US Emergency Department Trends in Imaging for Pediatric Nontraumatic Abdominal Pain

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abstract

OBJECTIVES: To describe national emergency department (ED) trends in computed tomography (CT) and ultrasound imaging for the evaluation of pediatric nontraumatic abdominal pain from 2007 through 2014.

METHODS: We used data from the National Hospital Ambulatory Medical Care Survey to measure trends in CT and ultrasound use among children with nontraumatic abdominal pain. We performed multivariable logistic regression to measure the strength of the association of ED type (pediatric versus general ED) with CT and ultrasound use adjusting for potential confounding variables.

RESULTS: Of an estimated 21.1 million ED visits for nontraumatic abdominal pain, 14.6% (95% confidence interval [CI], 13.2%–16.0%) had CT imaging only, 10.9% (95% CI, 9.7%–12.1%) had ultrasound imaging only, and 1.9% (95% CI, 1.4%–2.4%) received both CT and ultrasound. The overall use of CT and ultrasound did not significantly change over the study period (*P* trend .63 and .90, respectively). CT use was lower among children treated in pediatric EDs compared with general EDs (adjusted odds ratio 0.34; 95% CI, 0.17–0.69). Conversely, ultrasound use was higher among children treated in pediatric EDs compared with general EDs (adjusted odds ratio 2.14; 95% CI, 1.29–3.55).

CONCLUSIONS: CT imaging for pediatric patients with nontraumatic abdominal pain has plateaued since 2007 after the steady increase seen in the preceding 9 years. Among this population, an increased likelihood of CT imaging was demonstrated in general EDs compared with pediatric EDs, in which there was a higher likelihood of ultrasound imaging. Dissemination of pediatric-focused radiology protocols to general EDs may help optimize radiation exposure in children.

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Ms Niles performed the data analysis and was the primary author of the manuscript; Dr Cohen provided the study conceptualization and clinical context for the study in addition to contributing to the creation and editing of the manuscript; Dr Goyal provided clinical context to the study and contributed to the research methodology, study design, and editing of the study and manuscript; Dr Chamberlain provided the conceptualization and clinical context for this study and helped edit the manuscript; Ms Badolato assisted with the data analysis; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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WHAT'S KNOWN ON THIS SUBJECT: The use of computed tomography (CT) imaging in the diagnosis of pediatric nontraumatic abdominal pain increased every year between 1999 and 2007. During the same time period, ultrasound imaging did not change.

WHAT THIS STUDY ADDS: The use of CT and ultrasound imaging for the diagnosis of pediatric nontraumatic abdominal pain has not significantly changed between 2007 and 2014. However, pediatric emergency departments demonstrated a decreased use of CT imaging and an increased use of ultrasound imaging compared with general emergency departments.

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The use of computed tomography (CT) imaging in children presenting to the emergency department (ED) with nontraumatic abdominal pain increased every year between 1999 and 2007.[1] The increase in CT use from 2% in 1999 to 16% in 2007 was accompanied by no significant change in the use of ultrasound imaging during the same time period.[1] Additionally, children evaluated in pediatric ED facilities were 25% less likely than children evaluated at general ED facilities to undergo CT for nontraumatic abdominal pain.[1]

Between the years 2010 and 2013, among children with suspected appendicitis, the use of ultrasound imaging increased substantially, whereas CT use declined.[2] Despite the increased reliance on ultrasound studies, which are diagnostically less accurate than CT, condition-specific quality measures indicate that outcomes have not been negatively impacted.[2] The frequency of appendiceal perforation and ED revisits has remained stable, whereas negative appendectomies have slightly declined.[2] Ultrasound-first imaging paradigms (which recommend use of ultrasound and, only if inconclusive, consideration of a CT) are the most cost-effective method of imaging pediatric appendicitis.[3–8]

Much attention has been paid to understanding trends in CT and ultrasound imaging at the health plan, regional, and state levels, but there is a clear gap in examining these at the national level.[4–6,9–15] We performed this study to measure national trends in CT and ultrasound imaging for the evaluation of nontraumatic abdominal pain among children presenting to EDs between 2007 and 2014. We hypothesized that CT use would decrease and ultrasound use would increase throughout the study period. Furthermore, we hypothesized that pediatric EDs were more likely than general EDs to use ultrasound (as compared with CT) for the evaluation of nontraumatic pediatric abdominal pain.

