Radiology Rounds

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Janet Cochrane Miller, D.Phil., Author | **Raul N. Uppot, M.D., Editor**

Minimizing CT Radiation Dose

- **CT examinations improve health care and are an essential part of diagnosis and treatment planning**
- **Radiation exposure from CT is higher (2-15 mSv) than plain film radiography (0.05-2 mSv)**
- **No direct data have shown that CT examinations are associated with an increased risk of cancer; extrapolations from studies of radiation exposure suggest there is a very small incremental risk**
- **The risk for pediatric patients is likely to be greater than that for adults, dedicated CT protocols are in place at MGH to minimize their exposure**
- **Other strategies for minimizing radiation dose from CT include avoiding unnecessary CT examinations, utilizing alternate imaging modalities when appropriate, and using state-of-the-art CT dose reduction technologies**

The fine anatomical detail visible in computed tomography (CT) images has revolutionized diagnosis of both acute and chronic diseases and often provides information critical to the management and planning of treatment for both adults and children. As technological advances have increased, the range of examinations CT utilization has steadily increased and has recently been reported to be as high as 17% of the total radiology workload. However, the x-ray exposure from each CT scan is substantially higher (2-15 mSv) than plain film radiography (0.05-2 mSv) and, therefore, CT accounts for about 70-75% of the total ionizing radiation from diagnostic imaging. While these levels of radiation are well below those that cause deterministic effects (for example, cell death), there is concern that they may be associated with a risk of stochastic effects (such as cancer), albeit small.

No direct study has shown that CT increases the risk of cancer. Radiation scientists extrapolate the risks of x-ray radiation encountered during CT examinations from studies of the long-term outcome of people exposed to the atomic explosions in Japan and workers in the nuclear industry. According to these extrapolations, the projected lifetime risk of developing cancer from a single CT examination is one in 1,000-2,000 per 10 mSv. It should be noted that this projected risk is very small compared to the overall lifetime risk of developing cancer, which is about one in three. Furthermore, the majority of patients who receive CT scans already have cancer and/or life span limiting conditions. Nevertheless, there is an incremental risk with each additional scan and with higher radiation doses and, considering the large numbers of patients who receive CT examinations, a small individual risk translates into a larger risk from the public health perspective. In addition, there is greater concern for pediatric patients and pregnant women both because children and fetuses are more vulnerable to radiation and because they have more years to live. These potential risks must be weighed against the benefits of the CT examination. (For more information on radiation risks in pregnancy, see the February 2004 issue of Radiology Rounds).

Table 1. Scanning Parameters that Affect Radiation Dose
Tube current (mA)
Tube potential (kVp)
Gantry rotation time
Range of scan (length of body region scanned)
Pitch (slice overlap), table speed, and detector configuration
Number of image acquisition phases

Even though the radiation exposure from a CT scan carries, at most, a very small risk of developing cancer, it is prudent to minimize patients' exposure to radiation. Recognizing this, radiologists have adopted the principle of "as low as reasonably achievable (ALARA)" and manufacturers have been pro-active in developing dose reduction techniques. In CT scanning, a number of different parameters can be adjusted that affect radiation dose (Table 1) and several strategies are in use at MGH to minimize radiation dose while maintaining diagnostic quality (Table 2). In addition, the MGH continually explores new ways to achieve lower radiation exposure consistent with acceptable diagnostic image quality.

