What Is My Patient's Risk of Cancer from Radiation Exposure with Computed Tomography of the Abdomen and Pelvis? What Do I Tell My Patient?

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Pearls and Pitfalls
- Computed tomography exposes patients to ionizing radiation and can potentially result in an increased risk of developing cancers.
- Individual risks of radiation-induced cancer are low, but these small risks in the setting of exponentially increasing use of CT studies in a large population can translate into a substantial increase in the number of cancers with a considerable public health impact.
- The risk of radiation-induced cancer in the pediatric population is even higher than adults since pediatric patients are more sensitive to radiation, have a longer remaining life expectancy, and thus have more time for cancer to develop.
- It is important to consider various strategies to help reduce the number of radiation-induced cancers, such as (1) decreasing the number of unnecessarily performed CT studies and replace them with other diagnostic imaging options when practical and (2) using CT protocol based on patient size to prevent over exposure to unnecessarily high doses of radiation.

Since the invention and technological advancements of computed tomography (CT), CT has allowed physicians to noninvasively visualize the inside of the human body and help guide diagnosis and treatment of disease. Because of its speed, ease of access, and image quality, CT use has increased exponentially. From 1980 to 2005, the US population grew by approximately 50%, while the number of CT scans performed sky rocketed from 3 million to an estimated 60 million tests performed, resulting in a 600% increase in medical radiation exposure to the US population [1]. This may translate into an increased risk of cancer associated with exposure to ionizing radiation.

Sieverts vs Grays

It is important to understand the various terms that describe CT radiation dose delivery to the body. Absorbed dose is the radiation absorbed per unit mass and is measured in grays (Gy) or milligrays (mGy). One gray is equal to "1 joule of radiation energy absorbed per kilogram" [2]. Since not all radiation produces equal effects in humans, the absorbed dose is multiplied by a radiation weighting factor to give the dose equivalent. This measurement is expressed in sieverts (Sv) or millisieverts (mSv) and is used to compare the amount of energy absorbed from different types of radiation. For example, x-rays or gamma-rays have a weighting factor of 1.0. Therefore one gray equals 1 sievert [3]. As radiation is not uniformly absorbed and different radiographic studies expose different areas of the body to varying amounts of radiation, the concept of effective dose was created to allow "for a rough comparison between different CT scenarios" [2]. Thus, effective dose, expressed in sieverts, is "designed to be proportional to a generic estimate of the overall harm to the patient caused by radiation" for a standardized patient [2].

Radiation from CT Exposure

Abdominopelvic CT exposes patients to approximately 10–20 mSv depending on the type of study, institutional protocols, and use of contrast (e.g., traditional study ~10–15 mSv, dissection protocol ~24 mSv, multiphase ~30 mSv) [4]. CT exposes patients to significantly larger radiation doses than

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conventional "plain film" x-rays. For example, an abdominal radiograph results in a dose of about 0.25 mSV, which is over 50 times less than the corresponding dose from abdominal CT radiation exposure [5], and an abdominopelvic CT scan is approximately equal to that of 100–250 chest x-rays depending on patient size, sex, and scanner calibration [2, 5].

Lifetime Attributable Risk (LAR)

The Biological Effects of Ionizing Radiation (BEIR) report is a landmark study providing the most widely accepted models evaluating radiation exposure and the resultant cancer risk. Using the epidemiological data of survivors of the atomic bombings of Japan in 1945 alongside an unexposed cohort, the lifetime attributable risk to various doses of ionizing radiation can be calculated. The lifetime attributable risk is the additional risk of cancer above baseline cancer risk. In the United States, approximately 38% of the population will be diagnosed with cancer during their lifetime. According to the BEIR VII report, one resultant radiation-induced cancer with a 50% mortality rate will occur per 1000 patients exposed to a 10-mSv effective dose, such as one abdominopelvic CT scan [6, 7].

Smith-Bindman et al. [4] expanded on these risk models established by the BEIR report in order to calculate the LAR of various types of abdominopelvic CT scans. Across four sites in the San Francisco Bay area, the study calculated the effective dose (mSv) for four different types of abdominopelvic CT: no contrast, with contrast, multiphase scan, and aneurysm/dissection protocoled scans. The results demonstrated a huge variability in effective radiation doses received by patients, with median values ranging from 15 mSv without contrast to 31 mSv in multiphase scans. Combining the median radiation exposure with the applied effective doses, the estimated number of patients undergoing a routine abdominopelvic CT with contrast differs by age and sex: 470 CTs for a 20-year-old female, 620 CTs for a 20-year-old male, 930 CTs for a 40-year-old female, 1002 CTs for a 40-year-old male, and ~1360 CTs for 60-year-old patients. In a clinical context, a 20-year-old female receiving a multiphase scan is exposed to an effective dose of about 31 mSv. This corresponds to a LAR of four cancers per 1000 patients. In other words, there is a 0.004% increased risk of developing a radiation-induced cancer above the baseline risk for this particular patient.

