Cancer Risks from CT Scans: Now We Have Data, What Next?[1]

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It has been more than a decade since two articles were published that drew the attention of the wider community to the radiation exposures associated with pediatric computed tomography (CT) (1,2). One of the articles pointed out that most pediatric CT scans were being performed with adult-based settings, resulting in a higher radiation dose than was necessary in children who underwent CT scans (2). The other article (1) provided the first quantitative estimates of radiation risks associated with pediatric CT. The following day, the story hit the front page of *USA Today*, and the world of CT changed dramatically.

CT is a remarkable modality. It enables better surgery, better diagnosis and treatment of cancer, better treatment after injury, better treatment of stroke, and better treatment of cardiac conditions (3). Nonetheless, the suggestion that there might be some potential downside in terms of cancer risks has been vigorously challenged by many in the field (4–7). For example, a recent position paper from the American Association of Physicists in Medicine (5) states the following: "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 non-existent."

The original risk estimates for pediatric CT (1) were derived from studies of exposed Japanese atomic bomb survivors (8). Clearly, there are many differences between a CT scan and an atomic bomb exposure; however, about 30 000 atomic bomb survivors who were located several miles from the bomb epicenter did indeed receive organ doses comparable with those from a few CT scans and did show a significant increase in cancer risk (9). Of course, CT scans are typically focused on a particular part of the body, whereas atomic bomb exposure was to the whole body. As far as possible, these differences were taken into account when estimating CT scan risks; however, the prediction that there is a small but real cancer risk associated with radiation exposure from CT did not convince everyone.

Now the first results of the first of several ongoing epidemiologic studies of pediatric CT recently have been published by Pearce et al (10). The authors identified 180 000 patients who had undergone about 280 000 CT scans in the United Kingdom between 1985 and 2002 when they were younger than 22 years of age. First, they estimated individual brain and bone marrow doses for every patient. Next, they ascertained the subsequent cancer history of these 180 000 patients until 2008 by using the UK National Health Service Registry—a study that can be done in the United Kingdom and in various other countries but that would be extraordinarily difficult to do in the United States! The authors restricted their initial study to leukemia and brain tumors because these are the cancers that might be expected to appear first in irradiated children (11,12), and as best as they could, they eliminated patients who might have had cancer at the time of CT.

The bottom line (10) is that there were significant linear associations between the radiation dose to the brain and the brain tumor risk ($P < .001$), and between the bone marrow dose and the leukemia risk ($P = .01$). The risks were small, but they were undoubtedly real, with no obvious confounders of risk either for leukemia or for brain tumor (13). How small is small? Pearce et al (10) estimated that one head CT scan performed in the 1st decade of life would produce approximately one excess case of leukemia and one excess brain tumor per 10 000 patients who underwent CT, in the 1st decade after exposure.

Now that we have some data, what can we conclude?

First, it is clear that we have now passed a watershed in our field, where it is no longer tenable to claim that CT risks are "too low to be detectable and may be non-existent" (5). A large well-designed epidemiologic study has clearly shown that the individual risks are small but real.

A second conclusion follows from the fact that the estimated CT-related cancer risks are very small: It follows that

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if a CT examination is clinically justified, there is no doubt that its benefits will by far exceed its risks; there is no need for complicated benefit-risk calculations; this provides reassurance for the patient and, of course, the physician.

That being said, these new epidemiologic data do not yet give us the complete picture. The follow-up time in the Pearce et al study (10) was, on average, about 10 years, but from longer-term studies of other irradiated populations (12,14), we know that many radiation-induced cancers will not appear until 20, 30, or 40 years after exposure. Given a follow-up time of 10 years, about 30% (14) of the ultimate yield of radiation-induced leukemias probably have not yet appeared in the Pearce et al (10) cohort, while the proportion of radiation-induced brain tumors yet to appear in the cohort may be as high as 90% (12). We can use these numbers to roughly convert the 10-year risks from a head CT scan estimated by Pearce et al (10) to lifetime risks; thus, the reported 10-year 1-in-10 000 risk for leukemia might ultimately become a 1-in-7500 lifetime risk, and the reported 1-in-10 000 10-year risk for brain tumor might ultimately become a 1-in-1000 lifetime risk.

In fact, these lifetime risk estimates for CT based on the epidemiologic data are not so far from the various lifetime risk estimates derived from atomic-bomb survivor data that have appeared in the past decade: For example, Brenner et al (1) used organ doses and atomic bomb survivor data and estimated a lifetime leukemia risk of about 1 in 10 000 for pediatric head CT (compared with the 1 in 7500 lifetime risk estimate based on the data of Pearce et al [10]) and an estimated lifetime brain tumor risk of about 1 in 2000 (compared with the 1 in 1000 lifetime estimate based on the data of Pearce et al [10]). It follows that the standard method of estimating radiologic risks—estimating organ doses and applying atomic bomb survivor data—yields fairly reasonable results at CT-like doses. This is fortunate, given that we will need to wait several more decades for epidemiologically based lifetime risk estimates, and so we will remain reliant on this standard risk estimation method for many years to come.