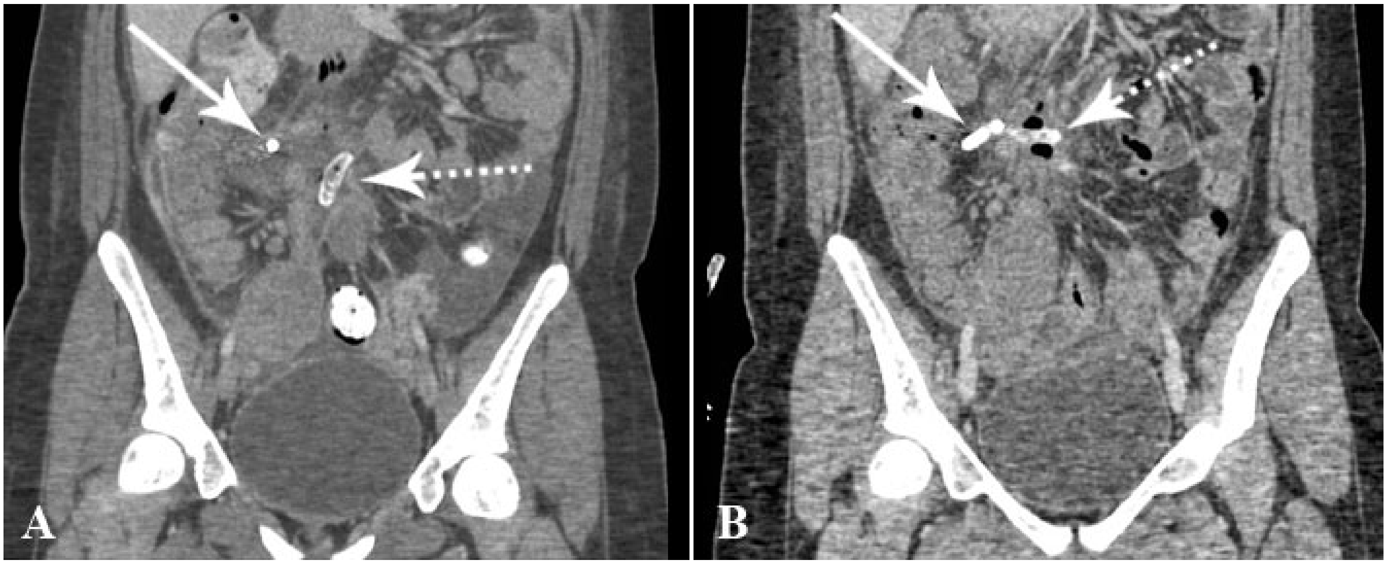

Figure 1. Abdomen and pelvic CT of a 15 year-old girl who had a perforated appendix. A. CT scan performed using standard setting (radiation dose, 10.9 mGy) B. A follow-up CT scan was performed 8 days later using pediatric dose reduction settings (radiation dose, 4.8 mGy). B is noisier than A but still of diagnostic quality. Scans show resolving inflammatory changes and a pigtail drainage catheter (solid arrows) with an appendicolith (dotted arrows) in the mid abdomen.

Avoiding Unnecessary CT Scans

There are several clinical scenarios in which unnecessary CT examinations may be performed, including cases in which CT is not the most suitable imaging modality for the presenting symptoms, duplicate examinations are ordered because of poor communication, the radiological findings are unlikely to affect treatment decisions, or follow-up examinations are not clinically justified.

Computerized Radiology Order Entry (ROE) with decision support informs the referring physician if the CT examination is not likely to be diagnostic, given the symptoms entered in the system, and suggests alternate imaging examinations. At the MGH, this strategy has decreased low yield CT examinations from 6% to 2% and has increased the percentage of CT examinations that have yielded clinically important findings.

In some cases, such as in situations where a patient is transferred from the care of one physician to another, a duplicate CT scan may be ordered unknowingly. If the order is made on ROE, there is an automatic alert if the patient has had a recent CT examination. If the order is made by other means, it is routine practice at MGH to check for prior radiology examinations and, if the new order is a repeat examination (not a follow up examination), a radiologist will contact the referring physician to confirm that a second scan is warranted.

Pediatric CT

Every request for a pediatric CT examination is pre-screened by a radiologist. If there is any doubt as to the appropriateness of the examination in any patient, radiologists may discuss alternatives with the referring physician.

Smaller patients require less radiation for the same image quality. For this reason, weighing machines are in place in most CT examination rooms at the MGH and scanning parameters, including both mA and kVp, are set according to the patient's height and weight, the clinical indication for the scan, and the number of previous scans for this indication. Implementation of this strategy to minimize radiation dose for pediatric patients while ensuring diagnostic image quality is aided by color-coded posters and memory cards, which have been developed to help the radiologists and technologists identify the lowest radiation dose and most suitable technique to answer specific problems on an individual patient basis. As a result of these adjustments in protocol, pediatric patients are exposed to 44-70% less radiation than if standard settings were used (Figure 1).

