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Dose Reduction in CT: the Time Is Now

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The radiation exposure due to CT scanning is of increasing public concern. Recently, scanning errors at a large radiology department, alleged to have led to radiation overdoses for over 200 patients, have led to public outrage and an FDA investigation (1,2). Media reports have also focused on the fact that medical radiation exposure is on an upward trend, much of it due to increases in CT imaging (3,4).

The main concern is that such exposure might lead to an increase in radiation-induced cancers (5). For example, one study projects a large contribution to cancer formation in women from medical imaging performed between the ages of 35 to 54 years (6). Despite intensive efforts by many investigators, it has been difficult to determine whether the “relatively low dose” (typically < 10 mSv) from medical imaging procedures actually leads to an increase in such cancers. Estimates of the effects of low radiation dose on cancer formation to a large extent are extrapolations from atomic bomb survivor data. The relevance of such data to the risks from medical radiation has been questioned (7,8). In addition, the risks of low-dose medical radiation exposure need to be put into context with other risks to which people are exposed as well as to the benefits to be gained from medical imaging in the appropriate clinical setting (8).

Despite the principle to keep radiation dose As Low As Reasonably Achievable (ALARA) (9), in the past, radiologists have not focused their efforts sufficiently on radiation dose reduction. That attitude is changing. An international effort on radiation dose reduction known as “Image Gently” is underway, primarily aimed at reducing dose to pediatric patients, (10, 11). Radiation doses are now routinely reported for each exam and are often available on the PACS. The National Institutes of Health Clinical Center now includes the per exam radiation dose in patients’ medical records and requires vendors who sell imaging equipment to NIH to provide the data in a way that makes electronic recording feasible (12).

General strategies for radiation dose reduction include reducing the tube current time product (mAs) for small patients, tube current (mA) modulation (angular modulation which takes into account variation in x-ray attenuation as the tube rotates around the patient; and longitudinal modulation which takes into account the variation in size of the patient from superior to inferior), real-time automatic exposure control and adjustment of kV based on patient size (13). Specific strategies are necessary for certain CT protocols. For example, it has been long recognized that doses for cardiac CT have been relatively high. Strategies to lower the dose at

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cardiac CT include the use of prospective ECG triggering of the scan, dual source CT and higher helical pitch (14,15). Since dose reduction techniques may adversely affect image quality, research on dose reduction strategies generally assess not just the change in dose but the effect on the diagnostic content of the exam.

In this issue of the journal, Guimarães et al. report on a technique called “projection space denoising” that enables CT dose reduction (16). The technique is a noise reduction computer algorithm that is applied to the raw projection data, unlike other noise reduction techniques that operate on the reconstructed CT images. They applied their technique to CT enterography images obtained at 80 kV. They used 80 kV imaging because the iodine signal is dramatically increased by a factor of 1.7 at 80 kV compared to 120 kV. The greater iodine signal enables better diagnosis of abnormal mucosal enhancement. A drawback of low kV scanning is an increase in unacceptable image noise, hence the need for a noise reduction algorithm. The authors assessed sharpness by measuring bowel wall thickness and the maximum CT number gradient across the bowel wall. The processed images had a number of desirable properties including high contrast, less noise and good image sharpness. The results were images that approached the quality of traditional CT enterography exams but which required only half the radiation dose. Since the main indication for CT enterography is Crohn’s disease imaging and Crohn’s patients are typically younger, the technique fulfills the goal to “image gently”.

The study had some limitations. The computer processing was relatively slow but would benefit from hardware implementation that could enable real time processing. The technique might not work as well in patients with large body habitus. The authors only compared their method to a small number of commercially-available methods. The technique was proposed as a general strategy and would require further evaluation to ensure optimal clinical implementation. The authors evaluated only the bowel wall and did not assess quality of depiction of other abdominal organs. The study did not address sensitivity for detecting bowel lesions.

There are other approaches to apply noise reduction during the image reconstruction process in ways that enable dose reduction as well. Adaptive statistical iterative reconstruction (ASIR) models the statistical behavior of the photon statistics and electronic noise and models the CT detectors’ response to incident photons (17,18). Dose reductions of as much as 50% have been achievable with ASIR for some low-dose CT protocols such as CT colonography (18).

Other researchers have investigated the use of low-dose CT in evaluation of Crohn’s disease. Kambadakone et al. found that they could substantially reduce the radiation dose administered to patients by selecting the optimal noise index level for their scanner’s automated tube current modulation software (19). They found that dose reductions of 31 to 64% were achievable without adverse effects on the diagnostic quality of the images. Allen et al., in a prospective study of 2310 CT enterography procedures, found that substantial dose reduction could be achieved by adjusting the reference tube current by patient weight and by altering automatic exposure control settings (20). In both of these studies, 120 kVp rather than the iodine signal-enhancing setting of 80 kVp was used.

Improvements in scanning technology and technique are not the only ways to reduce dose. Another strategy is to reduce the number of unnecessary radiology tests. A substantial fraction of radiology tests may be ordered unnecessarily (21). To improve the appropriateness of outpatient radiology imaging, Vartanians et al. incorporated a decision support algorithm into a computerized radiology order entry system (22). The algorithm required responsible clinicians rather than support staff to order “low-yield” studies, i.e., those studies having low utility or appropriateness. After incorporation of the decision support algorithm, the authors saw a substantial reduction in the number of low-yield examinations requested. One can also reduce dose by eliminating series from multiphase CT examinations. For example, with dual

source CT one can make virtual noncontrast images, avoiding a second scan (23,24). Another approach is to substitute a non-ionizing radiation imaging technique, such as ultrasound or MRI.

Will radiation dose reduction of 50% be sufficient to reduce or eliminate hypothesized radiation-induced cancers? At this time, no one can be sure because the biological effects of relatively low dose radiation on humans are unknown. Given the uncertainties, the time is now to be proactive and reduce dose As Low As Reasonably Achievable using techniques such as those presented by Guimarães et al. while collecting population-based data that may shed light on the murky and emotional issue of radiation effects of medical imaging.

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