Ionizing Radiation and Medical Imaging: What Midlevel Providers Need to Know

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Abstract

Medical imaging relies heavily on the use of ionizing radiation, which is a known carcinogen. Its increasing use, particularly through CT scans, has come under scrutiny due to safety concerns over cumulative radiation exposure. Midlevel providers may find themselves in a quandary, as they rely on the latest technology for evaluating clinical issues yet are bound to safe practice methodologies. This article provides the foundational information necessary for understanding the use of ionizing radiation in clinical practice, and offers suggestions for adjusting practice without compromising effectiveness of care.

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In 1972, I had a bicycle accident that resulted in a head injury, loss of consciousness, and concussion. An emergency room physician evaluated me, sutured the laceration, and sent me home with instructions for my mother to watch me carefully for the next 72 hours. In a present day emergency center, I would certainly have undergone computed tomography (CT) of the head.

Most midlevel providers practicing today cannot recall a time when CT scans were not a major tool in their diagnostic handbags. In 1980, 3 million CTs were performed in the United States; by 2007, the number of annual CTs had risen to 72 million—almost 200,000 scans daily (Berrington de Gonzalez et al., 2009; Brenner & Hall, 2007; Redberg, 2009). Although CT scans have historically been considered safe, a recent emphasis on radiation exposure has caught the attention of mainstream media. What does this mean for midlevel providers whose scope includes the ordering of radiographic tests such as CT scans? In particular, what does it mean for midlevel providers working in oncology, where regular treatment planning and evaluation rely on frequent and extensive CT imaging?

Ionizing Radiation

Radiation involves the transfer of energy, and is of two types: ionizing and nonionizing. Radio waves and visible light are examples of nonionizing radiation, whereas x-rays and gamma waves are examples of ionizing radiation. Ionizing radiation also occurs naturally in the environment. Ionizing radiation penetrates tissue and has energy sufficient to alter the structure of molecules within the body. This process initiates free radical formation, resulting in oxidative stress and cellular damage. If the energy dose is sufficient, the body may be unable to repair the damage, resulting in permanent DNA alteration. This is the basis on which ionizing radiation is considered carcinogenic.

In oncology, ionizing radiation is used for both diagnostic and therapeutic purposes. When used therapeutically in high doses to kill cancer cells, DNA damage is both desirable and necessary. Unfortunately, the surrounding healthy tissue can also sustain damage, leading to significant side effects. Midlevel providers working in oncology are certainly familiar with the "risk vs. benefit" rule that applies to the use of therapeutic radiation: Since the treatment goal is to cure or control a potentially fatal disease, the benefit almost always outweighs the risk.

A Framework for Understanding the Issue

The focus of this article is the use of ionizing radiation for diagnostic, not therapeutic, purposes. As previously stated, ionizing radiation is a known carcinogen, even at low doses (Berrington de Gonzalez et al., 2009). According to the Biological Effects of Ionizing Radiation (BEIR VII) Report released by the National Research Council (NRC), no level of ionizing radiation is considered safe; low doses of 100 millisieverts (mSv) or less have been associated with an increased risk of leukemia and cancer in general (NRC, 2006; Cardis et al., 2005). Radiation-induced cancers develop slowly, generally 10 to 20 years after exposure (NRC 2006; National Cancer Institute, 2010).

The sievert is the unit of measurement used to describe the amount of radiation or energy deposited in the body (NRC, 2006). Low-dose ionizing radiation is measured in millisieverts (a millisievert is 1/1000 of a sievert). In the United States, the average exposure from naturally occurring background radiation is about 3 mSv per year. The major source is radon gas, which is emitted by the earth. Cosmic rays from the sun are another source, accounting for the higher levels of background radiation as altitude increases. Even air travel increases the amount of background radiation from cosmic sources (NRC, 2006). In summary, everyone absorbs minute amounts of ionizing radiation on a daily basis.