When patients have had a previous scan for the same clinical indication, it is often possible to reduce the radiation dose. For example, if a second scan is performed for renal stones, it is possible to reduce the radiation dose by 50% and still obtain diagnostic information because of the high attenuation of renal stones. Radiation exposure in subsequent scans may be cut down even further. However, if the image contrast is expected to be low, as in lesions in the liver, it may not be possible to lower the radiation dose in follow-up scans.

Automatic Exposure Control

For most adult CT examinations, automatic exposure control techniques are used rather than manual adjustment of mA and kVp. Automatic exposure control software, installed on all CT scanners at MGH, automatically adapts radiation dose to patient size, including anatomical variation within the patient, while maintaining a specified level of image noise (Figure 2). Use of automated exposure control in, for example, the abdomen and pelvis in adult patients has been shown to decrease exposure by an average of 43%. The decreases are greater than average in slim patients; the radiation dose in obese patients may be higher but result in better image quality than if standard fixed current settings are used.

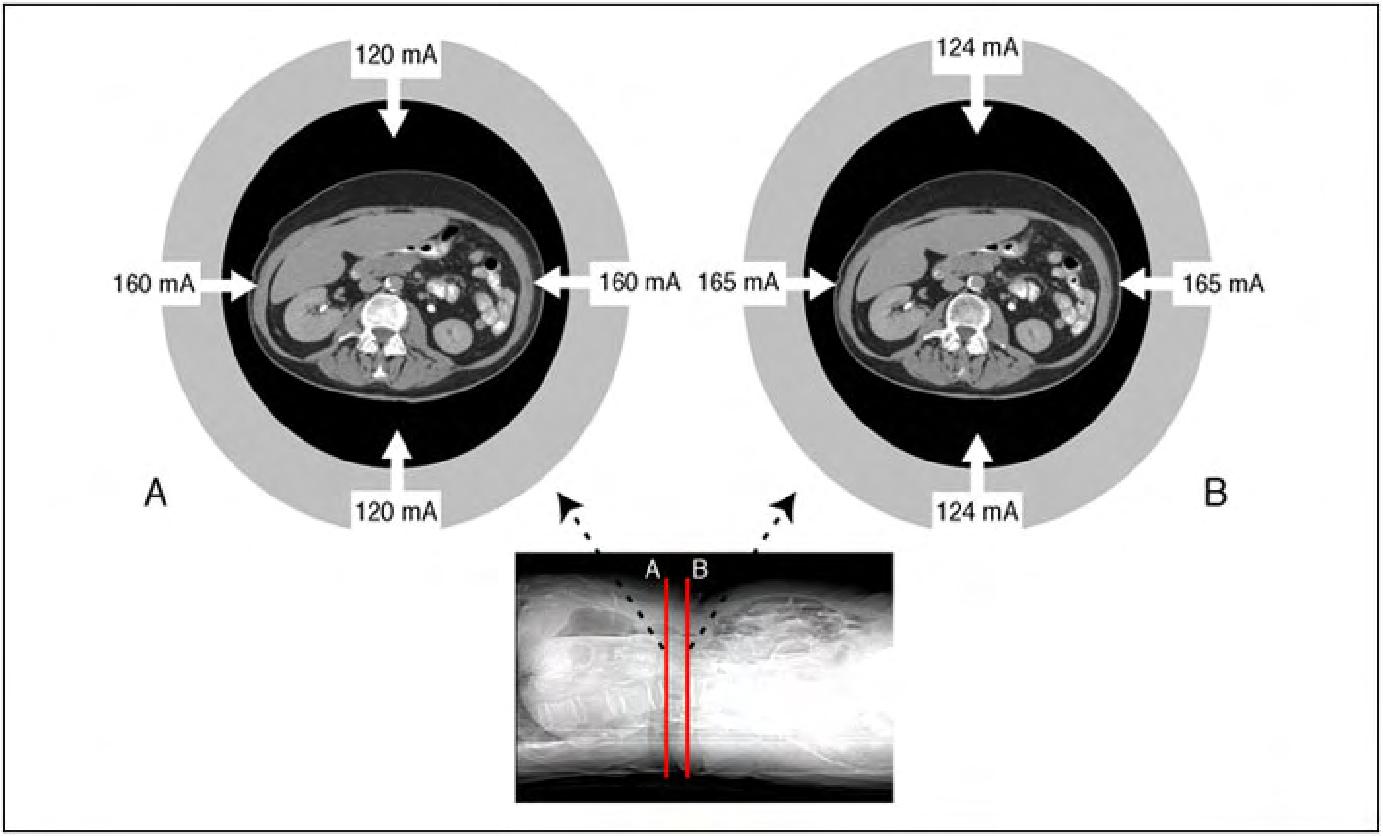

Figure 2. Automatic Exposure Control for CT examinations. The attenuation through one region of the body, A, is less than another, B, and is less in the anterior-posterior projection than the lateral. With automatic exposure control, the average x-ray tube current is lower at A than in B. In both A and B, the tube current is lower in the anterior-posterior projection than in the lateral projection.

Table 2. Strategies for Minimizing Radiation Dose
Eliminate inappropriate CT examinations
Avoid duplicate examinations
Perform follow-up scans only when clinically justified and limit to area of pathological findings
Use dedicated protocol chart for pediatric patients that optimizes dose to age, size, and clinical indications
