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

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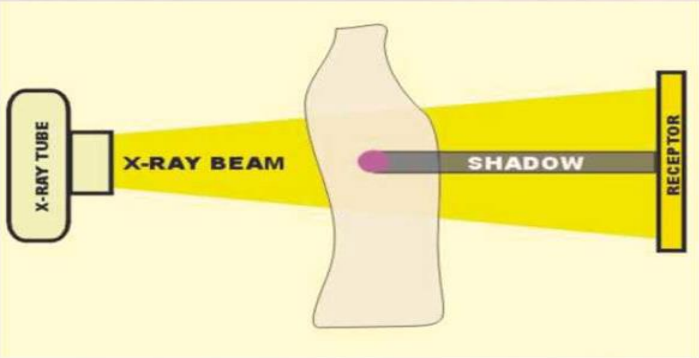
There is no question that CT has revolutionized medical practice

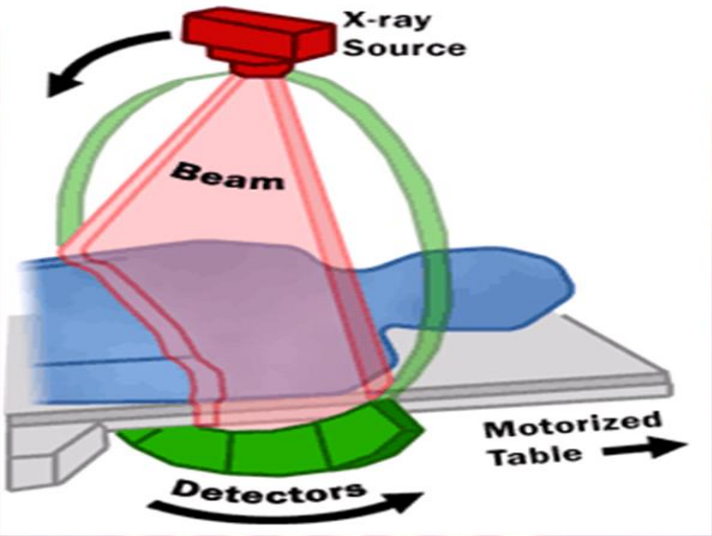
- ✓ *More effective surgical treatment*
- ✓ *Shorter hospital stays*
- ✓ *Elimination of exploratory surgeries*
- ✓ *Better diagnosis and treatment of cancer*
- ✓ *More efficient treatment after injury*
- ✓ *Better treatment of stroke*
- ✓ *Better treatment of cardiac conditions*

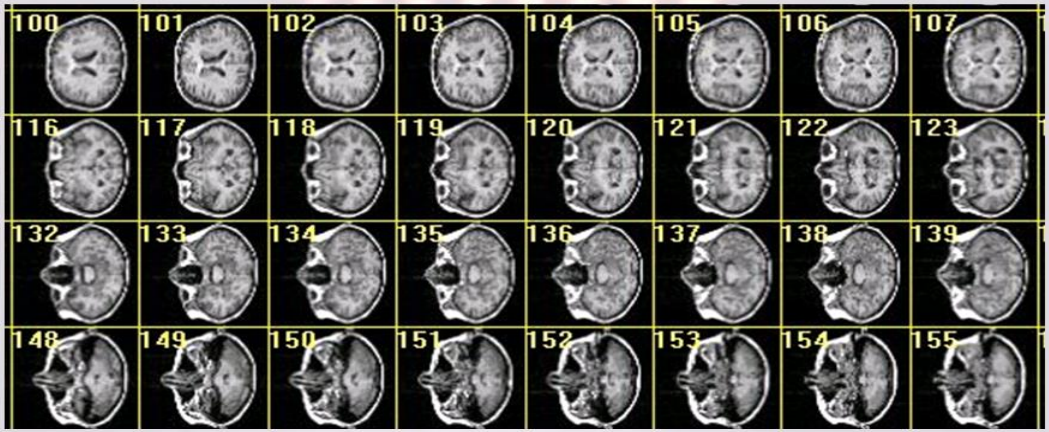
Why are we particularly interested in CT?