In addition to the issue of follow-up, a second aspect where the new epidemiologic data do not yet tell us the complete picture is in the range of cancer types studied. Pearce et al (10) wisely chose to study two malignancies that have shorter-than-typical latency periods in irradiated children, but follow-up of other radiogenic tumors is needed before we can see the complete picture.

The third aspect where the new data do not yet provide the complete picture relates to adult CT: The Pearce et al (10) study was for only pediatric CT, which is not unreasonable as the individual risks are almost certainly higher for pediatric scans than for adult scans; however, more than 90% of all CT scans are performed in adults (15), so the larger number of adult scans will almost certainly outweigh their smaller individual risks (16) from the perspective of population risk.

In summary, 10 years after the suggestion (1) that CT scans might produce a small cancer risk, Pearce et al (10) have shown that this is almost certainly the case, and they have confirmed the numerical magnitude of the risks; more complete epidemiologic studies are needed and several are indeed in progress (17), but in the interim, estimation of medical radiation risks based on atomic bomb survivor data appears to yield reasonable results. The new risk estimates clearly enable us to confirm that for every clinically justified CT scan, the benefit by far outweighs the risk. That being said, far too many clinically unnecessary CT scans are still being performed—these number in the tens of millions each year in the United States (18,19)—and here the benefit will not outweigh the risk. It is hoped that the publication of this landmark article (10) will provide an added stimulus to justify every medical imaging procedure, both in children and in adults.

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References

1. Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR Am J Roentgenol 2001;176(2):289–296.
2. Paterson A, Frush DP, Donnelly LF. Helical CT of the body: are settings adjusted for pediatric patients? AJR Am J Roentgenol 2001;176(2):297–301.
3. Hricak H, Brenner DJ, Adelstein SJ, et al. Managing radiation use in medical imaging: a multifaceted challenge. Radiology 2011; 258(3):889–905.
4. Tubiana M, Feinendegen LE, Yang C, Kaminski JM. The linear no-threshold relationship is inconsistent with radiation biologic and experimental data. Radiology 2009; 251(1):13–22.
5. American Association of Physicists in Medicine. AAPM Position Statement on Radiation Risks from Medical Imaging Procedures. http://www.aapm.org/org/policies/details.asp?id=318&type=PP. Published 2011. Accessed June 2, 2012.
6. McCollough CH, Guimarães L, Fletcher JG. In defense of body CT. AJR Am J Roentgenol 2009;193(1):28–39.
7. Hendee WR, O'Connor MK. Radiation risks of medical imaging: separating fact from fantasy. Radiology 2012;264(2):312-321.
8. Pierce DA, Shimizu Y, Preston DL, Vaeth M, Mabuchi K. Studies of the mortality of atomic bomb survivors. Report 12, Part I. Cancer: 1950–1990. Radiat Res 1996;146(1):1–27.
9. Preston DL, Ron E, Tokuoka S, et al. Solid cancer incidence in atomic bomb survivors: 1958–1998. Radiat Res 2007;168(1):1–64.
10. Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet 2012;380(9840):499–505.
11. Noshchenko AG, Bondar OY, Drozdova VD. Radiation-induced leukemia among children aged 0–5 years at the time of the Chernobyl accident. Int J Cancer 2010;127(2): 412–426.
12. Ron E, Modan B, Boice JD Jr, et al. Tumors of the brain and nervous system after radiotherapy in childhood. N Engl J Med 1988; 319(16):1033–1039.
13. Nygren C, Adami J, Ye W, et al. Primary brain tumors following traumatic brain injury: a population-based cohort study in Sweden. Cancer Causes Control 2001;12(8):733–737.
14. Preston DL, Kusumi S, Tomonaga M, et al. Cancer incidence in atomic bomb survivors. III. Leukemia, lymphoma and multiple myeloma, 1950–1987. Radiat Res 1994;137(2,Suppl):S68–S97.
15. Berrington de González A, Mahesh M, Kim KP, et al. Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch Intern Med 2009;169(22):2071–2077.
16. Shuryak I, Sachs RK, Brenner DJ. Cancer risks after radiation exposure in middle age. J Natl Cancer Inst 2010;102(21):1628–1636.
17. Einstein AJ. Beyond the bombs: cancer risks of low-dose medical radiation. Lancet 2012;2012;380(9840):455–457.
18. Malone J, Guleria R, Craven C, et al. Justification of diagnostic medical exposures: some practical issues—report of an International Atomic Energy Agency Consultation. Br J Radiol 2012;85(1013):523–538.
19. Brenner DJ. Slowing the increase in the population dose resulting from CT scans. Radiat Res 2010;174(6):809–815.