Ionizing Radiation in Abdominal CT: Unindicated Multiphase Scans Are an Important Source of Medically Unnecessary Exposure

Kristie M. Guite, MD[a], J. Louis Hinshaw, MD[a], Frank N. Ranallo, PhD[a,b], Mary J. Lindstrom, PhD[c], Fred T. Lee Jr, MD[a]

Purpose: CT radiation exposure has come under increasing scrutiny because of dramatically increased utilization. Multiphase CT studies (repeated scanning before and after contrast injection) are a potentially important, overlooked source of medically unnecessary radiation because of the dose-multiplier effect of extra phases. The purpose of this study was to determine the frequency of unindicated multiphase scanning and resultant excess radiation exposure in a sample referral population.

Methods: Abdominal and pelvic CT examinations (n = 500) performed at outside institutions submitted for tertiary interpretation were retrospectively reviewed for (1) the appropriateness of each phase on the basis of clinical indication and ACR Appropriateness Criteria® and (2) per phase and total radiation effective dose.

Results: A total of 978 phases were performed in 500 patients; 52.8% (264 of 500) received phases that were not supported by ACR criteria. Overall, 35.8% of phases (350 of 978) were unindicated, most commonly being delayed imaging (272 of 350). The mean overall total radiation effective dose per patient was 25.8 mSv (95% confidence interval, 24.2-27.5 mSv). The mean effective dose for unindicated phases was 13.1 mSv (95% confidence interval, 12.3-14.0 mSv), resulting in a mean excess effective dose of 16.8 mSv (95% confidence interval, 15.5-18.3 mSv) per patient. Unindicated radiation constituted 33.3% of the total radiation effective dose in this population. Radiation effective doses exceeding 50 mSv were found in 21.2% of patients (106 of 500).

Conclusions: The results of this study suggest that a large proportion of patients undergoing abdominal and pelvic CT scanning receive unindicated additional phases that add substantial excess radiation dose with no associated clinical benefit.

Key Words: Radiation, CT, abdomen, pelvis

J Am Coll Radiol 2011;8:756-761. Copyright © 2011 American College of Radiology

INTRODUCTION

CT scanning has become ubiquitous in medicine. Recent technical advances, including faster scan times, improved spatial resolution, and advanced multiplanar reconstruction techniques, have increased the usefulness of CT for virtually every anatomic abnormality. Concomitantly, a rise in defensive medicine and ownership interest in CT centers by referring physicians have resulted in a dramatic increase in utilization [1-3]. Approximately 3 million scans were performed annually in the United States in 1980, and by 2008, that number had grown to 67 million [4]. Along with this increased number of scans, an increasing awareness of medical radiation has permeated the popular and scientific press. More than two-thirds of all medical radiation can now be attributed to CT, with the majority resulting from examinations of the chest, abdomen, and pelvis [5-7].

Although there is no doubt that radiation exposure from CT has been increasing rapidly, the significance of this exposure remains unclear. High levels of ionizing radiation exposure are known to increase cancer risk [8-10], but the data for lower doses of radiation are less clear

[a]Department of Radiology, University of Wisconsin, Madison, Wisconsin.

[b]Department of Medical Physics, University of Wisconsin, Madison, Wisconsin.

[c]Department of Biostatistics and Medical Informatics, University of Wisconsin, Madison, Wisconsin.

Corresponding author and reprints: J. Louis Hinshaw, MD, University of Wisconsin, Department of Radiology, Mail Code 3252, 600 Highland Avenue, Madison, WI 53792; e-mail: jhinshaw@uwhealth.org.

Dr Lindstrom's contribution to this work was supported by a grant 1UL1RR025011 from the National Institutes of Health (Bethesda, Md).

0091-2182/11/$36.00 • DOI 10.1016/j.jacr.2011.05.011

and remain controversial [11-13]. Therefore, in the absence of clarity on this topic, the ACR, Health Physics Society, and other interested organizations have adopted the principle of ALARA, whereby physicians should minimize the amount of radiation exposure to only what is medically necessary [7,14,15].

