Is Medical Radiation Exposure A Public Health Concern?

The Downside to Technological Advances in Computed Tomography

BY SHELLEY NAN WEINER, MD

PUBLIC HEALTH OFFICIALS recognize the potential health consequences of radiation exposure, especially the possibility that it may cause cancer. Additionally, decreased intellectual development is associated with low-dose radiation exposure of the brain in infancy, according to a recent article in the journal *Nature* by Per Hall. The doses responsible are in the same range as radiation doses delivered by some computed tomography (CT) examinations.

CT Use Has Increased Dramatically

There has been a seven-fold increase in the use of CT for the entire population in the past decade. For Medicare beneficiaries, the use of CT scans increased 29.9 percent per capita from 1993 to 1999. The increase is not limited to adults: According to 2002 data from the National Institutes of Health, approximately two to three million CT examinations were performed on children.

The reasons for the increase in utilization are complex and could possibly be attributed to physicians who increasingly practice defensive medicine. Some of the most important contributing factors, however, are the widespread availability of multidetector spiral CT scanners capable of extremely rapid scanning (especially important in children since it significantly decreases the need for sedation), the development of user-friendly three dimensional software programs and multi-planar imaging, as well as CT angiography and colonography. The indications for CT have expanded to include the evaluation of suspected urinary tract calculi, appendicitis, pulmonary emboli, more accurate staging of malignancies, better character-

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ization of hepatic masses, determination of respectability of pancreatic masses, improved preoperative planning of complex fractures, and improved planning for radiation therapy.

"CT procedures could account for as much as 60 percent of man-made radiation exposures to Americans," Fred Mettler, Jr., MD, told attendees at a 2002 National Council on Radiation Protection and Measurements symposium. Mettler also indicated that CT scans represent about 15 percent of the total X-ray examinations performed at some tertiary hospitals, but represent 70 percent of the radiation dose medical procedures expose to the public. At the same meeting, an official with the FDA's Center for Devices and Radiological Health estimated that in 2000, approximately 57 million CT scans were performed in the United States.

What About the Risk of Radiation Exposure?

Most of the information about radiation-induced cancer comes from studies of Japanese atomic bomb survivors and from studies of individuals exposed to selected diagnostic or therapeutic procedures. While there is no definitive evidence that low-dose exposure is associated with increased cancer risk, the effects of radiation are thought to be cumulative. According to the United States Nuclear Regulatory Agency, however, any increase in dose is assumed to result in increased risk. The higher the dose, the sooner the effects will appear, and the higher the risk of morbidity. Cancers associated with high-dose exposures include leukemia, breast, lung, esophageal, ovarian and gastric cancers, and multiple myeloma.

As our understanding of radiation biology increased, so has public concern for radiation safety. The use of X-rays for medical imaging has been thought to have a positive risk benefit ratio. The public is exposed to many sources of low-level radiation, which include natural cosmic (from outer space) and terrestrial radiation. The U.S. Nuclear Regulatory Commission estimates that natural sources of radiation account for 82 percent of the dose received by the population. The remaining 18 percent results from medical procedures, but this proportion may be increasing. The issue of radiation exposure during medical procedures, especially CT, has become an important public health issue as the number of procedures increases. The concern is not for one or two CT scans but the fact that over a lifetime many individuals will have multiple CT scans for marginal indications, resulting in significant radiation exposure.

Radiation dose is measured as absorbed dose or grays (Gy), equivalent dose or sieverts (Sv), and effective dose also is measured in sieverts. The effective dose is an estimate of the whole-body dose, which would result in the same risk as the partial-body dose actually delivered during a radiological examination. This measure takes into account non-uniform exposure and organ sensitivity and allows for comparison to natural background radiation. It is considered the best measurement of radiation exposure currently available. According to the U. S. Nuclear Regulatory Commission, the average American receives an annual radiation exposure of 3.6 mSv (millisieverts) from all sources assuming no unusual exposures from medical procedures.

