A Community Hospital’s Experience With an Effective, Affordable, and Easily Implemented CT Radiation Dose Reduction Initiative

Ronnie C. Chen, MD, John O. Johnson, MD

RATIONALE

CT has become an invaluable diagnostic tool, and its use has surged dramatically over the past decade. However, one of its main disadvantages is the significant dose of ionizing radiation required compared with other imaging modalities, such as ultrasound and MR. Increasing concern among both health care professionals and the public regarding the long-term carcinogenic effects of radiation exposure has stimulated efforts toward radiation dose reduction and the creation of several campaigns (Image Gently® [1] and Image Wisely® [2]) to promote the guiding principle of diagnostic radiation exposure: “as low as reasonably achievable.” Although new scanner technologies and imaging processing techniques are continuously being developed to reduce doses, these innovations are often costly and not immediately available to the wider medical community. Consequently, more accessible techniques focused on controlling radiation exposure through the manipulation of patient-specific scanning parameters such as tube current and tube voltage have increasingly gained attention.

A basic understanding of x-ray production is essential in appreciating how adjustments in tube current and tube voltage can affect radiation dosages. X-ray production begins by heating a cathode, which excites and releases electrons from the cathode surface into the x-ray tube. These electrons constitute the tube current. Within the tube, there also exists a tube voltage, which serves to accelerate electrons toward the anode. As the electrons bombard the anode target, their kinetic energies are converted into a spectrum of x-rays released from the anode surface, forming the x-ray beam used for imaging. The rate of x-ray production can be roughly approximated as being directly proportional to the tube current and proportional to the square of the tube voltage [3]. Thus, changes in the tube voltage have a larger effect than changes in the tube current on the strength of the x-ray beam.

The tube current and tube voltage can be adjusted for each examination. Modern CT scanners are equipped with automatic exposure software capable of tailoring tube current to patient body habitus. Additionally, tube voltage can be manually selected. The concept of decreasing tube voltage has been used in pediatric imaging to reduce radiation exposure for children, whose growing organs are more radiosensitive compared with those of adults. Although most adult examinations are typically carried out using tube voltages of 120 to 140 kVp, pediatric examinations are often performed at voltages less than 100 kVp. In recent years, the dose reduction advantage of decreasing tube voltage has also been shown in nonobese adults, primarily in cardiac CT imaging [4-6]. These findings have spurred interest in using tube voltage reduction to decrease radiation dosages in other CT examinations.

On the basis of these reports, Scripps Mercy Hospital, an acute care tertiary hospital serving the metropolitan area of San Diego, California, initiated a low-cost and easily implemented radiation dose reduction program focused on manipulating patient-specific imaging parameters in nonobese patients.

IMPLEMENTATION

In August 2010, a radiation dose reduction initiative at Scripps Mercy Hospital was spearheaded by a lead radiologist and a lead CT technician. The template was modeled on a highly successful program initiated at Imaging Healthcare Specialists, a large metropolitan (San Diego) outpatient imaging network [7]. CT acquisition body protocols (chest, abdomen, and pelvis) were revised to reduce radiation doses for nonobese patients on the basis of body mass index (BMI). Tube voltage was decreased from the standard 120 kVp to 100 kVp if patients met specific BMI criteria. For chest examinations, patient BMI must have been less than 30 kg/m² to qualify for the low-voltage protocol. For abdominal and pelvic examinations, BMI must have been less than 25 kg/m². Studies were carried out using the Siemens SOMATOM Sensation 16 and the Siemens SOMATOM Definition 64 (Siemens Healthcare, Erlangen, Germany). Automatic exposure control via tube current modulation (Siemens CARE Dose 4D) was configured by manufacturer applications at the time of scanner installation and remained unchanged, with image quality reference tube current-time product set at 250 and 240 mAs for chest examinations.
tions and abdominal and pelvic examinations, respectively.