The main sources of manmade ionizing radiation are diagnostic imaging studies, of which computed tomography contributes the most (Fazel et al., 2009). Most concerning are tests that are ordered frequently in patients across the lifespan such as CTs of the head, chest, abdomen, and pelvis (Berrington de Gonzalez et al., 2009). Due to variation in individual characteristics and absorption, the actual amount of radiation received can vary 5- to 10-fold among individuals (Amis et al., 2007). For example, children absorb more than adults; women absorb more than men and are especially susceptible when the breasts are in the imaging field (Berrington de Gonzalez et al., 2009). Due to these variations, the term *effective dose* is often used to describe the risk of radiation to the body (Smith-Bindman et al., 2009).

Not only do radiation doses vary between individuals, but the delivery doses vary both within and between facilities, with some CT machines using much higher effective doses than others. In an analysis of data from four different institutions, Smith-Bindman et al. (2009) noted the effective dose for CTs varied as much as 13-fold between the lowest and highest doses. They also noted significant variation between the average expected dose for a certain exam and the actual effective dose required. The effective dose of many single CTs and nuclear medicine scans is in the range of 10–25 mSv. Smith-Bindman et al. (2009) found the median effective dose of a multiphase CT of the abdomen and pelvis to be 31 mSv. A patient can easily receive 50 mSv in a few days if undergoing multiple studies to evaluate a condition (Amis et al., 2007). This is concerning, as radiation doses in the subgroup of atomic bomb survivors with a significantly increased risk of malignancies ranged from 5 to 150 mSv, with a mean of only 40 mSv (Amis et al., 2007; Brenner & Hall, 2007). Additionally, an exposure of 100 mSv over 5 years or 50 mSv in any 1 year is the maximum recommended occupational exposure according to the International Commission on Radiological Protection (Cardis et al., 2005). Risk models estimate that the increased exposure to CTs every year could result in several thousand additional cancer cases (Berrington de Gonzales et al., 2009).

Low-dose ionizing radiation has been studied extensively, yet the actual threshold for increased risk remains controversial. Most of what is known is derived from studies of Japanese survivors of the atomic bombs, in which large groups of people were exposed to high levels of ionizing radiation over a short period of time. Additional information is available from studies of patients who were therapeutically radiated for both malignant and benign conditions. Theoretical models have been developed that extrapolate from this earlier data to estimate the risk of chronic exposure to lower levels of ionizing radiation. The latency period for chronic exposure is many years, during which time a person may be exposed to other environmental and dietary carcinogens (Cardis et al., 2005; NCI, 2010). One begins to appreciate the difficulty in estimating the absolute risk of chronic exposure to low levels of ionizing radiation. The risk is largely based on theoretical models and extrapolated data.

Implications for Midlevel Providers

Health care is driven by attention to safe practice, and many midlevel providers rely on practice guidelines to direct their care. Specialty organizations are beginning to publish guidelines for ordering imaging studies. However, until clear guidelines are established and adopted, the following suggestions may assist midlevel providers when ordering studies that utilize ionizing radiation.

- ***Awareness in Medical Decision-Making***—Recently published articles do not challenge the utility of CTs, but rather point out their significantly increasing frequency and urge clinicians to carefully consider the expected benefit of the scan (Amis et al., 2007; Brenner & Hall, 2007; Redberg, 2009). "Defensive medicine" has contributed to knee jerk ordering of some CTs. Always consider risk vs. benefit when ordering CTs. Even though recent analyses implicate several thousand unnecessary deaths per year from CTs, one must consider the number of lives saved through the appropriate use of imaging studies (Fazel et al., 2009; Redberg, 2009). Part of the midlevel provider's medical decision-making is in determining if a scan is *unnecessary* or *necessary*. Smith-Bindman et al. (2009) indicate that up to 30% of CTs performed are not necessary. Familiarize yourself with the average doses of commonly ordered imaging tests (see Table 1), and consider a lower-dose alternative if appropriate (Brenner & Hall, 2007). Be judicious with your orders: For example, if a CT of the abdomen is all that is clinically indicated, do not order a CT of the abdomen and pelvis simply because these two scans are often bundled together. Additionally, consider if a follow-up CT is truly necessary.
- ***Patient Education and Documentation***—Dialogue with the patient, parent, and/or caregiver regarding the potential risk, especially in children and young adults, or when ordering multiple studies. Avoid technical terminology such as millisieverts; instead use easily understood comparisons such as, "This is the equivalent of 100 chest x-rays." Document the conversation in the medical record, including the patient's participation in the decision-making process. Encourage patients to keep track of the number of scans they have had. Smith-Bindman et al. (2009) emphasize the importance of having a system-wide mechanism for tracking each patient's cumulative exposure. However, in our fragmented health-care system, a patient can undergo multiple scans from various providers, and the patient may be the only one who can realistically keep track of the total.

