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Managing radiation risk in the evaluation of the pediatric trauma patient

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Pediatric trauma is usually a nonoperative experience for the pediatric general surgeon. The pediatric trauma surgeon resuscitates the child and then evaluates and triages the identified injuries. A common diagnostic tool is the computed tomography (CT) scan. Most children who require evaluation for significant trauma will get a CT scan, but there are no national guidelines directing the assessment. Injuries to the head, cervical spine, chest, and abdomen can all be imaged with a CT scan; the question is whether the liberal approach to imaging children is appropriate. Over the past decade, concern has arisen about the radiation dose delivered by CT. This concern has generated a national campaign to "image gently." This article reviews the data involving the risk of medical radiation exposure and discusses strategies for managing the risk.
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In 1972, the computed tomography (CT) scanner was invented, forever changing the evaluation of injured patients. As the technology has improved, detailed images can be obtained in a rapid, almost effortless manner. CT scans permit the characterization of solid organ injuries, upon which our management protocols are based, and allow us to characterize multiple injuries to better triage our care. CT angiography has virtually supplanted interventional angiography. Additionally, CTs may facilitate the exclusion of occult injuries selecting candidates for early discharge.

In adults, CTs have become so popular that many have advocated for the "pan-scan" technique. Pan-scan involves the liberal scanning of the head, neck, chest, thoracic and lumbar spine, abdomen, and pelvis during the radiologic evaluation of a trauma patient. Pan-scans are quick, efficient, and thorough. Tillou found that a policy designed to limit the use of the pan-scan technique resulted in a potential missed injury rate of 17%.[1]

The casual approach to the use of CT changed in 2001 when Dr. David Brenner, a physicist at Columbia University's Center for Radiological Research, announced that, based on data from the atomic bomb survivors, the risk of a child developing a fatal cancer from the radiation offered by a single CT scan was 1 in 1000.[2] Children have tissue that is more radiosensitive than adults and more years of their life to await the potential impact of the radiation. Although no one has shown an actual increase in real cancers from medical imaging, and the methodology used by Dr. Brenner to derive radiation-induced cancer risk has been debated, it is clear that the issue of radiation risk has caught the attention of both the academic and popular press.[3,4]

There is no question that the CT scan has added a tremendous benefit to the evaluation and treatment of injured children; however, it is also inescapable that the study offers a small but material dose of radiation. The challenge to the clinician caring for the injured child is to regard the risk of the intervention and make rational choices about how to evaluate his/her patients.

Defining the risk of radiation

In 2009, the National Council on Radiation Protection and Measurement reported that the U.S. population is currently

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exposed to seven times more ionizing radiation than it was in the 1980s. Background sources account for half of this exposure, and medical imaging is responsible for the other half; CT scans are the primary offender.[5] The use of CT has increased nearly 700% in the last 10 years, with approximately 11% of all CT scans being performed in children.[6]

CT scans use a radiation dose that is significantly higher than standard radiographs. A typical abdominal CT in an adult has an estimated dose of 10-20 mGy, which is in comparison with 0.01-0.15 mGy for a plain chest radiograph.[7] Pediatric practitioners typically adjust the dose such that a child typically receives a dose of approximately 5 mGy. The interpretation of radiation doses can be confusing to the nonphysicist. Gray is the international system of units measure of absorbed ionizing radiation, and is defined as the absorption of 1 J of radiation by 1 kg of matter. A single Gray is a large dose of radiation, so most medical doses are expressed in milliGray (mGy). Sieverts are a measure similar to Gray but with weighting for the type of radiation and the tissue affected. In this way, sieverts, or more typically millisieverts (mSv), attempt to reflect the biological effects of the radiation. The natural background effective dose rate varies considerably from place to place, but typically is around 2.4 mSv/year (http://www.unscear.org/docs/reports/gareport.pdf).

For practical understanding of medical imaging, millisieverts and milliGray can be assumed to be equivalent.

The induction of cancer and genetic defects are attributed to stochastic effects. Stochastic effects are usually associated with exposures to low levels of radiation exposure over a long period (eg, years). The term stochastic means "random," which implies that low levels of radiation exposure are not certain to produce an effect. Theories about the stochastic effects of radiation have led to the "linear-no-threshold" hypothesis. This hypothesis states that there is no threshold level of radiation exposure below which we can say with certainty that cancer or genetic effects will not occur, and doubling the radiation dose doubles the probability that a cancer or genetic effect will occur. The consensus of national regulatory groups in both the United States and UK is that, for doses <100 mSv, the most appropriate risk model for radiation protection purposes is the linear no-threshold model.[7]

Data supporting cancer risk

Although epidemiologic data exist evaluating the risk of cancer from occupational radiation exposure,[8] the principle source of quantitatively assessing cancer risk from low-dose radiation has come from the survivors of the atomic bomb.[7-11] The two major conclusions from the A-bomb study are (1) "the risk of all solid cancers is consistent with a linear increase in radiation dose, from low doses up to $\sim$2.5 Sv," and (2) "children are much more radiosensitive than adults."[7] Additionally, the A-bomb data provide evidence that excess cancer risks may occur at doses from about 20 mSv and that children are 10-15 times as radiosensitive to radiation as adults. The risk of developing a fatal cancer, obtained from these data, is approximately 5%/Sv.[11]

The lifetime attributable risk of radiation-induced cancer varies with age at time of exposure.[11] To estimate the risk associated with a particular procedure, the dose to each organ is calculated as a function of age, gender, and type of CT examination. A cancer risk estimate is applied that is specific for that organ, age, and gender, and these risks are added together.[11,12]

In recent years, the largest source of general population exposure to radiation has become medical diagnostic and therapeutic radiologic procedures.[10] There is significant variation in estimated radiation doses from different diagnostic radiologic procedures.[10] In addition, differences in estimated effective doses are seen among pediatric patients of different ages and between pediatric and adult patients. The major reason for these differences is body size. Therefore, the smaller the size of a patient, the less the attenuation of the radiation beam; thus, a higher radiation dose is received. Furthermore, because the organs are closer together in children than adults, scatter from the primary beam can reach adjacent organs.[10]

Most radiation-induced cancers have a latency period of more than 40 years following exposure.[7,13] Bone marrow, thyroid gland, breast, and lung appear to be especially sensitive to radiation.[14] A population-based study of leukemia and postnatal diagnostic radiographs (mostly bone x-rays) from Canada demonstrated an increased risk of acute lymphoblastic leukemia with increasing numbers of x-rays.[15] Data evaluated from pediatric A-bomb survivors who were exposed to nearly the same range of effective doses as children examined by CT scan have shown that, even at this low-dose, there is a statistically significant increase in cancer rates.[7,11,16] Furthermore, scoliosis patients who have a large numbers of x-rays performed as children have a significant breast cancer risk, similar to that observed among A-bomb survivors at the same age.[17]

Using the linear no-threshold model, it has been estimated that approximately 29,000 future cancers could be related to the number of CT scans performed in 2007 alone, 15% of these from scans performed in those under 18 years of age.[18] Lung cancer is the most common projected radiation-related cancer followed by colon cancer and leukemia.[18]

Arguments against the risk of cancer

Despite the concerns about radiation doses, there is very little direct evidence that exposure to postnatal diagnostic radiation increases childhood cancer risk. Several studies reporting an increased cancer risk associated with diagnostic radiation were based on interview data or questionnaires regarding x-ray exposure. When medical records were re-

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