Conventional Radiograph



CT



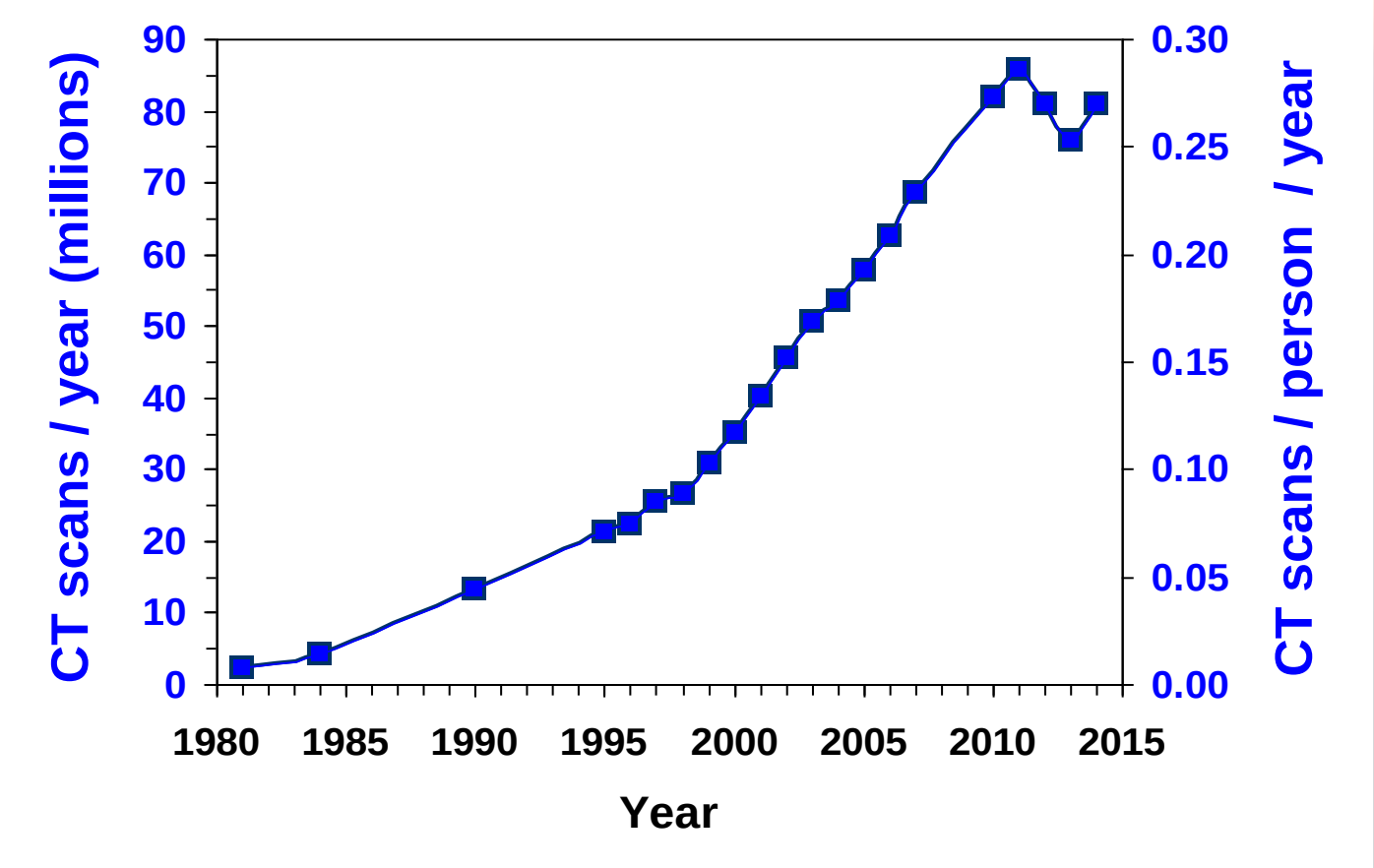


Why are we particularly interested in CT?

