



CT and Radiation Safety Issues

- The estimations of risk of human exposure to ionizing radiation are largely derived from extrapolations of data from high radiation dose exposures experienced by Japanese atomic bomb survivors
- Although substantially higher than that from conventional x-ray imaging, the radiation exposure associated with diagnostic CT imaging is considered to be low by the Health Physics Society
- At MGH, a number of dose-reduction strategies are in place to minimize radiation exposure from CT imaging
- Most CT scans are for older individuals and/or for those who already have cancer, for whom the risk is largely irrelevant; the risk for children is of more concern
- The diagnostic benefits of CT imaging are well established and should be considered together with the potential risks

Over the past 20 years, there has been dramatic growth in the utilization of CT, and around 72 million scans are now performed each year in the United States. Largely as a result of this growth, the radiation exposure associated with medical imaging now accounts for about 48% of the total exposure, up from 15% in 1987. Radiation doses from diagnostic CT can be several hundred-fold greater than that of conventional radiological procedures, such as a chest x-ray, and radiation from CT alone accounts for 24% of the total radiation exposure. There is no doubt that many patients have benefited from the rapid diagnoses made possible by CT and from its value for monitoring chronic disease. However, there is increasing concern regarding the risks of this exposure to radiation.

It is well established that radiation can be harmful and has both deterministic and stochastic effects. Deterministic effects, such as hair loss, skin burns, and cell death, are dose-dependent but do not occur below a threshold of 150-200 mSv. Since the typical estimated dose associated with proper use of CT is in the range of 2-10 mSv, deterministic effects are not normally a concern. Induction of cancer by radiation is a probabilistic (stochastic) effect, not a deterministic effect. That is, higher radiation doses are associated with a higher likelihood of carcinogenesis, but even low doses of radiation could potentially induce carcinogenesis and it is more difficult to assess a safe level of exposure.

Estimating the Risks of Cancer

The evidence that radiation induces cancer comes primarily from the longitudinal study of atomic bomb survivors in Japan (Figure 1). This study has collected data from approximately 100,000 individuals who experienced a one-time exposure from atomic bomb radiation and has been ongoing for over 60 years. In the Biological Effects of Ionizing Radiation (BEIR) VII report and that of the International Commission on Radiological Protection (ICRP), the risk of

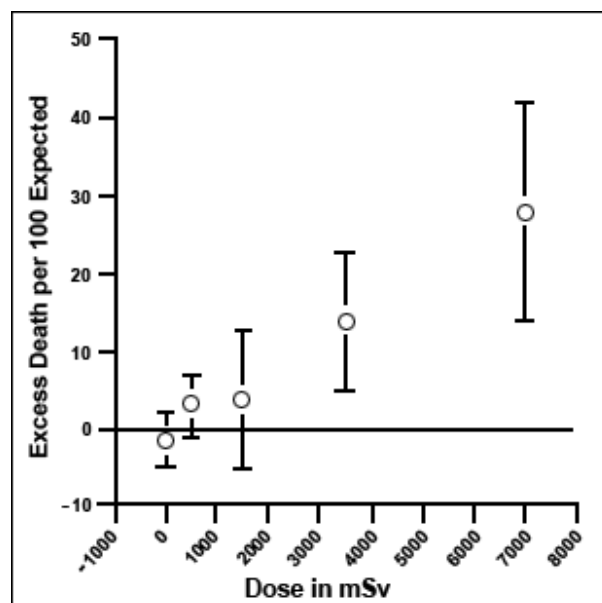


Figure 1. Chart showing numbers of excess deaths from solid tumors per 100 Japanese atomic bomb survivors (1950-1990) versus their dose. Error bars show 95% confidence limits. Note that four of the five data points are substantially higher than the radiation exposure from CT. Redrawn from Cohen, 2002.