METHODS

Study Design and Data Source

We conducted a repeated cross-sectional analysis using the publicly available National Hospital Ambulatory Medical Care Survey (NHAMCS) ED data set for 2007, the last year of data collected in the Hryhorczuk et al[1] study, through 2014, the year of the most recent publicly available NHAMCS data set.[16] The Institutional Review Board determined that this study did not meet the definition of human subjects research because we used a publicly available, deidentified data set.

The NHAMCS is a survey of hospital ED visits designed by the National Center for Health Statistics and administered annually by the US Census Bureau. The survey uses a 4-stage probability sampling design, sampling geographically defined areas, hospitals within those areas, EDs within these hospitals, and patients who have visited these settings. NHAMCS representatives collect visit information annually during a randomly designated 4-week period, and data are processed at a central facility and manually checked for accuracy. The NHAMCS survey collects data from ~25 000 visits and 480 hospitals yearly. The resulting publicly available data set uses observational weighting to derive national estimates. More information on the NHAMCS methodology can be found on the Centers for Disease Control and Prevention's Web site.[16]

Study Population

Consistent with the Hryhorczuk et al[1] study, pediatric ED patients aged 20 years and younger with a recorded reason for visit (reason for visit 1–3) of abdominal pain or possible appendicitis (NHAMCS codes 1545 and 2655.0, respectively) were identified for inclusion. Patients were excluded if their surveys indicated that there was trauma or injury associated with their abdominal pain.

Outcomes of Interest

The outcomes of interest were CT and ultrasound use during the ED visit for nontraumatic abdominal pain. Visits were categorized as having an associated CT or ultrasound if a CT scan, other than head CT, or ultrasound was performed during the patient's ED visit. From 2012 through 2014, more detailed information regarding anatomy imaged was incorporated into the survey, allowing for analysis to focus on imaging of the abdomen. However, from 2007 to 2011, the NHAMCS survey did not include anatomy imaged except in the case of head CT. For this reason, for the years 2007 to 2011, an assumption was made that imaging was focused on the abdomen because only patients presenting with abdominal pain were included. This assumption is consistent with the methodology of Hryhorczuk et al.[1]

Variables

The primary exposure variables were year and ED type, which was dichotomized as pediatric ED or general ED. Consistent with previous work, pediatric EDs were defined as those in which at least 75% of patients seen were aged 21 years or younger.[17] Covariables of interest included the following: patient characteristics (reason for visit, age, sex, race, ethnicity, and insurance type), ED characteristics (ED region and academic status), and visit characteristics (triage acuity level, ED visit time of day, ED visit day of week, and presenting level of pain). We also collected information about ultimate diagnosis of appendicitis among included visits as well as use of MRI.

Age was recategorized into the following 3 groups, consistent with

Hryhorczuk et al[1] methodology: infant (0–2 years old), child (3–12 years old), and adolescent (13–20 years old). We used the NHAMCS recategorized race variable of white, African American, and other. Insurance status was categorized as private, public (Medicare, Medicaid and/or state Children's Health Insurance Program, and worker's compensation), and self-pay or other. ED region was categorized by using the following NHAMCS-defined variables: Northeast, South, Midwest, and West. Also consistent with Hryhorczuk et al,[1] academic facilities were defined as those in which at least 25% of patients were cared for by resident physicians. Triage acuity level was defined by using the 5-level Emergency Severity Index. Shift times were categorized into 3 blocks of time (day, evening, and night), and day of the week was categorized as weekend or weekday. Pain scores were categorized by using the NHAMCS categories of no pain, mild pain, moderate pain, and severe pain. A discharge diagnosis of appendicitis was determined by using the *International Classification of Diseases, Ninth Revision* codes 540.0 to 543.9.