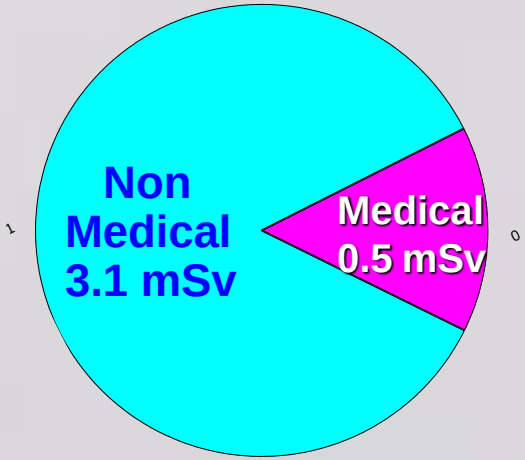
Examination	Relevant organ	Relevant organ dose (mGy)
Dental x ray	Brain	0.005
PA Chest x ray	Lung	0.01
Lateral chest x ray	Lung	0.15
Screening mammogram	Breast	3
Adult abdominal CT	Stomach	11
Adult head CT	Brain	13
Child abdominal CT	Stomach	10-25
Child head CT	Brain	20-25
Adult ^{18}F-FDG PET	Bladder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

Why are we particularly interested in CT?

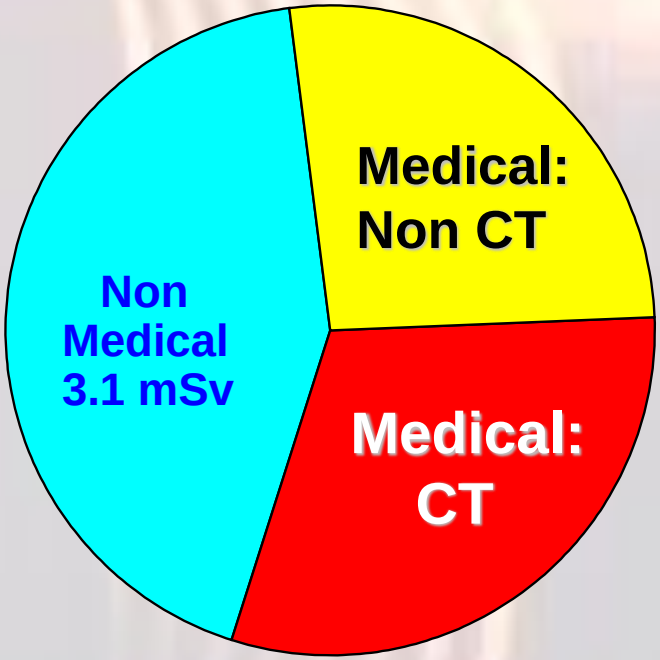
Frequency of CT scans per year in the US