OUTCOMES
To assess the efficacy of these changes, two common imaging examinations were chosen for analysis. Retrospective chart review was performed on all patients who underwent low-voltage CT angiography for pulmonary embolus or abdominal and pelvic CT with the renal stone protocol between October 2010 and October 2011. Patients were included in the analysis only if they satisfied the following criteria:

- Patients must have had at least one study performed with the low-voltage protocol and at least one comparison standard-voltage study in their medical records.
- These studies must have been carried out on identical scanner models under the same automatic exposure control settings for tube current.
- Patients must have met the above BMI criteria at the time both standard-voltage and low-voltage studies were performed.

Studies at standard- and low-voltages served as matched pairs for analysis. For CT angiography for pulmonary embolus, 26 patients with 26 pairs of imaging studies were collected. Comparing standard-voltage and low-voltage studies, average effective dose was decreased from 6.1 to 3.3 mSv, representing a 46% dose reduction when using the low-voltage protocol. For abdominal and pelvic CT studies with the renal stone protocol, 13 patients with 14 pairs of imaging studies were collected. Comparison of these studies showed a similar decrease in average effective dose from 8 to 4.5 mSv, representing a 44% dose reduction.

Despite the dramatic dose reduction, there was no associated adverse subjective degradation of image quality. Although examinations performed under the low-voltage protocol did exhibit more image noise, they nevertheless remained diagnostic (Figs. 1 and 2). These

Fig 1. Axial images from an abdominal and pelvic CT scan with the renal stone protocol performed in a man with a body mass index of 19 kg/m². Examinations were performed at (a) 120 kVp with a dose of 5.7 mSv and (b) 100 kVp with a dose of 2.7 mSv. Despite increased image noise in the 100 kVp examination, the right renal calculus is still identifiable.

Fig 2. Axial images from a CT angiogram for pulmonary embolus performed in a woman with a body mass index of 22 kg/m². Examinations were performed at (a) 120 kVp with a dose of 5.4 mSv and (b) 100 kVp with a dose of 3.3 mSv. Improved contrast is apparent when tube voltage is reduced to 100 kVp, aiding in the detection of emboli. An embolus is present within the left pulmonary artery.
studies were reviewed by 20 board-certified radiologists, and no complaints have been registered regarding image quality since the changes were initiated. Additionally, lowering tube voltage resulted in a previously described improvement in contrast related to the K-shell absorption edge of iodinated contrast media (Fig. 2) [8,9]. This was particularly beneficial in CT angiography, for which improved contrast can aid in the detection of emboli.

CONCLUSIONS
Significant dosage reductions were achieved by lowering tube voltage for patients on the basis of BMI criteria. However, the most striking aspect of this dose reduction program was the simplicity of its implementation. Initiation of the program required only the time of a lead radiologist and a lead CT technician for protocol revision and staff education. Thus, direct costs incurred were minimal. It is worth mentioning that continuous auditing was critical in the program’s success, particularly in the early phase. When protocol “drift” was detected, staff reeducation was necessary to ensure compliance with the new protocols.

In our experience, manipulation of patient-specific imaging parameters on the basis of BMI criteria has been an efficient first step in lowering radiation doses. Although new scanner technologies and image processing techniques may ultimately be necessary to achieve submillisievert CT scans, the techniques described here are an effective, affordable, and easily implemented first step for community hospitals seeking to initiate radiation dose reduction programs. Although significant progress has been made with this dose reduction initiative, there is still more to be done as we work toward our pursuit of “as low as reasonably achievable.” Attempts are already under way at our institution to further decrease radiation doses by manipulating automatic exposure controls for tube current.

REFERENCES

Ronnie C. Chen, MD, is from the Department of Radiology, UCLA Medical Center, Los Angeles, California. John O. Johnson, MD, is from Imaging Healthcare Specialists, San Diego, California.

Ronnie C. Chen, MD, UCLA Medical Center, Department of Radiology, 757 Westwood Plaza, Los Angeles, CA 90095; e-mail: rcchen@mednet.ucla.edu.