Statistical Analysis Methods

All analyses were performed by using SAS version 9.4 (SAS Institute Inc, Cary, NC), with survey procedures for weights, stratum, and primary sampling units provided by NHAMCS. We performed bivariable analysis to assess for differences in ultrasound and CT use with regard to year and by ED type. We performed multivariable logistic regression to adjust for potential confounding factors. An a priori decision was made to include age, sex, race, ethnicity, and region as covariables during multivariable modeling because these variables have been associated with diagnostic imaging decisions in previous studies.[14,18–20] In addition, all variables with $P < .1$ in the bivariable analysis were included in the multivariable models, ultimately leading to multivariable models that also included triage acuity level, pain score, and insurance status. Multiple regression models were fit for CT, ultrasound, and both CT and ultrasound use to derive adjusted odds ratios (aORs) with 95% confidence intervals (CIs). Reliability of data were ensured through analysis of missing data (<10%), use of a minimum of 30 unweighted records for all analysis, and an examination of relative SE (<30%).

RESULTS

During the 8-year study period, 5036 unique ED observations were collected for children with nontraumatic abdominal pain, representing an estimated 21.1 million ED visits. There was no significant change in rates of ED visits for pediatric patients with nontraumatic abdominal pain during the study period (*P* trend .37). Demographic and visit characteristics are listed in Table 1. Among those in the study, 14.6% (95% CI, 13.2%–16.0%) received only a CT scan, 10.9% (95% CI, 9.7%–12.1%) received only an ultrasound, and 1.9% (95% CI, 1.4%–2.4%) received both a CT and an ultrasound. Given the small numbers of MRI use, further subanalysis was not conducted for this imaging modality. Appendicitis was recorded as the ultimate diagnosis for 3.7% (95% CI, 2.9%–4.4%) of the patients included in the study.

Over the course of the study, the overall rates of CT and ultrasound use within this population did not significantly change (*P* trend .63 and .90, respectively). Additionally, there was no significant change in the use of both CT and ultrasound (*P* trend .63). The number of patients in this population who were ultimately diagnosed with appendicitis also did not change throughout the study period (*P* trend .07) (Fig 1).

Table 2 details the unadjusted odds ratios (ORs) and aORs for imaging modality and treatment in pediatric ED facilities compared with general EDs. Pediatric EDs had a lower likelihood of CT use when compared with general EDs (aOR 0.34; 95% CI, 0.17–0.69). Conversely, pediatric EDs had a higher likelihood of ultrasound use when compared with general EDs (aOR 2.14; 95% CI, 1.29–3.55). No significant difference was found between pediatric and general EDs in their use of both CT and ultrasound (aOR 2.2; 95% CI, 0.82–5.90). No significant difference was found between general EDs and pediatric EDs in their use of performing either CT or ultrasound (ie, any imaging) for patients with nontraumatic abdominal pain (aOR 1.00; 95% CI, 0.53–1.88).

The proportion of patients who were ultimately diagnosed with appendicitis remained steady throughout the study period ($P = .07$ for trend). Of 187 observations (representing 773 920 ED visits) of pediatric patients with an ultimate diagnosis of appendicitis, 59.1% (95% CI, 49.2%–69.2%) received only a CT scan, 9.2% (95% CI, 3.0%–15.4%) received only an ultrasound, 7.3% (95% CI, 3.0%–11.7%) received both CT and ultrasound imaging, and 24.3% (95% CI, 16.2–32.4) received neither a CT nor an ultrasound. Too few observations were found to compare CT and ultrasound use among pediatric patients with appendicitis receiving care in pediatric EDs and general EDs.

DISCUSSION

This study demonstrates that since 2007, the use of CT and ultrasound among children presenting to EDs for nontraumatic abdominal pain has remained constant. This finding stands in contrast with the increasing use of CT between 1999

