Radiation RISK

by Mark Otto Baerlocher, MD

Question:

What is the estimated risk of both nonfatal and fatal malignancy associated with a CT of the abdomen at 10 milliSieverts effective dose (mSv) in a 25-year old woman?

The use of medical imaging and related exams and procedures includes everything from X-rays, intra-operative fluoroscopy, CT scans, coronary angiography/angioplasty, embolizations, and endoscopic retrograde cholangiopancreatography (ERCP), among others. The use of these exams and procedures has rapidly increased over the last two decades, and has led to enormous improvements in both the diagnosis and the treatment of diseases and pathologies. With this increase comes a concomitant increase in the cumulative exposure to ionizing radiation to patients, and by extension, an increase in estimated associated cancer risk.

As patients are largely unaware of the associated risks, it is therefore imperative that health care workers become educated on the topic. The following article briefly discusses the background of radiation risk, the model used to estimate radiation-related cancer risk, and potential education strategies.

This article is written with a primary focus on patients. However, the issues apply equally to health care workers, and certainly, to surgical technologists, for their own protection. While patients are undergoing medical imaging and related exams and

LEARNING OBJECTIVES

- Examine the effects of radiation on the human body
- Compare and contrast the difference between necessary procedures and procedures that are perceived to be necessary
- Evaluate the rate of radiation-associated cancer risk
- Analyze methods of reducing radiation exposure
- Explore methods of tracking your personal radiation exposure level

procedures for their own health, health care workers are being exposed occupationally. A lack of awareness or appreciation could therefore lead to a lack of safety and appropriate protection in an occupational setting. And because there is potential for occupational exposure on a daily basis, a lack of appropriate protection could result in very high, systematic exposure rates. It is therefore crucial that all health care workers attain a basic understanding and awareness of the related issues, not only for the sake of patients, but for personal protection as well.

RADIATION

The simplest definition of the term, "radiation," is the transport of energy through space, which will eventually be absorbed by a material (the Earth, the human body, air particles, etc). Radiation comes in different forms—for example, a person is able to listen to his or her radio due to radio-wave radiation, and people can see their surroundings due to light-wave radiation.

The type of radiation used for medical imaging purposes is generally "ionizing," which means that the radiation carries sufficient energy to eject electrons from particles, resulting in the creation of ions.[1] Ionizing radiation is used in X-rays, CT scans, fluoroscopy, coronary angiography/angioplasty, and many other exams and procedures.

These positively-charged ions, once created, can then go on to cause damage in human tissue, by creating damage to DNA for example. Due to different protective mechanisms and growth characteristics, some cell types in the human body are more prone to radiation than others; *ie* they are more "radiosensitive." In general, it has been found that cell radiosensitivity is directly proportional to the rate of cell division and inversely proportional to the degree of cell differentiation. In short, this means that actively-dividing cells, or those not fully mature, are most at risk from radiation.[2] For example, hematopoietic cells, reproductive cells, and cells within the digestive tract are particularly radiosensitive.

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EFFECTS OF RADIATION

There are two categories of harm that may be caused by radiation: deterministic (nonstochastic), and stochastic.

Deterministic effects are those that occur once a given exposure is reached. Infertility and cataracts are two examples of deterministic effects. Skin erythema/redness occurs at a dose of at least five sieverts. The sievert is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of millionths of a sievert, or micro-sievert. To determine equivalent dose (Sv), you multiply absorbed dose (Gy) by a quality factor (Q) that is unique to the type of incident radiation.[1]

Stochastic effects are those effects that are probabilistic. In other words, there is no threshold above which the effect always occurs, however, the greater the exposure, the greater the probability of occurrence. The primary stochastic effect is the development of cancer.

ESTIMATION OF RADIATION-ASSOCIATED (CANCER) RISK

Estimation of radiation-associated cancer risks is very difficult due to numerous complexities involved. Many of the estimates are based on extrapolation from atomic bomb data. Arguably, the most expert risk-estimate model estimation comes from the National Academy of Sciences (NAS) Committee on the Biological Effects of Ionizing Radiation (BEIR) VII, which is available to read online at *http://www.nap.edu/catalog.php?record_id=11340*.

