Computed Tomography Use Among Children Presenting to Emergency Departments With Abdominal Pain

WHAT’S KNOWN ON THIS SUBJECT: Increased computed tomography (CT) use among adults and children presenting to emergency departments has spawned concern about associated radiation exposure. The risks and benefits of CT use for certain conditions, such as abdominal pain, among general pediatric populations remains unclear.

WHAT THIS STUDY ADDS: This study analyzes emergency department radiology trends between 1998 and 2008 among children with abdominal pain, highlighting a dramatic increase in CT use. Factors associated with CT ordering include older age, non-black race, and hospital admission.

abstract

OBJECTIVE: To evaluate trends in and factors associated with computed tomography (CT) use among children presenting to the emergency department (ED) with abdominal pain.

METHODS: This study was a cross-sectional, secondary analysis of the National Hospital Ambulatory Medical Care Survey data from 1998 to 2008. We identified ED patients aged <19 years with abdominal pain and collected patient demographic and hospital characteristics, and outcomes related to imaging, hospital admission, and diagnosis of appendicitis. Trend analysis was performed over the study period for the outcomes of interest, and a multivariate regression model was used to identify factors associated with CT use.

RESULTS: Of all pediatric ED visits, 6.0% were for abdominal pain. We noted a rise in the proportion of these patients with CT use, from 0.9% in 1998 to 15.4% in 2008 (P < .001), with no change in ultrasound/radiograph use, diagnosis of appendicitis, or hospital admission. Older and male patients were more likely to have a CT scan, whereas black children were one-half as likely to undergo a CT scan compared with white children (odds ratio: 0.50 [95% confidence interval: 0.31–0.81]). Admitted children had much higher odds of undergoing a CT scan (odds ratio: 4.11 [95% confidence interval: 2.66–6.35]). There was a plateau in CT use in 2006 to 2008.

CONCLUSIONS: There was a dramatic increase in the utilization of CT imaging in the ED evaluation of pediatric patients with abdominal pain. Some groups of children may have a differential likelihood of receiving CT scans. Pediatrics 2012;130:e1069–e1075
Abdominal pain is a common presenting complaint among children presenting to the emergency department (ED), and providers may be faced with significant diagnostic uncertainty in the evaluation of these patients. Depending on the age of the patient, there is a wide differential for the etiology of abdominal pain, ranging from benign to emergent surgical causes. A complete history can be difficult to obtain from a young patient, making the diagnosis challenging without imaging, regardless of whether plain film radiographs, ultrasound, or computed tomography (CT) scans are used.

Over the last 5 years, there has been increasing awareness of radiation exposure and the potential cancer risk from CT use. Excess radiation exposure and the potential cancer risk can be difficult to obtain from a young patient, making the diagnosis challenging without imaging, regardless of whether plain film radiographs, ultrasound, or computed tomography (CT) scans are used.

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Selection of Participants
We identified visits by children aged 0 to 18 years with a chief complaint of abdominal pain (including cramps, spasms, discomfort, and colic).

Data Collection
The following data were collected for each of the children: demographic characteristics (age, gender, race/ethnicity, and insurance status), imaging use (CT, ultrasound, and plain radiograph), ED characteristics (pediatric versus nonpediatric, academic versus nonacademic, and safety net versus non—safety net), geographic location (US region and urban area), disposition (admission versus discharge), and whether appendicitis was the final diagnosis by using the International Classification of Diseases, Ninth Revision codes 540.xx to 542.xx. Age categories were designated as <4 years, 4 to 11 years, and 12 to 18 years. Safety net status was assigned based on proportion of all visits in which the expected source of payment was Medicaid, self-pay, or no charge/charity as per previously described criteria. Urban areas were defined according to the US Census Bureau’s metropolitan statistical area (MSA) designation. Pediatric EDs were defined as ≥85% of visits by patients aged <21 years and academic EDs as facilities in which ≥25% of patients were evaluated by a resident physician.

NHAMCS does not distinguish between types of CT scans, and thus each imaging modality was coded as a dichotomous variable, assuming if a child presented to the ED with a complaint of abdominal pain, imaging would target that anatomic region. For years 2001 to 2004, NHAMCS collected a combined CT and MRI variable; because we could not separate the use of these modalities, 2 separate analyses were performed to evaluate CT use. First, we excluded 2001–2004 data from the study; we then performed a sensitivity analysis including CT and/or MRI for all years, with the assumption that a small minority of the patients had an MRI in the ED.