Mean individual total radiation dose in the US: 1980 vs. 2011

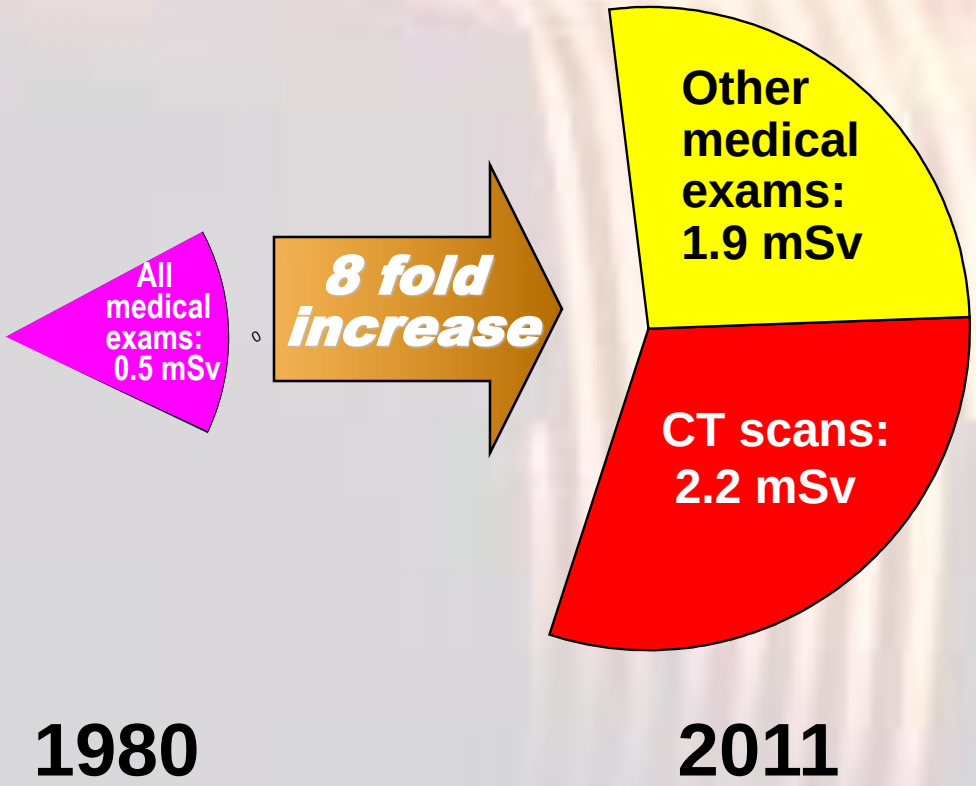


1980: 3.6 mSv



2011: 7.2 mSv

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



The key organ-dose ranges of relevance for CT

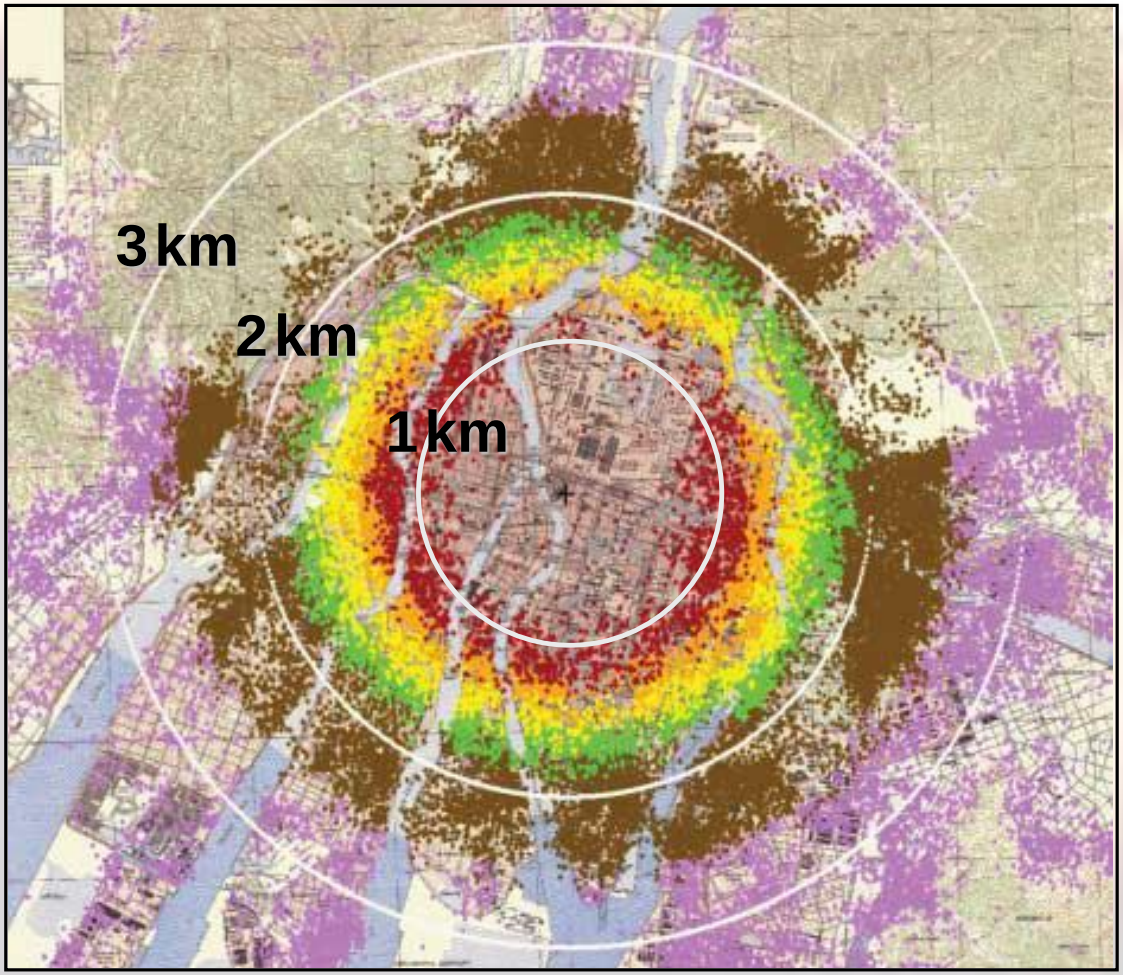
Taking into account

* **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

Atomic bomb survivor locations by dose



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

Douple *et al* 2011

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

AJR American Journal of Roentgenology
Diagnostic Imaging and Related Sciences

Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT

David J. Brenner[1]
Carl D. Elliston[1]
Eric J. Hall[1]
Walter E. Berdon[2]

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 standard practice, the same exposures (milliampere-seconds) were assumed, independent of age.

RESULTS. The larger doses and increased lifetime radiation risks in children produce a sharp increase, relative to adults, in estimated risk from CT. Estimated lifetime cancer mortality risks attributable to the radiation exposure from a CT in a 1-year-old are 0.18% (abdominal) and 0.07% (head)—an order of magnitude higher than for adults—although those figures still represent a small increase in cancer mortality over the natrual background rate. In the United States, of approximately 600,000 abdominal and head CT examinations annually performed in children under the age of 15 years, a rough estimate is that 500 of these individuals might ultimately die from cancer attributable to the CT radiation.

CONCLUSION. The best available risk estimates suggest that pediatric CT will result in significantly increased lifetime radiation risk over adult CT, both because of the increased dose per milliampere-second, and the increased lifetime risk per unit dose. Lower milliampere-second settings can be used for children without significant loss of information. Although the