Published in final edited form as:
Lancet. 2012 August 4; 380(9840): 455–457. doi:10.1016/S0140-6736(12)60897-6.

Beyond the Bombs: Cancer Risks from Low-Dose Medical Radiation

Andrew J Einstein
Division of Cardiology, Department of Medicine, and Department of Radiology, Columbia University Medical Center New York, NY 10032, USA

Andrew J Einstein: andrew.einstein@columbia.edu

It's been a decade since Brenner and colleagues published their landmark paper[1] suggesting that the radiation doses from paediatric computed tomography (CT) scans would cause a significant number of cancer deaths, sometime in the future. The following day the story hit the front page of *USA Today*, and the world of CT scans was changed forever.

It was never in question that CT is a remarkably effective modality, but the message that there might be some potential downside in terms of cancer risks was one that was immediately and vehemently questioned by many practitioners.

Specifically, these risk estimates for paediatric CT, as well as subsequent estimates for other medical exposures[2], were derived using risk projection models based on data from studies of Japanese atomic bomb survivors.[3, 4] Clearly there are many differences between a CT scan and an atomic bomb exposure, even though about 28,000 atomic bomb survivors (a couple of miles from the epicenter) did indeed get radiation exposures comparable to those from a few CT scans. For one thing CT scans are typically focused on a particular part of the body, whereas atomic bomb exposures were to the whole body. These differences are taken into account, insofar as possible, in the models used to estimate CT scan risks, but were the predictions correct that there is a small but real cancer risk associated with CT scans?

Many medical practitioners suggested that the evidence for a small but real cancer risk associated with CT scanning was simply speculation. For example a position paper[5] from the American Association of Physicists in Medicine states that "Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be nonexistent." Others suggested that the risk estimates were based on the best available science at the time. Indeed, no epidemiologic study has been previously published that convincingly demonstrates increased cancers associated with low-dose radiation from medical imaging during childhood or adulthood. Into this tangle enter the study in *The Lancet* by Pearce et al.[6]

The authors investigated a cohort of 178,604 children without cancer who underwent x-ray CT between 1985 and 2002 in a wide range of hospitals across the United Kingdom. They used state-of-the-art dosimetric methodology to estimate radiation doses to individual organs of these children, and identified subsequent cancers via linkage to the National Health Service Central Registry. To avoid confounding the data with CT scans performed for cancer diagnosis, they excluded leukaemias occurring within 2 years of the scan and brain tumours occurring within 5 years, lag periods during which it is not thought that radiation-related cancers occur.

In the present publication[6], the initial analysis of this cohort, analysis is limited to leukaemia and brain cancer risks, with a typical follow-up of about 10 years after exposure and maximum follow-up time of 23 years. Over this follow-up period, statistically significant

increases in leukaemia incidence were found in the children with cumulative bone marrow doses from CT of at least 30 milliGray (here equivalent to 30 milliSieverts), while significant increases in brain tumour incidence were found in children with brain doses of at least 50 milliGray (i.e., milliSieverts). Using current typical doses, the authors thus found that 2–3 head CTs could triple childrens' risk of brain cancer and that 5–10 head CTs could triple the risk of leukaemia. The risk of leukaemia was significantly positively associated with the radiation dose to the bone marrow, and the risk of brain tumour was similarly associated with dose to the brain. The findings of Pearce et al suggest a higher but statistically-compatible radiation-attributable brain cancer risk per unit than does the atomic bomb survivor data, and a similar leukaemia risk.

In addition to the UK cohort, at least a dozen other groups are studying or are planning to study national cohorts of children (Table). Large Australian and Canadian cohorts are expected to report findings in the next year or two, while the EPIdemiological Study to Quantify Risks for Paediatric Computerized Tomography and to Optimise Doses (EPI-CT) is expected to report a pooled analysis of data from 9 European cohorts in 2016. Future analyses of UK children are expected to identify cancer risks from other solid tumours and be based on longer follow-up and an expanded cohort. Together, these studies will provide us with a more robust evidence base informing our understanding of radiation-induced malignancy at low doses.

What implications does this study have for clinical practice and policy? The Pearce paper[5] should reduce the number of debates about whether CT risks are "real", but in fact the field has anyway changed remarkably in the last decade, even while the risk debates raged on. New CT scanners all now have dose-reduction options, and there is far more awareness among most practitioners about the need to both *justify* and *optimise* CT doses – an awareness which will surely be bolstered by the Pearce et al study.[6]