Data Analysis
Descriptive statistics are reported for patient demographic characteristics, and the χ² trend test was used to evaluate changes in the annual proportion of imaging use, diagnosis of appendicitis (including ruptured appendicitis), and hospital admission. Visits were stratified into 3-year blocks corresponding to the beginning and end of the study period (1998–2000 and 2006–2008), and, for unadjusted comparisons, the Pearson χ² statistic was used to compare proportions. A multivariable logistic regression model was then used to estimate adjusted odds ratios (ORs) for factors associated with CT use. Covariates were selected for the model by using a hierarchical stepwise regression (adjusted Wald test) based on association with CT use at P < .20 as cutoff for inclusion. Statistical analysis was performed by using Stata 11.1 (Stata Corp, College Station, Texas).
We identified 91,669 ED visits among pediatric patients within NHAMCS from 1998 to 2008. Among these, 5516 (6.0%) visits were for abdominal pain (Table 1). The overwhelming majority of patients were female and in the middle and older age categories. Approximately one-half of visits were by white/non-Hispanic children. Most visits were to non-academic and nonpediatric hospitals.

Over the 11-year study period, all outcome measures, other than CT use, remained relatively stable (Table 2). Although total visits to EDs increased over the time period,8 there was no statistically significant change in the proportion of pediatric ED visits for abdominal pain. We did, however, identify a steep rise in CT use over the specified time period, from 0.9% in 1998 (95% confidence interval [CI]: 0.1–1.9) to 15.4% in 2008 (95% CI: 11.7–19.0), with P < .001 for the temporal trend (Fig 1). This finding remained unchanged when analyzing trends in combined CT and/or MRI use. The proportion of children obtaining an ultrasound or plain radiograph did not change significantly (P = .11 and P = .46, respectively). Analysis among children with chief complaints other than abdominal pain, such as vomiting or a combination of nausea, vomiting, vague gastrointestinal symptoms, or decreased appetite, yielded a statistically significant 3- to 4-fold increase in CT use over the same study period (data not shown).

Over time, there was no change in the proportion of children with abdominal pain who were ultimately diagnosed with appendicitis (P = .30). Furthermore, in sensitivity analysis, we found no change over time in the proportion of ruptured appendicitis (data not shown). Although hospital admissions for children with abdominal pain in 2008 were 30% lower than in 1998, the trend was not statistically significant (P = .17) and similar to overall pediatric hospital admissions during the same period (27% decrease, trend P = .10).

In unadjusted analyses, the youngest age group (aged 0–3 years) had no significant change in the proportion undergoing CT scanning, whereas the 4- to 11-year-old and 12- to 18-year-old groups showed the greatest increase in CT use (Table 3). Black children were one-half as likely as white children to receive a CT scan, both in unadjusted analyses (12.4% vs 6.2%) and adjusted analyses (OR: 0.50 [95% CI: 0.31–0.81]). There was less CT use in uninsured children compared with those privately insured (OR: 0.57 [95% CI: 0.34–0.97]). Our data suggest that the magnitude of increased CT use is greater in nonacademic and nonpediatric facilities. We identified no statistical difference between CT use in urban versus nonurban areas.

In multivariate analysis, after controlling for year of visit and triage acuity level (in addition to the variables listed in Table 3), children admitted to the hospital were much more likely to have a CT scan performed (OR: 4.01 [95% CI: 2.57–6.28]), and this association was stable in both the beginning and end time periods of the study. In addition, each subsequent year of visit was associated with increasing CT use in 1998–2000 (OR: 3.56 [95% CI: 1.64–7.73]) but not in 2006–2008 (OR: 1.04 [95% CI: 0.84–1.29]), showing a plateau in the pattern of CT use.

**RESULTS**

**DISCUSSION**

In this analysis, using a robust, nationally representative sample of US ED visits...
visits over an 11-year period, we identified a steep rise in CT utilization among pediatric patients presenting with abdominal pain. This trend may represent the introduction of more routine CT scanning into the practice of pediatric emergency medicine, increased access to CT scanners, a lower threshold for CT use by emergency providers and consultants, a change in the culture or standard of care in emergency medicine, or other unseen forces. Concurrent with this overall increased reliance on CT imaging among pediatric patients with abdominal pain, there was no demonstrable change in other imaging use, hospital admission, or ED diagnosis of appendicitis.

Interestingly, whatever the reasons for increased CT utilization are, the application is not uniform, with fewer black and uninsured children receiving scans. We postulate that this is partly a function of the resources of the hospital because minority patients may tend to receive care in urban public facilities with fewer resources.9,10 However, our findings corroborate recent findings that black children who present to the ED with abdominal pain are less likely to undergo CT scanning and being admitted. We cannot observe a concurrent rise in hospital admissions and have no reason to believe that the severity of illness changed during the study period. Furthermore, in some instances, we should expect that the use of CT would effectively rule out a pathologic condition and decrease diagnostic uncertainty, allowing for discharge from the hospital rather than admission for observation. Taken together, this may suggest that there is a trend toward obtaining CT scans in children for whom the decision has already been made to admit. We cannot know whether this affected any outcomes, altered management, or modified the hospital course. Although the current data set does not allow for inference to be made, it does suggest that the benefits of CT scanning with respect to other utilization or outcomes in this population are unclear.