Table 1. Typical Radiation Dose from Medical Imaging

Year	Lateral chest x-ray	Chest CT	Abdomen & Pelvis CT	Head CT
Historical benchmark	0.15 mSv	10 mSv	20 mSv	2 mSv
2010 (at MGH)	0.15 mSv	4 mSv	7 mSv	1.5 mSv

harm is estimated by using linear extrapolation of data from high radiation doses, the linear no-threshold (LNT) model. This model makes the assumption that there is no threshold below which there are no risks from radiation and assumes that the risk of radiation-induced cancer is about 0.05% per 10 mSv. However, it should be noted that there are some who dispute this conservative model and cite evidence of lower cancer rates in populations that have been exposed to low doses of radiation (hormetic effects). In addition, there is no direct evidence to date that CT is linked to cancer because of the long latency period of 30-40 years for solid tumors to develop and because of the difficulty of detecting an elevated risk at the relatively low levels of radiation exposure associated with CT when even without medical radiation exposure, one in three to one in four individuals in the U.S. will develop cancer in their lifetime. Nevertheless, it is wiser to be cautious and to assume that there is a risk, albeit small, from the radiation associated with CT scans. The small incremental risk of a potential radiation induced cancer should be weighed against information that CT can provide in a wide variety of appropriate clinical indication, a task aided by the MGH Radiology Order Entry Decision Support system.

Using the LNT model, it is estimated that the population risk of developing cancer is 4-6%/1000 mSv. The BEIR VII report estimated that the individual risk is approximately one in 1,000 for an adult who receives an abdominal CT and one in 550 for children and women. However, it should be noted that most solid cancers have a latency period of 30 years or more and that the majority of CT scans are for older individuals and/or for those who already have cancer, for whom the risk is largely irrelevant. Overall, the risks are low for the individual compared to the lifetime risk of developing cancer from all causes. However, the effect on overall public health could be significant; one recent projection concluded that as many as 29,000 future cancers could be related to CT scans performed in 2007. These risks must be balanced against the known diagnostic benefits of CT (Table 1). Patients need to be aware that one can point to individuals who have been harmed by not having CT when applied by accepted standards, but not vice versa.

Minimizing the Risk by Minimizing the Radiation Dose

For some years, radiologists have believed that the best strategy is to image using the ALARA (as low as reasonably achievable) principle. There are a number of strategies for minimizing the radiation dose associated with CT. Some of these strategies, including tube-current modulation, cardiac gating, applying specific protocols for pediatric patients, and iterative reconstruction techniques have been described in previous issues of Radiology Rounds, [Minimizing CT Radiation Dose](#) and [Iterative Reconstruction Methods](#).

Some tissues, particularly those that are growing, are more sensitive to radiation effects. Because of the greater potential of harm to children, Mass General Imaging has some specific strategies designed for this population. The radiation dose for a CT study is modified according to the patient's size, the clinical indication, the body region, and whether there has been a prior CT. At the time of order entry, the information system knows these factors and can recommend the most appropriate scanning protocol. In addition, each request for pediatric CT is pre-screened by a radiologist and each patient is weighed prior to imaging to further optimize dose. The aim is to use the lowest dose to obtain a diagnostic quality image but not necessarily the "prettiest" image. Similarly for adult patients, body weight is a factor in the selection of radiation dose, with different sets of protocols for patients <135 lbs, 135-200 lbs, and >200 lbs.

Another strategy to reduce radiation exposure is to avoid unnecessary CT scans or to use alternate imaging modalities. The Radiology Order Entry (ROE) system at Mass General Imaging has recently been upgraded and now automatically detects duplicate orders, thus avoiding some unnecessary scans. In the case of pregnant patients, there is concern about the growing fetus. Therefore, only emergent CT is acceptable, in which case shielding is put in place and special protocols used. Alternatively, MRI or ultrasound will be used if those methods are likely to yield a diagnosis.

In the case of patients over 50 years or for those who already have cancer, the risks associated with CT are negligible because of the long latency period of cancer development which could span to 30-40 years for radiation-induced solid organ cancers. For all other patients, it must be recognized that the risk to the individual is low compared to many other risks in life and that the benefits of prompt diagnosis are real. However, ordering physicians must remember that adults are at lower risk of developing radiation induced cancer compared to children.

Scheduling

CT can be performed at Mass General Imaging in Waltham, Mass General Imaging Chelsea, Mass General/North Shore Center for Outpatient Care, or the main MGH campus and can be ordered online via the Radiology Order Entry (<http://mghroe>) or by calling **617-724-XRAY(9729)**.

Further Information

For further questions about CT radiation dose, contact [Sanjay Saini, MD](#), or [Mannudeep K. Kalra, MD](#), Mass General Imaging, at **617-726-3043**.

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