risk–benefit balance is still strongly tilted toward benefit, because the frequency of pediatric CT examinations is rapidly increasing, estimates that quantitative lifetime radiation risks for children undergoing CT are not negligible may stimulate more active reduction of CT exposure settings in pediatric patients.

The use of CT has increased rapidly in the past two decades, fueled in part by the development of helical CT [1]. For example, the estimated annual number of CT examinations in the United States rose approximately sevenfold from 2.8 million in 1981 [2] to 20 million in 1995 [3]. By their nature, CT examinations contribute disproportionately to the collective diagnostic radiation dose to the population; for example, in Britain it has been estimated that approximately 4% of diagnostic radiology procedures are CT examinations, but their contribution to the collective dose is approximately 40% [4].

Figure 1 shows a breakdown of the number of CT examinations by age at examination, based on the results of a 1989 British survey [5]; in this survey, approximately 4% of CT examinations (which corresponds to about 10^6/year in the United States) were performed on children under the age of 15 years. The proportion of childhood CT examinations is rapidly increasing (indeed, an average value of 0% was estimated in 1993 [6]); for example, Coren et al. [7] reported a 63% increase in requests for pediatric CT between 1991 and 1994.

The recent increase in pediatric CT examinations is particularly marked in the United States. Figure 2 shows the number of abdominal and pelvic CT examinations of children under a given age at a major American children's hospital for 1990 through 1999. This figure shows, for example, a 92% increase between 1990 and 1999 in abdominal and pelvic CT examinations on children less

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▸ The red carpet, 5D

By Robert Hanashiro, USA TODAY

Roberts: Smiles for *Erin Brockovich*.