Optimize radiation dose to patient size and clinical indications in adults patients with automated tube modulation
Use EKG gating to minimize dose during coronary CT angiography

Coronary CT Angiography

Without dose reduction techniques, coronary CT angiography requires a relatively high radiation exposure because images of the coronary arteries are acquired in multiple phases of the cardiac cycle. In order to minimize the dose while maintaining image quality, a physician technologist team tailors both the kVp and mA to each patient in order to optimize the risk: benefit ratio. In addition, when the heart rate is low and steady, ECG-gating is used to modulate the current, lowering the current to 4-25% of the nominal value during the systolic phase, which allows to reconstruct high quality images of the coronary arteries in one phase at the cost of noisier images at other phases (Figure 3).

Quality Control

The Department employs a certified medical physicist, who ensures proper calibration and quality control of all CT scan systems. All MGH Radiology technologists and staff are educated on the potential risks involved in radiation exposure from CT imaging. Additionally, MGH CT protocols and practices meet the American College of Radiology (ACR) Practice Guidelines and Technical Standards, which are evidence-based guidelines to assist medical providers in the safe and appropriate use of diagnostic imaging (including CT). Using our customized scanning approaches, radiation dose reduction can be achieved without compromising image quality and therefore interpretation accuracy is not impacted by the lower amounts of radiation used with optimized protocols. The Department also employs a “lock-in” security system for its scanners whereby only designated radiologists and/or CT operation managers can set the scanning techniques in order to maintain consistent scanning techniques and minimize possibility of higher than required radiation dose.

