Impact of Socioeconomic Status on Ionizing Radiation Exposure From Medical Imaging in Children

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Purpose: To characterize cumulative radiation exposure from diagnostic imaging (CEDI) in pediatric patients and to investigate its relationship to patients' socioeconomic status and comorbid medical conditions.

Methods: A retrospective cohort study of >19,000 pediatric patients seen within the outpatient clinic system of an academic tertiary care urban medical center during the month of January 2006 was conducted to estimate CEDI from all procedures performed within 3 years of the index visit (until January 2009). Socioeconomic status was estimated from census tract geocoding. Comorbid medical conditions were identified from the electronic medical record.

Results: A total of 19,063 patients underwent imaging tests within the index month. The mean age was 8.9 ± 6.3 years. Most had private insurance (56%), with 36% receiving Medicaid and 8% private payers. Our population lived in census tracts in which 27 ± 16% of the population were below the federal poverty level with 62% living in areas in which 20% of residents were living below the poverty level. There were differences in CEDI ($P < .0001$) by age, insurance type, and percentage poverty in the census tract of residence but not among racial groups ($P = .6508$). The association between poverty and CEDI was generally explained by the 26 Elixhauser diagnoses, with the exception of rheumatoid arthritis.

Conclusion: Patients living in areas of greater poverty were exposed over time to more radiation from diagnostic testing than those living in areas with lower percentages of residents living in poverty. This association was explained almost entirely by the presence of disease burden. No direct association was found between socioeconomic status and CEDI.

Key Words: Radiation dose, radiation exposure, exposure to patients and personnel, socioeconomic factor, access to health care, pediatrics

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INTRODUCTION

Although the benefits of radiographic imaging are generally accepted, the side effects of ionizing radiation exposure from CT scans, fluoroscopy, and nuclear medicine studies are receiving more attention. A recent study indicated that approximately 40% of children aged < 18 years in the United States are exposed to at least one ionizing radiation examination over a 3-year period from medical imaging procedures [1]. Studies suggest that radiation exposure may be more hazardous in children because their tissues are still growing and may be more prone to somatic genetic damage. Additionally, children's greater life expectancy provides a longer observation time for adverse events [2-8]. The use of CT has increased rapidly, with an estimated 70 million CT scans performed in 2007 in the United States [9]. Primarily on the basis of epidemiologic data from atomic bomb survivors, it has been estimated that 1.5% to 2% of future cancers in the United States may be attributable to current CT use and that 29,000 cancers may be attributable to the CT scans performed in 2007 [10]. Furthermore, some have estimated that the mortality from radiation exposure is 1 death per 4,000 scans and 1 excess cancer per 1,000 scans [11].

Understanding the factors associated with the utilization of radiologic imaging is important in correcting

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possible differences in the delivery of health care services according to patient demographic characteristics (health disparities). Lower socioeconomic status (SES), lack of health insurance, and belonging to a disadvantaged race or ethnicity are associated with increased disease prevalence, decreased access to care, and worse health outcomes across a broad spectrum of diseases [12-16]. In a study of adult patients undergoing myocardial perfusion imaging, those patients without health insurance underwent fewer tests involving radiation and had lower cumulative effective doses than patients with any health insurance [17]. Our objective was to test the association in children between SES and medical radiation exposure and diagnostic imaging utilization in the US health care setting. We hypothesized that because of increased disease burden, lower SES may contribute to an increase in exposure to medical ionizing radiation. Our population was primarily African American and Latino children living in varying degrees of poverty who were followed for 3 years at an urban medical center. We tested our hypothesis by evaluating the associations between cumulative radiation exposure from diagnostic imaging (CEDI) and SES, race, ethnicity, and insurance status, controlling for comorbidities.

METHODS

Data Sources

This was a retrospective cohort study of patients from a tertiary care academic urban medical center with specialized pediatric outpatient, inpatient, and emergency facilities. We accessed our institution's computerized medical record system using Clinical Looking Glass version 3.3 (Montefiore Medical Center, Bronx, New York), an interactive software application, to derive radiation exposure (estimated effective dose), geocoding (census tract of residence), comorbidity reports, demographics, and insurance status. The study was approved by the medical center's Institutional Review Board for the Protection of Human Subjects and was compliant with HIPAA.

Study Population

The population was defined to include all patients aged ≤21 years at the time of an initial visit during January 2006 at any of the institution's 14 outpatient clinic sites, which all use the electronic medical record system. Patient records were reviewed through January 2009 to identify all medical imaging studies performed over this time period. Patients who died during the 3 years of follow-up were excluded to minimize potential bias due to numerous examinations preceding their deaths and the truncation of their observation period. Patients with <3 years of follow-up were also excluded. Age, gender, race, and ethnicity were self-reported by the patient or guardian at registration. Ethnicity was defined as either Hispanic or Latino or non-Hispanic or non-Latino. Insurance information was based on the source of payment recorded for the original outpatient encounter and was subsequently categorized as private insurance, Medicare, Medicaid, or no insurance (self-pay).

SES

The percentage of people living below the poverty level in a census tract has previously been used as a measure of SES [18]. To validate this approach in this cohort, 100 randomly selected addresses geocoded by the Clinical Looking Glass geocoding report were compared with the census tract on the US Census Bureau's geocoding Web site [19]. Eighty-two percent of addresses were assigned the same census tracts by both methods, 10% could not be geocoded by the census Web site, and a small fraction (8%) were assigned different census tracts. To account for the possible nonlinearity of the relationship between census tract percentage of persons living below the poverty level and radiation exposure, percentage poverty categories of 0% to 10%, >10% to 20%, >20% to 30%, >30% to 40%, >40% to 50%, >50% were created. Bronx County has one of the highest poverty rates in the nation (28.3% in 2009), and the study population therefore did not replicate the previously used cutoff of >20%, the federal definition of a poverty area, as the highest poverty group [20].

Examination Utilization and Estimation of Radiation Dose

All diagnostic radiology examinations, nuclear medicine examinations, and cardiac catheterizations were recorded for 3 years from the original outpatient visit date for each patient. These included all procedures performed at multiple imaging facilities, including inpatient, emergency, and outpatient settings. Mean radiation doses were assigned to the common examinations performed in radiology, nuclear medicine, and invasive cardiology on the basis of literature-reported values [21,22] available before the initiation of this cohort. The estimated radiation doses for all examinations for the 3-year period of each patient were then summed, yielding a total estimated cumulative radiation dose in millisieverts. Actual measured radiation exposures vary widely and also tend to be higher than estimated mean calculated exposures [9,22,23].

Comorbidities

Because SES is associated with disease risk, we incorporated comorbidities into our analyses to account for increases in imaging procedures due to increased burden of disease. We determined the presence of each of 26 Elixhauser diagnoses for each patient using International Classification of Diseases, ninth rev., codes for the entire 3-year study period. Elixhauser diagnoses have been shown to be positively associated with mortality and hospital charges [24].

Statistical Analysis

Descriptive statistics are presented as mean ± SD for continuous variables and as relative frequencies for cate-