The BEIR VII committee uses the linear-no-threshold (LNT) model, which assumes that radiation risk is linear, and non-threshold (*ie,* there is no minimum radiation exposure which must be surpassed in order to increase the associated risk of developing cancer). As with any model, there are inherent deficiencies and inaccuracies. However, as additional data become available, the risk estimates are re-evaluated and modified.

RADIATION IN MEDICINE

As mentioned above, ionizing radiation is utilized quite extensively in medicine, both in diagnosis (X-rays, CT scans, nuclear medicine scans, fluoroscopy, coronary angiography, ERCP, etc) and in treatment (embolizations, angiogplasty/stenting, ERCP, etc). One of the largest sources of cumulative radiation exposure in medicine is from CT scans, which has increased rapidly over the last two to three decades.[3] There have been estimates, for example, that if current CT usage rates continue, up to one and a half to two percent of all cancers in the United States may be caused by CT radiation in the future.[3]

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While patients assume that any test or procedure requested is clinically indicated or necessary, this may not always be the case. There has been evidence, for example, that not all exams ordered may be clinically indicated, and a substantial minority may be ordered for other reasons, such as miscommunication or medico-legal reasons.[3] Perhaps one contributing factor is an underestimation of the risks of radiation-associated cancer by many clinicians.[4]

Periodically, there are very high-profile papers published in high-impact medical journals such as the *New England Journal of Medicine*,[3,5] which then lead to articles published in the mainstream media (*eg U.S. News & World Report*, CBS, *The Wall Street Journal*, *USA Today*, CNN, etc). Following such stories, there may be a tendency for misinformation to propagate and misunderstanding to ensue.

DECREASING RADIATION EXPOSURE

There are a number of approaches that are necessary in order to decrease radiation exposure, or more specifically, to ensure that *unnecessary* radiation is avoided.

EDUCATION

The primary and the crux of any approach must be education, both of health care workers, and of patients. Without at least a general awareness of radiation risk issues, there is little likelihood either group would include radiation risk into decisions regarding their own, or their patients' care.

This author is currently a final-year radiology resident in Toronto, Ontario, Canada. All radiology residents undergo mandatory, extensive radiology and radiation physics training, which includes radiation-risk education. The topic is formally tested on the final medical boards exam (in fact, in the United States, one part of the board exams for the American Board of Radiology is specifically focused on radiology-related physics). As medical imaging and related exams and procedures are so pervasive that they are relevant for most all health care workers, this author suggests that all health care workers be given at least some basic education on radiation-risk awareness. This could be in the form of formal lectures during training, during continuing medical education-style courses and conferences, and in formal publications such as *The Surgical Technologist*.

The best example of an international, large-scale radiation risk awareness initiative is the *Image Gently*℠ campaign by The Alliance for Radiation Safety in Pediatric Imaging, a consortium of professional societies concerned about the amount radiation exposure children receive when undergoing medical imaging procedures (*www.pedrad.org*).

The campaign has achieved much success in increasing awareness among both health care workers and patients, and continues to increase its reach, influence, and its partners. Although this author may hold an obvious bias as a resident in radiology, it is his opinion that the leadership on radiation risk education and awareness should come from within the field where it is most relevant—radiology. This is certainly the case, as the *Image Gently*℠ campaign demonstrates.

INCREASED COMMUNICATION

Communication, or lack thereof, is one potential cause of unnecessary radiation, such as redundant exams.[3] Communication includes exchanges between patients and health care workers, as well as among health care workers themselves. For example, if there is a concern that an exam may be redundant due to miscommunication, contact the relevant person and clarify prior to exposing the patient to potentially unnecessary radiation.

PROTOCOL OPTIMIZATION

Depending on the modality and type of exam or procedure, consideration should always be given to decreasing radiation exposure to the patient by optimizing the technique and protocol. This may include the use of shielding and protective garments, and adjustment of specific imaging parameters.

The proper use of protective garments for the personal safety of health care workers is crucial. Whereas patients tend to undergo solitary exams sporadically, occupationally-exposed health care workers may have the potential for exposure on a daily or near-daily basis, and therefore, improper protection may lead to very high, systematic, cumulative exposure.

