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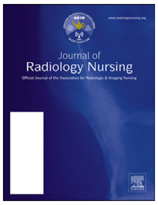

Radiation, Risks, and … a Rational Approach in Diagnostic Imaging: What the Radiology Team Should Know CE

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ABSTRACT

Medical imaging that uses ionizing radiation is extremely valuable in patient care at all ages. However, because radiation is used, patients, parents, and other caregivers may have questions and even concerns about the possibility of risk, especially as there are unique considerations when imaging children. These questions and concerns are often directed at those most involved in direct patient engagement in radiology practices, especially nurses and technologists. Because of this, there is a need for informed discussions (including access to resources) about the amount of radiation used, potential risks, and general strategies for examination optimization. The manner in which these discussions ensue is also important. This balance of content and delivery style can be most effective in reassuring those we care for.

Introduction

Diagnostic imaging is a widely recognized and valuable tool in the care of adults and children. In fact, computed tomography (CT) has been heralded as one of the greatest medical advancements in the past several decades (Fuchs & Sox, 2001). The benefits of medical imaging are evident on a daily basis and range from life-saving information to reassurance in the setting of a normal examination (Hricak et al., 2011; Pandharipande et al., 2016a, 2016b; Rubin, 2014). The information gathered during a medical imaging examination is dependent on a team approach, which consists of a core of radiology nurses, technologists (and sonographers), and radiologists, with input that includes radiation safety experts and medical physicists. Much of the imaging that is performed, specifically radiography, fluoroscopy, CT, and nuclear imaging, depends on ionizing radiation. The landscape in radiology practice for over a century has been one of radiation awareness and protection. Although measures are routinely taken to minimize radiation exposure to patients and staff, there is less understanding of doses (in reality, dose estimations), risks, and strategies to discuss these risks. For example, in surveys of patients, caregivers, other health care providers, and other radiology personnel, radiation doses attributed to certain imaging studies and potential risks of radiation from these studies in developing cancer are not well understood (Boutis et al., 2013; Irving, Leswick, Fladeland, Lim, & Bryce, 2016; Lam, Larson, Eisenberg, Forman, & Lee, 2015; Puri et al., 2012; Rehani & Berris, 2012; Sadigh, Khan, Kassin, & Applegate, 2014; Steele et al., 2016). Radiation use in medical imaging is also part of the patient and public awareness and can be a point of concern, amplified through the lay press (Anonymous_A, 2016; Anonymous_B, 2016; Brenner & Hall, 2007; Cohen, 2015; Redberg & Smith-Bindman, 2014; Sternberg, 2001). Because many of the responsibilities with technologists and nurses in medical imaging place them front and center with direct patient engagement, there may be questions that arise. Therefore, it is worth addressing issues related to ionizing radiation and diagnostic imaging, including what is the current position on radiation risk. For this reason, the following information is a brief review of radiation biology, patterns

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of use of imaging modalities, particularly those that are relatively higher in radiation use (especially CT), current understanding of potential radiation risks, and provides suggestions for approaches to discussion and resources related to these conversations. It is important to realize that, although the major focus of this article will be dealing with ionizing radiation and potential risks, the benefits of medical imaging that use ionizing radiation are far in excess of real and potential risks.

Radiation and medical imaging

The word radiation evokes feelings of anxiety and fear for many reasons (Jorgenson, 2016). Radiation is a form of energy along the electromagnetic spectrum that includes microwaves and radio waves. The type of radiation that will be discussed today is *ionizing radiation*, which is a higher energy than many other types. From here on, when the word radiation is used alone, it will imply the ionizing type. The modalities that use ionizing radiation are radiography (computed radiography and digital radiography), fluoroscopy, CT, and nuclear imaging. In nuclear imaging, the ionizing radiation is emitted from agents that are administered, most often intravenously, and emitted radiation is detected by a camera external to the body rather than radiation passing through the body, such as radiography, fluoroscopy, and CT. Ionizing radiation gets its name from radiation that comes from the X-ray tube (in radiography, fluoroscopy, and CT) and causes ionization or removal of an electron in atoms or molecules in tissue, and a release in energy in these tissues; this ionization can damage DNA. This damage may be repaired but may not be repaired correctly. When it is not repaired correctly, it can, depending on the functions of that piece of DNA, result in cell death or in some modification of function. This modification can result in dysfunction and development of cancer. We know that radiation in high doses can damage tissue directly, for example, as hair loss or skin erythema, which can be expected side effects of some radiation therapy for cancers. With few exceptions, diagnostic medical imaging uses what is considered low-level radiation where the biologic effects are less certain. This will be discussed subsequently in this article. Although there have been reports of tissue injury such as hair loss and skin redness during diagnostic imaging, these have been more associated with improper functioning of equipment or improper use of properly functioning equipment (Anonymous_C, 2016; Anonymous_D, 2016). For the purposes of this article, low-level radiation is generally below 100 milliSieverts (mSv). This threshold dose will have more meaning when one understands the doses that result from diagnostic medical imaging, discussed shortly. Finally, in general, younger patients, especially children, are more vulnerable to radiation than adults as they have growing tissues and a longer life span in which cancer that may be induced by radiation can occur. This can take years to decades. It is also worth noting that not all cancers are more likely after radiation, and that for some cancers, children and adults have equivalent risks, and for a few, such as lung cancer, adults are more vulnerable to radiation induction (United Nations Scientific Committee on the Effects of Atomic Radiation, 2012).