Most strategies to reduce radiation associated with CT have focused on vetting CT as the appropriate diagnostic test, limiting the examination to the anatomic area in question, and optimizing scanning parameters (particularly in pediatric patients) [2,16-18]. Applying optimized technical parameters alone can decrease radiation exposure by up to 65% [15,16]. However, an important but potentially overlooked source of medically unnecessary radiation is the use of multiphase examinations when a single or lesser number of phases would suffice [16]. The different phases that are possible with state-of-the-art CT scanners are myriad and include scanning before and after contrast administration, delayed imaging, venous and arterial phases, and others. Considering the dose-multiplication effect of extra phases, it is possible that inappropriate multiphase CT could be an important source of excess radiation exposure. Recognizing the need for guidelines addressing multiphase examinations, the College has developed evidence-based ACR Appropriateness Criteria® describing scanning protocols with specific phase selections for various clinical conditions [19].

The purpose of this study was to determine the frequency with which the ACR Appropriateness Criteria for abdominal and pelvic CT are being followed, the frequency of unindicated phases, and the magnitude of excess radiation exposure for patients when unindicated phases are performed.

METHODS

Selection and Description of Participants

This study was approved by the human subjects committee of our institutional review board, with a waiver of the requirement for informed consent. The patient group consisted of 708 consecutive abdominal and pelvic CT scans performed at outside institutions during a 4-month period (February 26, 2008, to June 6, 2008) and submitted to our institution for an official "overread." Excluded were nondigitized images; pelvis-only examinations; specialty examinations, including CT colonography, CT-guided biopsies, and vascular studies; and studies for which the clinical indication was unknown. The final cohort was composed of 500 patients with a median age of 60 years (range, 9 months to 90 years). There were 263 female (53%) and 237 male (47%) patients, with 18 patients aged $\leq$ 18 years. The studies were primarily from referring institutions in Wisconsin and Illinois, with a smaller number coming from Michigan, Minnesota, Iowa, Ohio, Florida, Missouri, and Alaska.

Appropriateness Criteria

CT examinations were reviewed by one of two experienced abdominal radiologists (F.T.L. or J.L.H.) to determine which phases were indicated for the given clinical indication. ACR Appropriateness Criteria [19] were used as the gold standard. A CT phase was considered to be appropriate (indicated) if the ACR Appropriateness Criteria score was $\geq$4 (on a scale ranging from 1 to 9, scores of 4 to 6 indicate that studies "may be appropriate", and scores of 7 to 9 indicate that studies are "usually appropriate") and unindicated if the score was $<$4. Each examination that had an unindicated phase or phases was reviewed to determine if there was an incidental finding on the scan that could justify additional scanning for further characterization (eg, incidental liver mass necessitating delayed imaging). If so, these phases were categorized as "unindicated but justified."

Technical Information

Radiation Effective Dose Calculations. The clinical history, indication, phases performed, scanning parameters (including CT scanner make and model, tube current, kilovoltage, slice thickness, collimation, rotation time, and pitch), and body part were all recorded. CT scanner models from GE (Milwaukee, Wis), Siemens (Erlangen, Germany), Toshiba (Tokyo, Japan), and Phillips (Andover, Massachusetts) were represented. The collected parameters were used to calculate effective dose for each phase using the ImPACT CT Patient Dosimetry Calculator (version 0.99x 20/01/06), and the effective dose in millisieverts was recorded [20]. For patients with more than one phase, doses were added together to obtain a total dose per patient. Patients with unindicated but justified phases were analyzed with the unindicated group. These patients were initially identified to determine which patients had incidental findings that if noted on the CT scanner could warrant additional phases. However, because it was impossible to determine if these findings were identified before or after the patient left the CT scanner (with the latter thought to be more likely), we analyzed these patients as part of the unindicated group.

Rotation time and pitch were unavailable for 56 of 500 subjects. For these patients, the rotation time and pitch were estimated using the mean values obtained from all other scans that used the same CT scanner model.

Statistical Analysis

The distribution of total effective dose, indicated effective dose, and excess effective dose were all skewed, so that a log transformation was necessary to obtain approximate Gaussian distributions. Differences be-