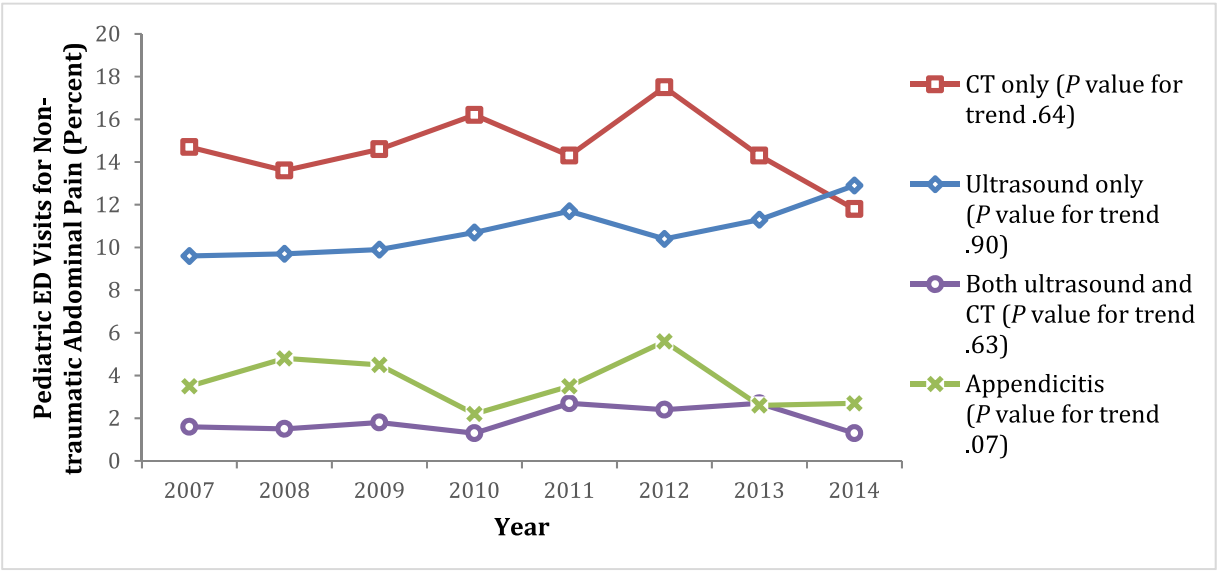

FIGURE 1
Imaging modality use and appendicitis among children presenting to the ED with nontraumatic abdominal pain (2007–2014).

TABLE 1 Demographics of Children Who Underwent CT or Ultrasound ED Imaging for Nontraumatic Abdominal Pain, 2007–2014

Characteristic	Weighted Frequency (SD), in Thousands	Percentage of Visits (95% CI)
Boys	6788 (365)	32.1 (30.4–33.9)
Age		
Infant (0–2 y)	770 (73)	3.7 (3.0–4.3)
Child (3–12 y)	8017 (440)	38.0 (35.8–40.1)
Adolescent (13–19 y)	12 331 (643)	58.4 (56.2–60.6)
Race		
White	10 562 (595)	50.0 (47.1–52.9)
African American	10 557 (587)	50.0 (47.1–52.9)
Hispanic or Latino ethnicity	5174 (392)	24.5 (21.5–27.5)
Insurance status		
Private	6904 (373)	35.0 (32.9–37.1)
Public	9729 (553)	49.3 (46.8–51.9)
Self-pay or other	3083 (213)	15.6 (14.1–17.2)
ED type		
General	19 185 (932)	90.8 (87.7–94.0)
Pediatric	1934 (359)	9.2 (6.0–12.3)
Academic facility	1284 (166)	6.1 (4.5–7.6)
Region		
Northeast	3066 (314)	14.5 (11.7–17.3)
Midwest	4849 (444)	23.0 (19.2–26.7)
South	8518 (684)	40.3 (35.7–45.0)
West	4684 (490)	22.2 (18.2–26.2)
Pain score		
None	1538 (121)	7.3 (6.2–8.3)
Mild	1827 (145)	8.7 (7.6–9.7)
Moderate	5315 (328)	25.2 (23.4–26.9)
Severe	7310 (441)	34.6 (32.4–36.8)
Unknown	5127 (370)	24.3 (21.5–27.0)
Triage acuity level		
High or urgent (1–60 min)	12 622 (649)	59.8 (56.7–62.8)
Semiurgent (>1–2 h)	4466 (331)	21.1 (19.0–23.3)
Nonurgent (2–24 h)	759 (101)	3.6 (2.7–4.4)
No triage or unknown	3272 (309)	15.5 (13.0–18.0)

and 2007.[1] Additionally, this study demonstrates that pediatric EDs are more likely than general EDs to use ultrasound, rather than CT, when imaging children with nontraumatic abdominal pain.