From a population health perspective, Berrington de González et al. [8] also used these risk models from the BEIR report and combined them with estimates of CT scan frequencies in the United States to project radiation-induced cancer risk. They estimated that about 57 million scans were performed in 2007 in the United States (excluding scans associated with preexisting cancer and scans performed in the last 5 years of life). Using the LAR of radiation-induced cancer and mortality rates determined by the BEIR report, they estimated that 29,000 future cancers and 14,500 cancer-related deaths could occur from exposure to CT in 2007. Based on these projections, it could be expected that 2% of the 1.4 million annually diagnosed cancers in the United States could be related to CT radiation exposures.

Risk of Radiation-Induced Cancer in the Pediatric Population

The risk of radiation-induced cancer in the pediatric population is even higher than adults since pediatric patients are more sensitive to radiation and have a longer life expectancy. Miglioretti et al. [9] estimated that as a result of 4 million pediatric CT scans performed annually in the United States, it is projected that 4870 future radiation-induced cancers will arise. This retrospective study evaluated pediatric scanning practices of six health care systems and calculated ranges of effective doses from a variety of scanners. These results were applied to the estimated 4 million pediatric CT scans performed nationally to obtain lifetime attributable cancer risks in the pediatric population. They found that cancer risks were highest in the abdominopelvic studies and projected 1 radiation-induced cancer from every 300–390 abdominopelvic scans in females and 670–760 abdominopelvic scans in males. When comparing these values to the previously mentioned study by Smith-Bindman [4] on the lifetime attributable risk of abdominopelvic CT with contrast, one can see that pediatric risk of radiation-induced cancer, particularly in females, is generally higher than in the adult population.

Applying the Data to Individual Patients

It is important to remember that even though the data reported by BEIR and other studies can be used to estimate the risk of cancer mortality, there is an uncertainty factor of two to three for a standard adult patient. That is, these approximations can either be two to three times higher or lower than estimated given that each patient drastically differs from another when considering age, size, and gender [3]. Thus, effective dose can be convenient in evaluating health risks of a variety of radiologic studies performed on a standard patient, but it is not especially applicable in determining the excess relative risk in the individual patient.

One way to help patients place these risks in perspective is by comparing CT effective doses with natural or societal effective doses (Table 6.1) [3, 5]. For example, the general population will be exposed to a baseline natural radiation effective dose of about three to four mSv per year compared to an effective dose of 10 mSv from an abdominopelvic CT [3, 5]. Another proposed method is to compare the additional risk of death from cancer associated with CT radiation exposure

Table 6.1 Average low-dose radiation exposures

Exposure	Radiation dose (mSv)
Adult abdominal computed tomography	10
Flight – New York to London, round-trip	0.1
Background natural radiation exposure	3–4 per year
Radiation worker exposure limit	20 per year
International space station exposure	170 per year

Refs. [3, 5]

Adapted from Brenner et al. [5]. Ref. [3]. With permission from the National Academy of Sciences. Copyright (2003) National Academy of Sciences, U.S.A.

Legend: *mSv* = millisieverts

with the risk of death associated with common activities that are largely considered acceptable [3]. For instance, there is a minimal risk of death (4×10^{-6}) when flying approximately 7200 km (4500 mi) compared to a very low risk of death (1×10^{-4}) for a CT scan of the abdomen and pelvis [3]. In the end, it is important for the physician to convey that despite the small increased risk of radiation-induced cancer, the benefits of a medically necessary CT scan far outweigh the risks since it can provide significant diagnostic value.

What Do I Tell My Patient?

How much do emergency medicine physicians know about radiation doses/risk and what do they tell their patients? Lee et al. [10] recently conducted a survey of 45 emergency medicine physicians in a US academic medical center to determine awareness of radiation dose of abdominopelvic CT scans, lifetime cancer risk from exposure, and if this information was outlined to their patients. They found that in this particular group, 73% of ED physicians underestimated radiation doses, 91% believed there to be no lifetime increased risk of cancer, and only 22% of these physicians outlined the risks and benefits of the CT scan to the patient. A similar study performed by Puri et al. [1] found that only approximately 18% of emergency medicine providers surveyed had accurate knowledge of lifetime attributable cancer risk associated with abdominopelvic CT scans. This demonstrates how important it is that emergency medicine providers are educated about diagnostic imaging radiation doses and lifetime cancer risks in order to be able to have informative discussions with patients about associated risks and benefits.

Summary

Individual risks of radiation-induced cancer are very low, but these small risks in the setting of exponentially increasing use of CT studies in a large population can translate into a substantial increase in the number of cancers and a considerable public health issue in the future. Therefore, it is important to consider various strategies to help reduce the number of radiation-induced cancer such as (1) decreasing the number of unnecessarily performed CT studies and replace them with other diagnostic imaging options when practical and (2) using CT protocols based on patient size to prevent overexposure to unnecessarily high doses of radiation.

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