Other recent studies have shown an increase in ED CT utilization in general medical practice, although the magnitude of increase has been modest compared with the increase among pediatric patients with abdominal pain.11 An NHAMCS study of pediatric head trauma showed a substantial although less dramatic increase in CT use, and likewise, there was no appreciable impact on patient outcomes.12 Although there are a variety of indications for which to order a CT scan in children who have abdominal pain, including trauma, a common reason is to evaluate for appendicitis. This entity is 1 of the 3 most common diagnoses associated with malpractice litigation in children.14 Even in the hands of experienced clinicians, accurately diagnosing appendicitis can be challenging.1 It is not surprising that a study using NHAMCS reported that as of 2006, nearly 60% of children with a final ED diagnosis of appendicitis underwent CT scanning.15 The American College of Emergency Physicians clinical policy on evaluation and management of appendicitis published in 2010 specifically addresses the role of CT and ultrasound in children.16 They cite level B and C recommendations to use an ultrasound (perhaps
as the initial modality of choice) to rule in appendicitis but also relying on a CT scan to either rule in or rule out appendicitis. Because our study period ended in 2008, we are unable to assess whether this policy statement has had an impact on ultrasound or CT use patterns.

A recent investigation from 2 tertiary care pediatric EDs identified no change in abdominal CT use from 2003 to 2010 among children with abdominal pain, although when nonradiation-based modalities such as ultrasound were options, there was decreased CT use.17 Although these findings may initially seem incongruous with our overall results, closer analysis shows that pediatric EDs had higher rates of CT use in 1998–2000 compared with nonpediatric facilities. However, the magnitude of increased CT use is attenuated in the pediatric ED group, lending support to the narrative that although pediatric facilities may have had more access to and liberal use of CT in the earlier years of our study, providers at these facilities may have become more conscientious of the radiation risks and mitigated CT use in more recent years.

The focus of this study was on CT utilization; however, practitioners and institutions should be interested in the potential implications of these patterns with respect to improvements in patient care, increased cancer risk, and rising health care costs. In the short-term, or at the individual patient level, CT use may improve the care provided to children. However, recent attention has been given to the potential long-term risks of CT use, particularly radiation exposure in younger patients causing cancer.3,4 Based on the best available evidence for radiation risks associated with CT scans, some groups have advocated for the routine requirement of informed consent before CT use.18 Furthermore, when considered at the population level, increased reliance on expensive technology, including radiologic testing, contributes substantially to rising health care costs,19 often with inconclusive causal benefits in terms of outcomes.20 Although this study used a large, nationally representative data set over 11 years, there are some limitations that need to be addressed. First, CT utilization data for 4 years of the study were grouped with MRI use. Our sensitivity analysis combining both CT and MRI confirms our CT-only analysis because the proportion undergoing MRI was small. Furthermore, CT of the abdomen and pelvis is not a separate variable in the data set, and we have used any CT scan as a surrogate as described in the Methods section.

Second, outcomes of clinical interest, such as change in disposition, impact on follow-up, patient and provider satisfaction, or long-term risks of CT use, are difficult to ascertain in this cross-sectional analyses. We cannot identify the ordering provider or motivations for ordering, and as such, cannot distinguish emergency provider-initiated CT scans from those done at the recommendation of or ordered directly by consultants while the patient is still in the ED.

Finally, although the NHAMCS data set is robust, our methodology relied on multiple stratifications, reducing statistical power for some analyses. In particular, the relative infrequent number of CT scans performed in the early years of the study results in high SEs. Furthermore, the small numbers of patients with a ruptured appendicitis in each year’s strata make it difficult to
evaluate utility of CT to reduce complications of appendicitis.

**CONCLUSIONS**

We observed a dramatic increase in the utilization of CT imaging in the ED evaluation of pediatric patients with abdominal pain. Although these results suggest that emergency providers increasingly rely on this testing modality, neither the reason for, nor the benefits of, this trend is clear. CT use was not uniform between racial and ethnic groups of children, and this finding should be evaluated within the context of health disparities research.

Additional studies should focus on the current state of CT use among children, specifically with respect to clinical outcomes, costs to the medical care system, clinical decision rules to eliminate tests with low diagnostic yield, and longitudinal analysis of radiation risk.

**REFERENCES**

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