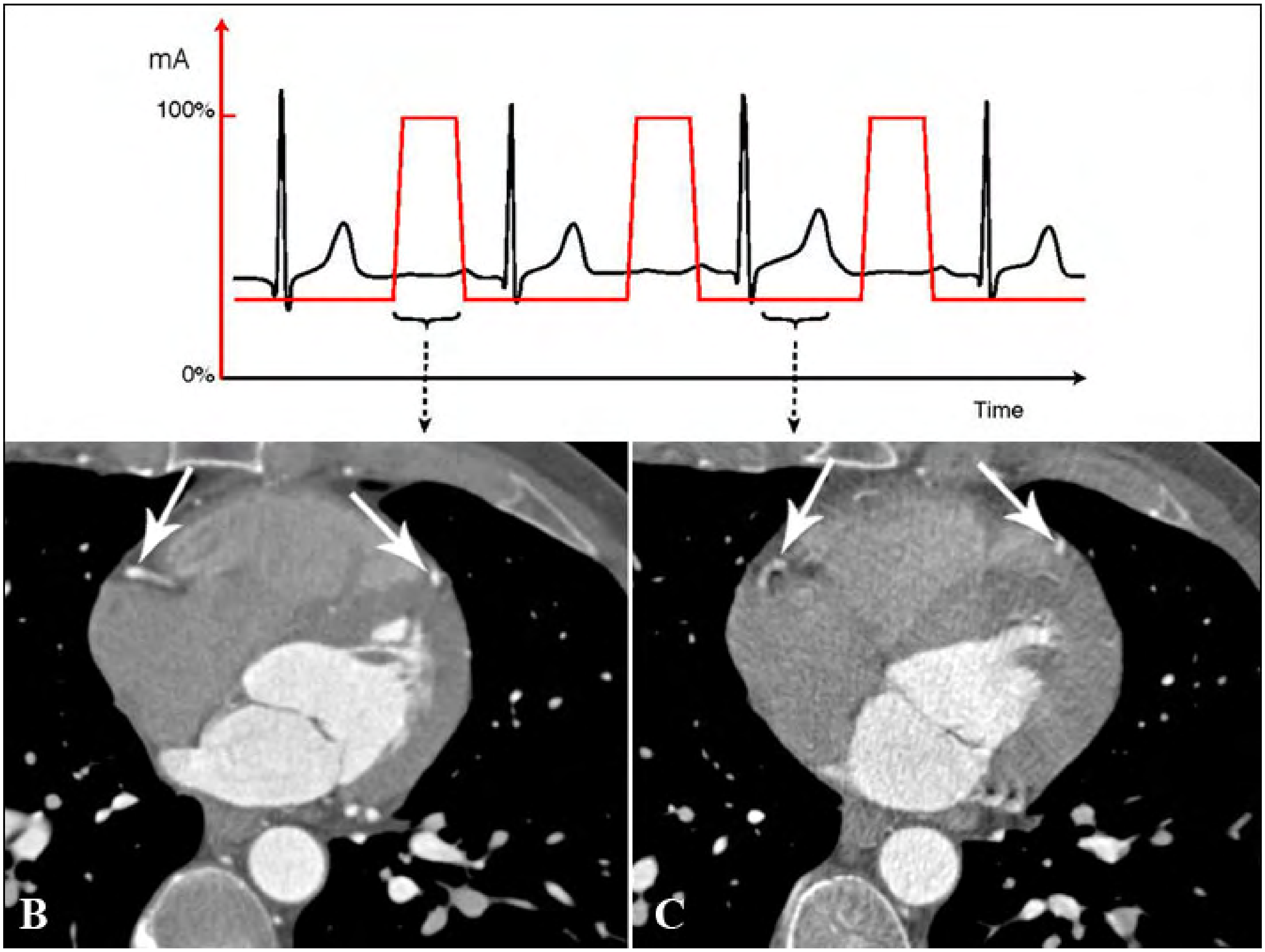

Figure 3. ECG-Gated Cardiac CT Angiography. A. The x-ray tube current is lowered prospectively during part of the cardiac cycle and increased during the phase at which the heart has least motion. High signal-to-noise images (B), reconstructed from the data acquired at standard tube current, show detailed anatomy including the coronary arteries (arrows). Images with lower signal-to-noise (C) are reconstructed from data acquired at low tube current.

Scheduling

Radiology examinations may be ordered online via the Radiology Order Entry (http://mghroe) or by telephone 617-724-XRAY (9729) for all locations. CT is performed at the main campus as well as Mass General West Imaging, Waltham and Mass General Imaging, Chelsea.

Further Information

An informational handout suitable for patients who have concerns about radiation dose is available on the Department of Radiology, CT Division website. CT Scans and Radiation Risk.

For further questions, please contact Hani H. Abujudeh, M.D., Director of Quality Assurance, MGH Department of Radiology at 617-726-8366 or Dushyant Sahani, M.D., Director of CT, MGH Department of Radiology at 617-726-3937.

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