Cumulative Radiation Exposure Estimates of Hospitalized Patients from Radiological Imaging

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Purpose: To examine the use of inpatient diagnostic imaging and image-guided procedures to estimate cumulative radiation exposure, radiation exposure based on imaging modality, and compare estimated doses based on patient demographics including age, gender, and diagnoses.

Methods: Two hundred consecutive hospitalized adult patients who underwent diagnostic imaging studies at 2 large, affiliated hospitals were identified, and every study in each patient's electronic record that took place during a single hospitalization was reviewed. Dose estimates were calculated for each CT, fluoroscopy, nuclear medicine, plain film, and interventional radiology study or procedure based on reported dose length product, published reference values, and conversion factors. Medical records were reviewed to determine patient gender, age, diagnoses, length of stay, admitting service, and time in an intensive care unit (ICU).

Results: Two hundred inpatients (46.5% male; mean age, 60.4 years) underwent 2,751 imaging studies (79.3% radiographs, 9.7% CT, 6.1% ultrasound, 2.5% interventional radiology, 2.2% MRI, 0.4% nuclear medicine). The mean dose estimate per patient was 14.8 milliSieverts (mSv) and the range was 0 mSv to 130.5 mSv. Mean cumulative dose estimates were significantly higher for patients whose hospitalizations included time in an ICU (17.9 mSv versus 11.3 mSv [$P = .01$]). CT examinations accounted for 82.1% of the total radiation dose estimate. Eleven patients (5.5%) received radiation dose estimates $\geq$50 mSv, including 2 $\geq$100 mSv.

Conclusions: Of imaged inpatients, 62% underwent at least 1 CT and the majority (82.1%) of inpatient radiation exposure was attributable to CT examinations. Mean dose estimate was 14.8 mSv per patient; 5.5% of patients experienced estimated doses $\geq$50 mSv.

Key Words: Imaging utilization, inpatients, radiation exposure, hospitalization, CT, cumulative

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INTRODUCTION

Advances in medical imaging, in particular CT, have made it possible to acquire extremely high-resolution images in a very short period of time. For example, using a 64-slice multidetector CT scanner, an entire adult abdomen and pelvis can be imaged with a .625 mm slice thickness in as few as 5 to 7 seconds. The ability to acquire such high-resolution images rapidly has transformed the way many medical conditions such as intracranial hemorrhage, blunt trauma, pulmonary embolism, and acute appendicitis are diagnosed with a picture truly being worth a thousand words.

However, recent publications have emphasized the potential future cancer risk from radiation exposure due to CT examinations [1,2]. It is estimated that 1 individual in 1,000 will develop cancer from an exposure to 10 milliSieverts (mSv) of low-dose radiation [3].

To our knowledge, cumulative radiation exposure estimates for hospitalized patients during a single hospitalization have not been reported previously. Prior investigations of radiation exposure due to diagnostic imaging have focused on large general populations [4], emergency department patients [5,6], patients with specific diagnoses, such as Crohn's disease [7,8], and pediatric oncology patients [9].

The aim of this study was to examine the use of diagnostic imaging in a cohort of patients during a single hospitalization within a tertiary care hospital system to

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estimate cumulative radiation exposure, investigate radiation exposure based on imaging modality, and evaluate estimated doses based on patient demographics including age, gender, and diagnoses.

METHODS

This study was a retrospective review of images and patient medical records. Institutional review board approval was obtained for this Health Insurance Portability Accountability Act (HIPAA)—compliant study, and a waiver of informed consent was granted. Data were collected from Emory University Hospital and Emory University Hospital Midtown.

Patient Population

Two hundred patients were selected for inclusion in this study by reviewing the Emory University Hospital and Emory University Hospital Midtown radiology informatics system inpatient imaging lists on October 1, 2010 and recording the first 100 consecutive inpatients at each hospital who had a diagnostic imaging study or procedure in the radiology department that day. Both hospitals are within a single health system. One is a 579-bed hospital with 93 intensive care unit (ICU) beds and provides the main training rotations for medical students, residents, and fellows. The other hospital is a hybrid academic-private practice in a community hospital setting with 511 hospital beds, including 68 adult ICU beds.

Electronic medical records were reviewed by the primary investigator to access discharge summaries for each patient's hospital stay spanning October 1, 2010, which were used to identify total length of stay, whether or not an ICU stay occurred, the service to which the patient was admitted, and general demographics (age, gender, and primary and secondary diagnoses) (Table 1). Patients undergoing imaging as an outpatient were not included. Patients ≥18 years of age were included in the study. Radiological imaging from outside hospitals in transferred hospital patients was not included in this study.

Radiation Exposure and Dose Estimates

Each patient's electronic imaging record was reviewed using a PACS (GE Centricity, GE Healthcare, Waukesha, WI) to identify all imaging studies or image-guided procedures performed in the radiology department during the hospitalization spanning October 1, 2010.

For each radiographic study, the number of images and the projection of each image were recorded (example, frontal versus lateral chest radiograph). Published reference values (Table 2) were used to estimate radiation dose for each image. Fluoroscopic study (example, barium enema) dose estimates were also assigned using published reference values (Table 2).

For all CT studies, it is routine practice at our institution for the technologist to send a machine-generated dose report page to PACS with a total dose length product (DLP) for every CT examination. These DLPs were recorded. For 27 patients and 31 imaging studies, a dose report page was not available, and we applied the mean DLP for each study to patients that had missing data. Conversion factors from the American Association of Physicists in Medicine were used to convert DLP values to radiation dose estimates in milliSieverts (Table 3).

For interventional radiology procedures using fluoroscopic guidance, dose estimate values were extracted from the literature (Table 4). Published dose area products were converted to milliSieverts using the conversion factors referenced from published literature in Table 4. For nuclear medicine examinations, all dose estimates were extracted from the literature (Table 5).

Imaging performed outside of the radiology department was not available on the PACS and, therefore, was

Table 1. Clinical features of patient population (N = 200)

Clinical Parameters	n	% or SD
Average age (years)	60.4	SD, 16.7
Gender		
Female	107	53.5%
Male	93	46.5%
Average length of stay (days)	15.6	SD, 15.7
ICU stay		
Yes	105	52.5%
No	95	47.5%
Clinical service (in decreasing frequency)		
General medicine	60	30.0%
Cardiothoracic surgery	39	19.5%
Cardiology	21	10.5%
Critical care/pulmonary	20	10.0%
Neurosurgery	16	8.0%
General surgery	11	5.5%
Medical oncology	9	4.5%
Vascular surgery	5	2.5%
Nephrology	4	2.0%
Other*	15	7.5%
Primary diagnosis (in decreasing frequency)		
Myocardial infarction	15	7.5%
Pneumonia/Pneumonitis	13	6.5%
Respiratory distress/failure	12	6.0%
Coronary artery disease/other ACS	12	6.0%
Heart failure exacerbation	10	5.0%
Heart valve replacement	9	4.5%
Bacteremia/sepsis	8	4.0%
Cerebral hemorrhage	7	3.5%
Lung cancer	7	3.5%
Altered mental status	5	2.5%
Gastrointestinal cancer	5	2.5%
Genitourinary cancer	5	2.5%
Symptomatic anemia	5	2.5%
Transplant surgery	5	2.5%
Brain tumor	4	2.0%
Failure to thrive	4	2.0%
Other†	64	32.0%

ACS = acute chest syndrome, ICU = intensive care unit, SD = standard deviation.
*Includes neurology, transplant surgery, urology, hepatology, surgical oncology, obstetrics and gynecology, and orthopedics.
†Includes deep vein thrombosis, fracture, and pulmonary embolus.