TRACKING/LOGGING EXPOSURE, RADIATION PASSPORT FOR THE IPHONE/IPOD TOUCH

There are several excellent electronic and online resources available that have the potential to both educate patients (such as the *Image Gently*[SM] campaign and Web site), and now to track radiation exposure and estimate associated risks.

One such resource is an application for the iPhone and iPod Touch that this author co-developed with Tidal Pool Software and his brother, Adrian Baerlocher, called Radiation Passport. Radiation Passport is an application that is meant to be useful for both health care workers and patients alike. The application serves two primary functions. It can be used to estimate the associated (nonfatal and fatal) cancer risk from a given medical imaging exposure, related exam or procedure for a patient of a given age and gender; and it can also track or log all of the radiation exposures from medical imaging over a patient's lifetime, and estimate the associated cancer risks from that radiation.

The average effective radiation doses associated with the relevant exams and procedures (modality and body part) were obtained by performing an OVID/Medline search of published medical literature (though if known, users can enter custom radiation doses instead for any given exam or procedure). The risk estimates are based on the LNT model used by the BEIR VII committee (linear, non-threshold, cumulative). The risks are customized to the exam or procedure modality, body part, age, and gender of the patient. (*See* figures 1-4). The application also includes a series of

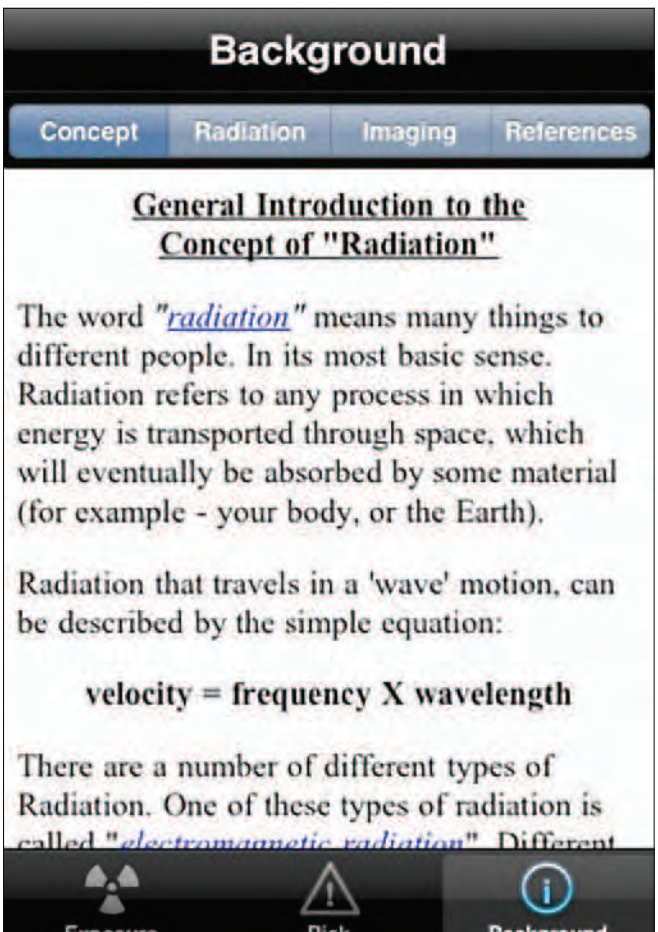

Figure 1. Screenshot from Background Information section of Radiation Passport application for the iPhone/iPod Touch.