The images produced by state-of-the-art CT intrigue health care providers and patients alike. "CT appears to be ordered at the slightest provocation, maybe not quite willy-nilly, but certainly at the drop of a hat. And just as certainly, not all the patients are desperately ill," wrote Lee Rogers, MD, in an editorial several years ago in the *American Journal of Radiology*. Unfortunately, in the wake of our enthusiasm, concern for the risk of radiation is now divorced from the precision from images provided through CT.

The risk from radiation is assumed proportional to the dose and is cumulative over an individual's lifetime. Previously, most medical procedures delivered low doses of radiation and therefore the risk was considered small. For example, the average chest X-ray results in a dose of 0.02 mSv, which is equivalent to the dose of naturally occurring radiation an individual would receive over the course of a couple of days. Conversely, the estimated dose from an abdominopelvic CT scan for patients evaluated for a complaint of abdominal pain is between 9.6 mSv and 13.1 mSv, depending upon imaging parameters. This is equivalent to almost three to four years of natural radiation or, put into perspective, between 480 to 650 chest X-rays.

Radiologists have always been aware of the need to keep radiation doses to patients "as low as reasonably achievable" (ALARA). However, a study in *Radiology* earlier this year indicates that even after many publications have addressed this issue, when it comes to CT radiation dose, radiologists and referring physicians (specifically emergency department physicians) who request large numbers of CT studies are unaware of the radiation dose delivered during a CT scan and its possible risks. Equally important, the issue of radiation dose remains largely undiscussed with patients.

When it comes to plain film examinations (analogue studies), image acquisition and display depend on technique (tube current and voltage), as well as the film screen combination. If the technique is too high, the film will be too dark; if the technique

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is too low, the film will be too light. However, CT is a digital technology in which image acquisition and display are independent. The greater the technique or dose, the higher the signal to noise ratio, the better the appearance of the image produced. According to some researchers, CT images are often performed with high radiation exposure to obtain the best quality image with the lowest noise, despite the fact that radiologists have long known that quality images are not always diagnostic and diagnostic images are not always of the highest quality.

Multiple Images Part of the Problem

The increase in CT scans performed has resulted in greater reliance on scanning protocols rather than problem-directed scans designed for individual patients based on a particular clinical problem. As a result, "one of the key elements of radiation protection in CT, namely supervision by the radiologist," has been removed from the process. Often protocols are designed for the interpreting physician's convenience and efficiency. Since the studies are not monitored in real time this results in obtaining more images than are necessary.

The speed of multi-detector helical scanners has made obtaining multiple phase scans easier through a rotation process. Previously, CT scans were usually single-phase studies but now are often a double- or triple-phase examination equivalent to two or three scans. This doubles or triples the radiation dose from one procedure often without regard to whether or not the additional images add value to the study.

Children Bear an Added Burden

In 2001, David Brenner, MD, a researcher from Columbia Presbyterian Medical Center, and others, published an article bringing to light to the medical imaging community some of the potential negative utilization consequences of these technological advances, especially in children. Brenner describes a 92 percent increase in CT utilization in children under age 15 between 1996 and 1999 at a major children's hospital. More importantly, researchers indicated that for a given set of technical parameters during a CT of the head, abdomen, or pelvis, children receive a significantly larger dose of radiation compared to adults. Researchers conclude that in view of this heavier radiation burden and the increased life expectancy of children compared to adults, CT scans could theoretically result in greater lifetime cancer mortality in children, to one in 1,500 for a single head CT and one in 500 for a single abdominal CT. For any given set of imaging parameters, the radiation dose delivered to children is significantly higher than that delivered to adults because dose is inversely proportional to the patient's diameter. These authors advocate decreasing the tube current (mAs) used for CT scans on children as a means of decreasing the radiation dose without compromising diagnostic quality.

What Can We Do to Reduce Exposure?

Since the risks of radiation are cumulative, it is essential that radiologists try to reduce the radiation dose delivered by each CT scan administered. To accomplish this, it is important to understand how multi-detector helical CT scanners work.

