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How to identify high radiation burden from computed tomography: an example in obese children

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ABSTRACT

Background: Radiation burden from the use of computed tomography (CT) imaging may not be evenly distributed. We tested whether overweight and obese children receive higher radiation burden from CT imaging.

Methods: An automated software tool (DoseWizard) assessed patient-level radiation dose from CT and merged results with clinical data from the electronic health record. CT scans of the head, chest, and abdomen/pelvis (A/P) performed at our institution from January 2013 to August 2015 on patients aged <16 y were processed using this software. Patients were categorized as overweight/obese if they had a body mass index (BMI) greater than the 85th percentile for age. Radiation exposures were compared between groups. Higher dose CT scans were identified as having a radiation dose in the top decile. Multivariate analysis identified factors associated with high-dose CT scans.

Results: About 7212 CT scans were included. Overweight/obese patients received similar radiation dose for head CT as compared with normal weight patients (1.51 versus 1.49 mSv, $P = 0.04$) but higher radiation dose for chest (1.14 versus 0.81 mSv, $P < 0.001$) and A/P (1.97 versus 1.43 mSv, $P < 0.001$). In multivariable regression models, being overweight/obese increased the odds of a higher dose chest CT (odds ratio 2.24, $P < 0.001$) and A/P CT (odds ratio 7.24, $P < 0.001$).

Conclusions: Overweight and obese children receive higher radiation burden from CT imaging and are one group that deserves consideration of dose monitoring. This software tool can be used to measure changes in radiation exposure and run clinical decision support in future studies targeting high radiation exposure to children.

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Introduction

Computed tomography (CT) is a widely used diagnostic tool with approximately 7 million scans performed in pediatric patients in the United States annually.^{1,2} Concerns have been raised about the amount of ionizing radiation it contributes on a population level as higher radiation exposure has been correlated with higher rates of radiation-related malignancy.^{3,4} This is of specific interest in children. The increased radiosensitivity of developing tissue, coupled with the additive nature of radiation over a patient's lifetime necessitates the development of methods for identifying pediatric cohorts at risk for higher levels of radiation burden. Professional organizations such as the American College of Radiology and more specifically the Image Gently initiative have reduced pediatric CT radiation burden through robust professional and lay education programs. The American College of Radiology maintains a voluntary CT dose registry to help institutions gauge their dosing against peer institutions. However, there are currently no available tools to calculate and monitor radiation dose and merge it with meaningful clinical data at the patient level. Combining radiation dose calculations with clinical patient information allows for both individual patient radiation dose monitoring and identification of cohorts of children at risk for high radiation burden. This information could be used to monitor radiation exposure and guide our health care system to further minimize radiation burden to patients.

The purpose of this study was to evaluate whether an automated process could be established for CT scan parameter extraction, radiation dose calculation, and the merging of these data with electronic health record (EHR) data for the purpose of identifying pediatric patient groups at our institution with the highest radiation exposure from CT imaging. Patient conditions, such as obesity, can influence the amount of radiation a patient receives both in the rate of CT scan prescribing and in the dose of radiation per CT scan. Specifically, overweight/obese patients may be more likely to receive a CT scan due to difficulties in obtaining a diagnosis using other imaging modalities such as ultrasonography.^{5,6} In addition, although there are reduced radiation protocols for CT imaging in children, patients of larger body thickness may have greater beam attenuation and may receive greater amounts of radiation from CT imaging due to automatic exposure control systems.⁷

In this report, we test whether radiation burden is higher among overweight/obese children. We hypothesize that using our methods, we would identify that overweight/obese children would receive higher radiation exposure from CT imaging than their normal weight counterparts.

Methods

Study design

Technology development

Our team created a software tool that automates rapid calculation of effective and organ-specific radiation dose from

individual scan parameters extracted from the Picture Archiving and Communications System and merges it with patient-level characteristics from the EHR in near real time. This was completed by (1) leveraging open source software that queries and extracts dose data from imaging files (Radiance, www.radiancedose.com)⁸; (2) operationalizing protocols for data extraction from our institutional EHR platform; (3) automating effective and organ-specific dose calculation using a software tool created by the National Cancer Institute^{9,10}; and (4) custom programming that merges the results from each of the aforementioned data sources (DoseWizard, patent 62/251,485). This process was tested in over 10,000 patients at our institution. Samples of subcohorts of scan types (head, abdomen/pelvis [A/P], and so on), and clinical data were manually validated confirming that 100% of the sampled records were accurately extracted, transformed, and loaded into a research database.

Cohort development

This was a retrospective study comparing CT scans performed in overweight/obese children *versus* nonoverweight children at our institution from January 2013 to August 2015. For this study, the normal weight cohort includes all patients who were not overweight/obese. The study was limited to pediatric patients, defined as age less than 16 y. For all analyses, overweight/obese was defined using the following strategy. If a child was less than 2 y of age at the time of their scan, overweight/obese was defined as a weight for length percentile of greater than or equal to the 85th percentile based on the World Health Organization's 2006 gender-specific growth curves.¹¹ If a child was at least 2 y of age at the time of their scan, overweight/obese was defined as a body mass index (BMI) percentile of greater than or equal to the 85th percentile based on the Centers for Disease Control's 2000 age- and gender-specific growth curves.¹² The documented BMI at the hospital encounter at which the CT occurred was used when available. When not available, the closest preceding BMI value in the EHR, up to 6 mo before the CT scan, was used. When there was no BMI documented in the 6 mo before the scan, the closest height and weight values documented within the preceding 6 mo were used to calculate BMI. If none of these strategies produced a value for BMI, it was considered missing. Although we recognize that the terms overweight and obese are not commonly used to describe children under 2 y of age, we chose to use these terms because the relative size of patients influences radiation dosing regardless of patient age.

Method for radiation dose evaluation

The amount of radiation that is output from the CT scanner to perform a CT scan on a particular patient in clinical practice is based upon a protocol that is selected by the radiologist and the CT technician. This amount of radiation may or may not be modifiable based upon the indication for the CT scan and how it is protocolled. The automatic exposure control system of the CT scanner will increase radiation output from the machine for thicker targets (heavier patients) to try to

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