Justification of any CT scan prescription is important, because there is good evidence that 20–50% of CT examinations could either be not done at all, or could be replaced with some other type of imaging.[7] On a patient level, justification should take account of all available information, including details of the proposed procedure and alternative management strategies, patient characteristics, the expected radiation dose and its associated degree of risk, information on previous or expected procedures, and patient preferences.[8] A shared responsibility between referring and performing healthcare providers[8], justification is facilitated by the "3 As" of *awareness*, *appropriateness*, and *audit*—awareness by knowledgeable providers who assist the patient in balancing the immediate benefits of medical radiation with its downstream radiation risk, use of appropriateness guidelines to ensure that those referred for radiological examinations need them, and *post hoc* audit of imaging use against agreed-upon standards of good practice.[7]

Optimisation incorporates keeping radiation exposure as low as reasonably achievable (ALARA) for any and every study. A variety of modality- and procedure-specific techniques are available, though they are not always utilized. In paediatric CT, for example, these include "child sizing" scan parameters such as the x-ray tube current and voltage, personalizing protocols on the basis of referral indication, limiting the area scanned, and scanning only once.[9] However the wide range of dose indices reported for the same CT procedures[10] underscore the extensive efforts still needed to ensure that radiation exposure is optimized for every patient.

In summary, a decade after the suggestion[1] that CT scans might produce a small cancer risk, Pearce et al[6] have shown that this is almost certainly the case. CT usage continues to rise,

generally with good clinical reasons, so we must redouble our efforts to justify and optimize every CT scan.

Acknowledgments

Supported by US National Heart, Lung, and Blood Institute R01 HL109711, a Victoria and Esther Aboodi Assistant Professorship, and the Louis V. Gerstner, Jr. Scholars Program. AJE has received previous research support from GE Healthcare and Spectrum Dynamics, and has been a consultant for Kyowa Hakko Kirin Pharma.

References

1. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR Am J Roentgenol. 2001 Feb; 176(2):289–96. [PubMed: 11159059]
2. Einstein AJ, Henzlova MJ, Rajagopalan S. Estimating risk of cancer associated with radiation exposure from 64-slice computed tomography coronary angiography. JAMA. 2007 Jul 18; 298(3): 317–23. [PubMed: 17635892]
3. Preston DL, Ron E, Tokuoka S, Funamoto S, Nishi N, Soda M, et al. Solid cancer incidence in atomic bomb survivors: 1958–1998. Radiat Res. 2007 Jul; 168(1):1–64. [PubMed: 17722996]
4. Einstein AJ. Effects of radiation exposure from cardiac imaging how good are the data? J Am Coll Cardiol. 2012 Feb 7; 59(6):553–65.
5. American Association of Physicists in Medicine. AAPM Position Statement on Radiation Risks from Medical Imaging Procedures. Policy date 12/13/2011. http://aapm.org/org/policies/details.asp?id=318&type=PP&current=true
6. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation exposures from CT scans in childhood and subsequent risk of leukemia and brain tumors, an historical cohort study. Lancet. 2012 FULL CITATION HERE.
7. Malone J, Guleria R, Craven C, Horton P, Jarvinen H, Mayo J, et al. Justification of diagnostic medical exposures: some practical issues. Report of an International Atomic Energy Agency Consultation. Br J Radiol. 2012 May; 85(1013):523–38. [PubMed: 21343316]
8. The 2007 recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Annals of the ICRP. 2007; 37(2–4):1–332.
9. Strauss KJ, Goske MJ, Kaste SC, Bulas D, Frush DP, Butler P, et al. Image gently: Ten steps you can take to optimize image quality and lower CT dose for pediatric patients. AJR Am J Roentgenol. 2010 Apr; 194(4):868–73. [PubMed: 20308484]
10. Smith-Bindman R, Lipson J, Marcus R, Kim KP, Mahesh M, Gould R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch Intern Med. 2009 Dec 14; 169(22):2078–86. [PubMed: 20008690]

Table 1

Table Cohort Studies of CT Exposure and Cancer Incidence

Country	Exposed Cohort Size	Exposed Age Range	Start Accrual	Estimated Report
Belgium	30,000	0–15	2002	2016
Denmark	30,000	0–18	2000	2016
France	90,000	0–5	2000	2016
Germany	140,000	0–15	1985	2016
Netherlands	40,000	0–18	1998	2016
Norway	20,000	0–20	2005	2016
Spain	200,000	0–20	2005	2016
Sweden	95,000	0–18	1984	2016
UK	400,000	0–21	1985	2012
EPI-CT (Pooled European)	1,045,000	0–21	1984–2002	2016
Australia	660,000	0–19	1985	2012–3
Canada (Ontario)	370,000	0–17	1985	2013
Canada (Ontario)	4,105,000	18+	1991	2013
Israel	42,000	0–22	1985	2013
Israel	18,000	0–22	1999	2013

European studies adapted from http://epi-ct.iarc.fr/index.php

Additional data kindly provided by Drs. Gabriel Chodick, Ausrele Kesminiene, Vicki Kirsh, John Mathews, and Isabelle Thierry-Chef.