Excellent reviews of the factors that determine radiation dose delivered by these scanners appear in several articles recently published in the journal *Radiology*. The important factors to consider are the tube current (mA), the tube voltage (Kvp), and time or speed of gantry rotation. Slice thickness and number of slices also contribute to radiation dose calculations. Additionally, with multi-detector helical CT (MDCT) scanners, pitch (the distance of table movement per gantry rotation divided by the slice thickness) is important in calculating dose. Depending upon the parameters used, a 16-slice MDCT scanner is capable of producing outstanding images with greater detail and lower dose than an 8-slice MDCT scanner, which is capable of producing outstanding images at lower doses than a 4-slice MDCT scanner. This is due to the differences in gantry geometry between an 8- and 16-slice MDCT compared to a 4-slice MDCT or a single-slice scanner. The difference permits the acquisition of high-quality images with equivalent noise at lower mA settings on the 8- and 16-slice machines. By decreasing the mA, we decrease the dose. Additionally, by increasing table speed (pitch), slice thickness, or the number of detectors used, we can also decrease the dose. However, the potential for dose reduction with the 8- and 16-slice MDCT scanners is lost during multiphase scanning or when we obtain higher resolution images using thinner slices and lower pitch.

Education Is Essential

Some of the CT utilization increase is appropriate, resulting in more accurate diagnoses that are established safely and efficiently. However, patient demand for the newest technology, changing practice patterns of physicians who are overly dependent on laboratory and imaging test results, and duplicative imaging that does not always add significant information to the diagnosis have combined to increase the inappropriate use of medical imaging.

To control, and hopefully reduce, radiation exposure from medical imaging it is vital for health plans to educate health care providers (interpreting physicians, technologists, and referrers) and plan members regarding radiation dose from CT. We may thereby decrease the potential risks for iatrogenically induced cancers.

By encouraging good utilization management, health plans can reduce members' exposure to radiation as well as decrease costs.

In 2002, researchers writing for *The British Journal of Radiology*, made the following recommendations:

1. Every CT scan must be clinically appropriate. Will the information obtained from the scan influence patient management? If not, is the scan medically necessary? Is there an alternative imaging procedure involving less radiation exposure?

2. Every CT scan should be problem-directed and the imaging parameters adjusted so that the lowest possible dose is used to obtain the needed information.

3. Limit the scanning phases as the clinical problem dictates.

4. Use the lowest tube current possible, especially for high-resolution scans (thin section, low pitch).

In a 2003 issue of *Radiology*, researchers made further suggestions:

1. Never transfer techniques from one scanner to another without considering the differences in scanner design that impact radiation dose and image quality.

2. If tube voltage is increased to penetrate better, the tube current should be reduced.

3. If tube rotation time is increased, the tube current should be reduced.

4. Understand how a particular scanner works. Some machines automatically increase tube current when pitch is increased, thereby eliminating the dose savings afforded by the higher pitch.

In the *Radiologic Clinics of North America*, researchers caution physicians to use MDCT technology wisely. It is an extremely powerful tool, which generates incredible images. It permits fast (even single-breath hold) imaging over long distances with fewer motion artifacts than earlier scanners. Due to the speed, lower doses of intravenous contrast can be used.

Take advantage of new technology. Some newer CT equipment includes automatic exposure control devices to help decrease radiation dose and obtain diagnostic information for every study performed.

Radiologists should not hesitate to use the full power of this technology when indicated, but must also be careful not to overuse it simply to produce aesthetically pleasing images at the expense of unnecessary radiation exposure.

Finally, by educating members and referring physicians regarding the appropriate use of CT and the radiation issues involved, health plans can positively impact this growing public health concern, while improving the quality of care that their members receive.

Further Implications

Although we have focused on issues of radiation dose and CT, it's important to recognize that this is not the only diagnostic imaging modality using X-rays where radiation exposure is of concern.

For example, there is a published case of radiation skin burns in a patient who had undergone a lengthy percutaneous coronary angioplasty and atherectomy. Subsequently, examples of other cases of radiation-induced skin burns were reported in patients who had undergone percutaneous coronary interventions. Researchers caution interventional cardiologists on the need for better training and awareness of radiation exposure risks to themselves and their patients. Better training in radiation safety and understanding ways to decrease radiation dose delivered to patients during interventional procedures performed by a specialists are also encouraged. C

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