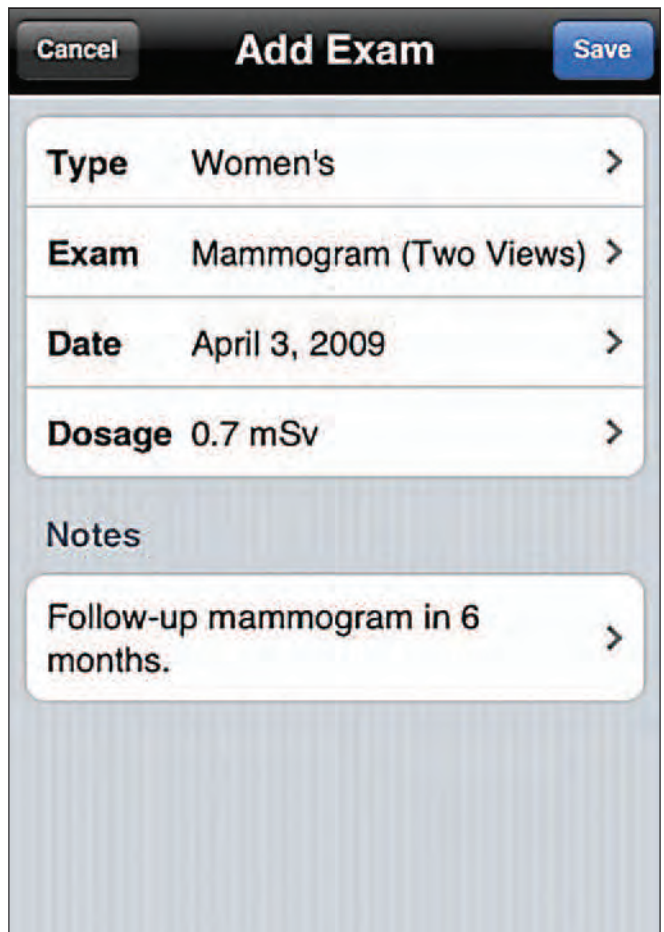

Figure 2. Screenshot from Radiation Passport application demonstrating example exam entry.

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questions to estimate background (nonmedical) exposure, as well as an extensive background/information section.

The application is available on Apple's iTunes electronic store. Additional information can be found at *http://www.tidalpool.ca/radiationpassport/*. *

While many countries require mandatory radiation logs for those deemed "radiation workers," most do not require a similar log for patients and other health care workers. This author suggests that it is time that this is considered.

SHOULD PATIENTS BE INFORMED OF THE RISKS?

There has been some implied criticism questioning whether or not it is fair to give patients information about the radiation risks, with the worry that they may refuse an exam or procedure based on this information.[6]

This author argues that not only is it fair, but it is necessary for patients to be provided with full disclosure on potential radiation risks. When any given treatment or procedure is prescribed to a patient, it is implied that the risk-benefit equation tips favorably toward the potential benefit side, meaning that the perceived and potential benefits of the treatment or procedure outweigh the perceived and potential risks. Both sides of the equation should be explained to the patient, as well as all feasible options. The patient should be allowed to make the final treatment decision.

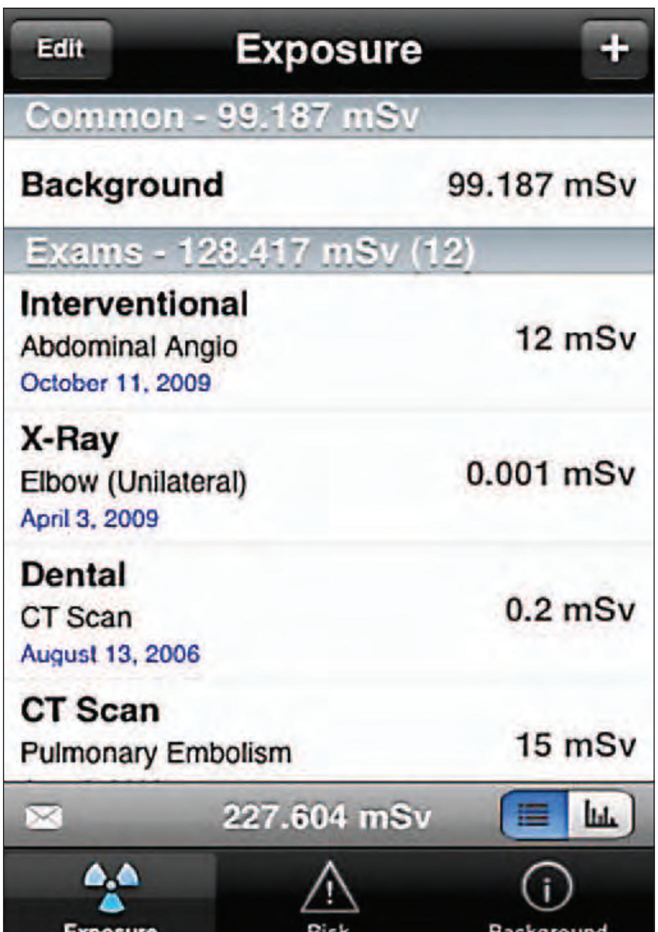


Figure 3. Screenshot from of Radiation Passport application demonstrating list of example exposures.

