Potential for Adult-Based Epidemiological Studies to Characterize Overall Cancer Risks Associated with a Lifetime of CT Scans

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"Retrospective analysis of CT exposure and cancer incidence data from a population-based cohort of 0.4 to 1.3 million CT-exposed adults, aged 25-65 in 1980, provides 80% power for detecting cancer risks from chest and abdominal CT scans"

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