Monday, January 22, 2001

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Asia stocks mixed overnight

Japan's Nikkei average is down 137 points, 1.0%, to 13,852 early today. Hong Kong's Hang Seng index is up 136 points, 0.9%, to 16,069.

CT scans in children linked to cancer later

By Steve Sternberg
USA TODAY

Each year, about 1.6 million children in the USA get CT scans to the head and abdomen — and about 1,500 of those will die later in life of radiation-induced cancer, according to research out today.

What's more, CT or computed tomography scans given to kids are typically calibrated for adults, so children absorb two to six times the radiation needed to produce clear images, a second study shows. These doses are "way bigger than the sorts of doses that people at Three Mile Island were getting," David Brenner of Columbia University says. "Most people got a tenth or a hundredth of the dose of a CT."

Both studies appear in February's *American Journal of Roentgenology*, the nation's leading radiology journal. The first, by Brenner and colleagues, is the first to estimate the risks of "radiation-induced fatal cancer" from pediatric CT scans. Until a decade ago, CT scans took too long to perform on children without giving them anesthesia to keep them still. Today's scanners spiral around the patient in seconds, providing cross sections, or "slices," of anatomy.

Doctors use CT scans on children to search for cancers and ailments such as appendicitis and kidney stones.

"There's a huge number of people who don't just receive one scan," says Fred Mettler of the University of New Mexico, noting that CT scans are used for diagnosis and to plan and evaluate treatment. "The breast dose from a CT scan of the chest is somewhere between 10 and 20 mammograms. You'd want to think long and hard about giving your young daughter 10 to 20 mammograms unless she really needs it."

Mettler recently published a study showing that 11% of the CT scans at his center are done on children younger than 15, and they get 70% of the total radiation dose given to patients. Children have more rapidly dividing cells than adults, which are more susceptible to radiation damage. Children also will live long enough for cancers to develop.

Researchers led by Lane Donnelly at Cincinnati's Children's Hospital found that children often get radiation doses six times higher than necessary. Cutting the adult dose in half would yield a clear image and cut the risk a like amount, Brenner says. "Radiologists genuinely believe the risks are small," he says. "I suspect they've never been confronted with numbers like this."

Not everyone was convinced…

AJR American Journal of Roentgenology

Taking Care of Children

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 [illegible] considerable unwarranted anxiety among the parents of our patients.

[illegible] emphasized in the articles by Paterson 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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New York, NY 10021

"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."

Could an epidemiological study of CT risks be performed in the US?

The 2012 UK CT Study

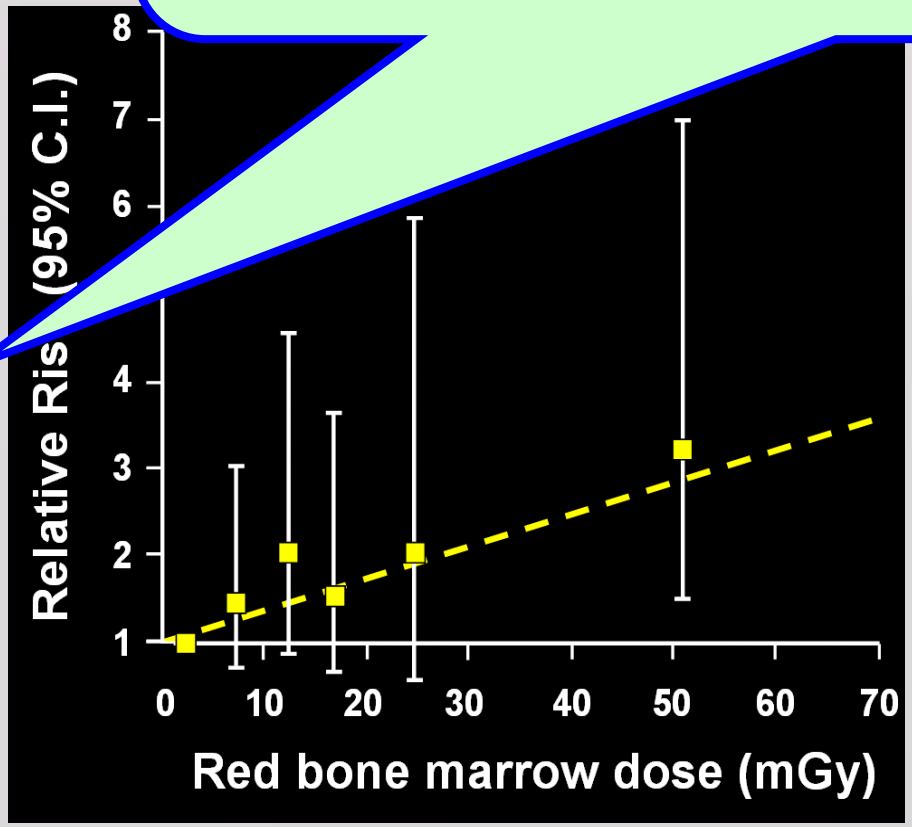
Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