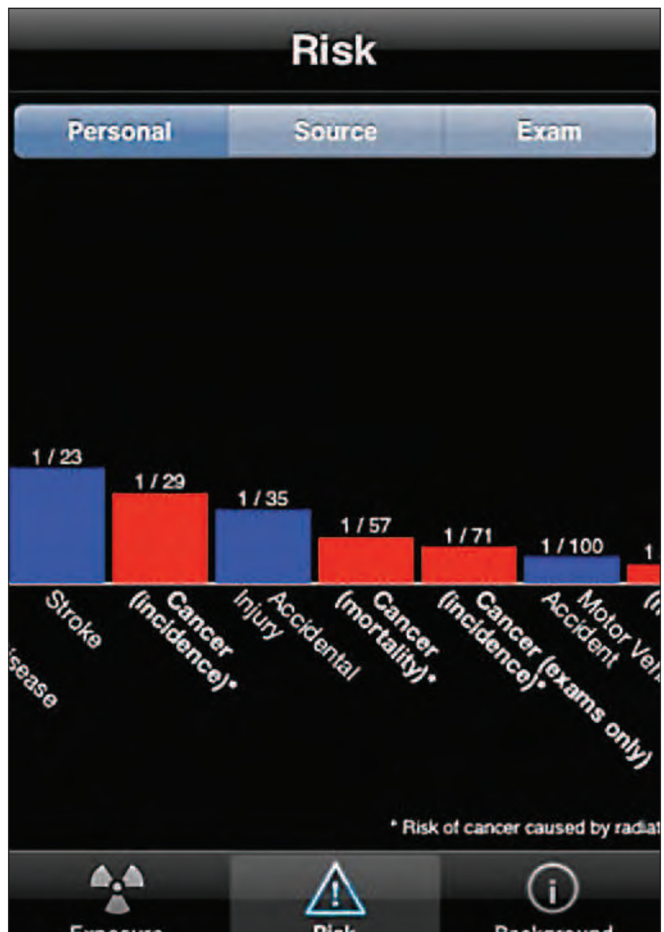


Figure 4. Screenshot from of Radiation Passport application demonstrating estimated risk for customized exposure log.

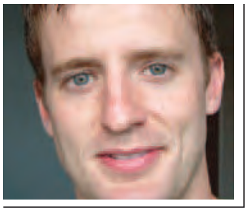
In the case of imaging and imaging-related procedures that utilize ionizing radiation, one of the potential risks is developing associated radiation-induced malignancy, and therefore, patients should be made aware of this information. This author co-authored a study that is currently under review, which demonstrates that 92 percent of patients about to undergo an imaging-related exam or procedure are unaware of any radiation risks. The more information patients are empowered with, the better (though it may be to the chagrin of many health care workers who then have to spend additional time discussing the risks). As a patient, if you are about to undergo a cholecystectomy, you would probably want to be informed of the associated major and relevant risks. This is analogous in this author's opinion, except that the primary risks are of radiation, and potentially contrast reaction, contrast-induced nephropathy (CIN), and extravasation (if relevant).

PREPARE YOURSELF WITH KNOWLEDGE

There is no question that both the diagnostic and treatment abilities of health care workers has been significantly improved with the greater use of more sophisticated imaging and related exams and procedures. However, it also comes with a price—the increasing risk of radiation-induced cancer. The precise balance between use and misuse, as well as more accurate estimates of radiation risks, will surely come under increasing examination in the coming years.

In the meantime, it is the responsibility of those involved with its use to become educated on the topic, both for their own sake, and for the sake of patients. As surgical technologists, you are often the face patients will see coming into and out of their surgery.

ABOUT THE AUTHOR



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Answer to question at the start of the article:

Approximately risk of nonfatal malignancy to single CT abdomen at 10 mSv for a 25-year old woman: 1 in 1500.

Approximately risk of fatal malignancy to single CT abdomen at 10 mSv for a 25-year old woman: 1 in 750.

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