Radiation doses for medical imaging

There are various ways of estimating doses for medical imaging. Direct measurements are impractical in clinical imaging as this would require sophisticated and invasive methods of detecting radiation. Suffice it to say that most doses that are discussed with respect to the various modalities are in fact *estimations* of what dose a patient may give but do not represent an individual patient's dose. Somewhat of an exception to this is in nuclear imaging where administered activity is known, and more detailed dose estimations to the whole body or various organs are available. There is a range of doses resulting from each examination that depend on many factors, such as the modality used, clinical question, body region examined, individual practice preferences for imaging (e.g., protocol design), and individual patient factors, such as gender and size. It is beyond the scope of this article to provide a comprehensive range of doses, but a more practical range of doses in imaging for adults and children can be found in several sources (Anonymous_E, 2016; Anonymous_F, 2016; Johnson et al., 2014; Mettler, Huda, Yoshizumi, & Mahesh, 2008). From a day-to-day standpoint, it is worth remembering that in general, radiography provides lower doses than fluoroscopy, which provides lower doses than CT. Nuclear imaging doses can have a wide range depending on the type and can be as low as fluoroscopy but can be as high as or higher than CT.

Doses in children tend to be lower because not as much ionizing radiation is necessary in smaller individuals to achieve diagnostic levels of information. A simple analogy for this is found with a flashlight and your hand. If you hold a flashlight up to the palm of your hand, you cannot see the light on the other side. However, if you hold the flashlight up to the web of your fingers, light (which is on the electromagnetic spectrum, like ionizing radiation) goes through the web of your fingers. The web is more like a child, and the palm of your hand could be considered equivalent to an adult. Less light (i.e., radiation) is needed to go through a child than an adult.

Radiation measures include units for exposure, organ dose, and effective dose (ED). These can be quite confusing. I would offer that in daily practice and engagement with patients, individual units and explanation of these dose quantities is challenging. Often relative descriptions of dose are more helpful, such as that a radiograph is on a very low dose and a CT examination is still low-level radiation but higher than a dose of chest X-ray. The dose metric most often used to encompass the range of doses in imaging modalities in clinical conversations is the Sievert (and in diagnostic imaging, the measure is typically in milliSieverts [mSv]), the unit for ED. ED is determined by adding together dose estimations from exposed organs, multiplied by a weighting factor that takes into consideration the organ differences in sensitivities to radiation. The more sensitive the organ is, the higher the weighting factor. ED in mSv is a whole body dose metric, even when exposure is limited to a particular part of the body, such as a head CT. I have used the analogy that it is similar to the annual rainfall in a country. This annual amount does not provide seasonal or geographic variations, and it is not possible to extract those from the annual rainfall, but it is useful in comparing the rainfall in one country to another country or in the changes in rainfall year to year. Likewise, ED dose offers a means to compare different modalities, even if the exposed area is different, but individual organ doses are not known for that patient. For example, a 2.0 mSv chest CT provides a *lower* ED than a 10 mSv pelvis CT but provides a *higher* dose to the breast tissue. ED also does not account for size, age, or gender differences.

Multiples of doses between the various imaging modalities and even with the same modality for similar examinations can vary widely from a few times to several hundred (Mettler et al., 2008; Miglioretti et al., 2013; Smith-Bindman et al., 2009). It is important to remember though, even given this variation, we are still in the range of low-level radiation with virtually all single examinations. We can look at children for a moment. In pediatric imaging, the doses in children range from about 0.01 to 0.03 mSv for a single view chest X-ray radiography to 3 to 10 mSv for a single-phase abdominopelvic CT; dose depends on age and size as well as technique used. The adult range is higher than this, but in general, most single-phase CT examinations are going to be no higher than about 15 to 20 mSv (Mettler et al., 2008).