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

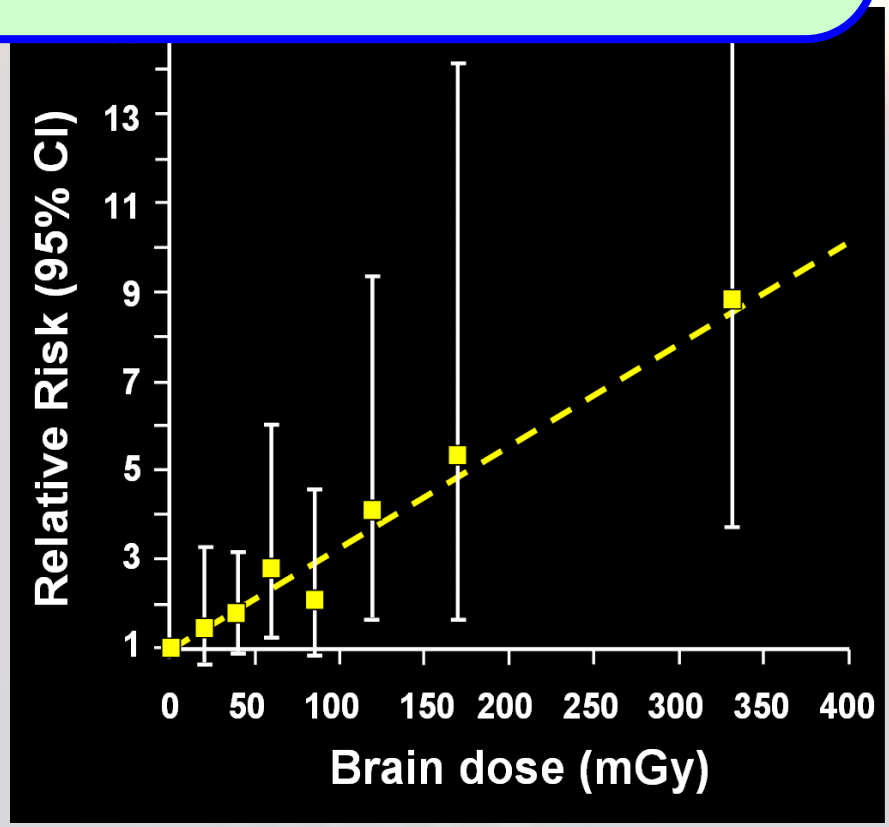
www.thelancet.com **Published online June 7, 2012** **DOI:10.1016/S0140-6736(12)60815-0**

~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)**



Leukemia



Brain tumors

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

	UK CT study (corrected to lifetime follow-up)	*A-bomb estimates, (corrected to lifetime follow-up)*
Leukemia	**1 in 7,500**	**1 in 10,000**
Brain tumor	**1 in 1,000**	**1 in 2,000**
	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 ¼ of CT scans that may not be clinically warranted**