Table 1. Ionizing Radiation Sources and Amounts

Source of ionizing radiation	Radiation dose
Coast-to-coast round-trip commercial flight (US)	0.03 mSv
Background radiation, US average per year	3 mSv
X-ray: extremity (bone)	0.001 mSv
X-ray: dental	0.005 mSv
X-ray: chest	0.1 mSv
X-ray: spine	1.5 mSv
CT: head	2 mSv
CT: spine	6 mSv
CT: chest	7 mSv
CT: Abdomen and pelvis	15 mSv
CT: Abdomen and pelvis with and without contrast	30 mSv

Note. Adapted from RadiologyInfo.org (2011)

Table 2. Comprehensive Online Resources

www.acr.org	The official website for the American College of Radiology. The *ACR Appropriateness Criteria* can be located through the *Quality & Safety Resources* link. These evidence-based guidelines can assist midlevel providers in the decision-making process. The comprehensive guidelines list an appropriateness rating for various clinical conditions, and include the "relative radiation level" for each.
www.RadiologyInfo.org	This website includes comprehensive information for patients about imaging procedures, including the issue of radiation safety and related regulatory initiatives. It also includes a "Medical Imaging History" card that patients can print for the purpose of tracking their radiologic exams.

- ***Professional Education***—Mentor new graduates and other providers who may be unaware of the risks of ionizing radiation. Nurse practitioners or physician assistants involved at the academic level can influence their program's curriculum. Information about radiation exposure is critical, and is concise enough to be easily incorporated into nurse practitioner and physician assistant curricula.
- ***Resources***—Radiologists are extremely helpful in situations of radiation safety; consider familiarizing yourself with a radiologist who can serve as a resource when needed. Use American College of Radiology (ACR)-accredited facilities and indicate on the radiology request any concerns so the radiologist can adjust the order to minimize exposure.

The white paper by Amis et al. (2007) lists numerous resources and recommendations in their action plan, including two extremely informative websites. All midlevel providers are encouraged to view the online resources listed in Table 2.

Additional Implications for Midlevel Providers Working in Oncology

CT imaging is used liberally in oncology for restaging, surveillance, evaluation of clinical signs and symptoms, and even screening. Midlevel providers may find themselves ordering multiple series of "necessary" CTs for patients during and after treatment when the risk of recurrence is high. In these situations, the cumulative risk of radiation exposure from CTs is balanced by the benefit they add to managing complications and recurrence. As the risk of recurrence declines, however, the frequency of surveillance imaging should also decline. During the long-term phase of survivorship when risk of recurrence is low, the appropriate use of CT becomes a much more pertinent discussion. For example, many cancer survivors are told they will need annual surveillance CTs for the rest of their lives, and continue to undergo multiple scans every year for many years. This is particularly concerning for survivors of childhood and young adult cancers who have many years of life ahead; providers must consider the implications of cumulative radiation exposure from surveillance CTs. Evidence-based practice guidelines are needed to direct the imaging schedules for long-term cancer survivors, including recommendations for discontinuing routine surveillance CTs. Midlevel providers in oncology are in a prime position to assist in the development of such disease-specific evidence-based guidelines.

Conclusion

The utility of CT scans is obvious, yet the increasing use is concerning due to the known risks of ionizing radiation. Originally ordered for the most challenging and potentially life-threatening of situations, CT scans are now ordered routinely for evaluating and following various acute and chronic conditions. They are being used increasingly for screening and early detection, contributing even further to radiation exposure. The trend toward overuse is concerning, and increased governmental regulation is likely to occur in the future. The degree to which CT scans and other imaging studies contribute to cancer risk remains unclear. What is certain is that no level of ionizing radiation is considered safe. Therefore, midlevel providers must exercise caution and prudence when ordering such studies.

DISCLOSURE

The author has no conflicts of interest to disclose.

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