Our findings of a plateau in the rate of CT use between 2007 and 2014 are consistent with a growing national awareness of risks and motivation to reduce radiation exposure in children. In 2007, the Image Gently Alliance, a coalition of health care organizations that began as a committee within the Society for Pediatric Radiology, launched the Image Gently campaign.[21] The campaign publishes general information for parents and caregivers, protocols for professionals imaging pediatric patients, and strategies for raising awareness in both the medical and nonmedical communities about radiation exposure with an ultimate goal of changing practice.[21] Since the initiation of the Image Gently campaign, clinical decision guidelines have been developed to minimize ionizing radiation exposure in children.[7,8,21] A causal relationship cannot be confirmed between the Image Gently campaign and the

TABLE 2 Unadjusted ORs and aORs of Diagnostic Imaging by ED Type

ED Type	CT Only		Ultrasound Only		Both Ultrasound and CT		No Imaging (Neither CT nor Ultrasound)	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Pediatric[a]	0.24 (0.12–0.46)	0.34 (0.17–0.69)	1.2 (0.79–1.85)	2.14 (1.29–3.55)	1.36 (0.55–3.37)	2.20 (0.82–5.90)	1.63 (1.14–2.31)	0.93 (0.62–1.40)

All multivariable modeling adjusted for year, age, sex, race, ethnicity, region, triage acuity level, pain level, and insurance type.
[a] Compared with general ED.

plateau of CT use. However, it is important to acknowledge that increased efforts by stakeholders within the radiology, pediatric, and quality-measurement specialties to alter diagnostic protocols and practice are potential driving forces behind the shift in the imaging modality trends observed in this study.

In addition to communication put forth by the Image Gently campaign, clinical guidelines and studies continue to encourage stepwise imaging protocols for pediatric patients with nontraumatic abdominal pain that begin with ultrasound and are followed by CT only if the diagnosis remains uncertain after the initial ultrasound.[3,8–10,20,21] Although it is possible that further analysis may show increased rates of complicated appendicitis and/or admission with an ultrasound -first approach to diagnosis for appendicitis, previous studies have found no such associations.[2]

The selection of either CT or ultrasound was associated with ED type. The use of only CT was less likely among pediatric patients treated in pediatric ED facilities than those treated at general EDs. Conversely, the use of only ultrasound was more likely among pediatric patients treated in pediatric EDs than those treated in general EDs. Among pediatric ED patients with nontraumatic abdominal pain, the use of both CT and ultrasound (potentially representing a stepwise protocol) was found to be similar among those treated in pediatric EDs and general EDs. Given that ~80% of children are cared for in general EDs, increasing the awareness of pediatric-focused radiology protocols may help optimize radiation exposure in children in the future.[22]

There are several potential limitations to this study. The main limitation was the use of retrospective data from a large, national data set, which provides a high-level view of imaging trends but limits the available granularity of the data. Therefore, we could not control for severity of illness, for example. Additionally, this study was unable to ascertain the timing of recorded CT and ultrasound imaging in cases in which both modalities were found in a record. However, it would be unusual for a patient to have a CT scan followed by an ultrasound. Another limitation was that we were unable to account for any imaging that patients, such as those of whom were transferred from other EDs or urgent care centers, may have received before their ED visits. For example, if a patient had received an ultrasound at a previous facility and was subsequently transferred to an ED for a CT scan, that ED visit would have been categorized as receiving a CT only. However, typically when children are transferred to an ED for higher-level care, they are usually transferred from a general ED to a pediatric ED rather than vice versa. This study was also limited by the fact that from 2007 to 2011, the NHAMCS survey did not include anatomy imaged except in the case of head CT. However, it is possible that patients had other imaging, such as scrotal or pelvic ultrasound. Another limitation is that because of small numbers, we were unable to analyze the use of MRI. Future work may benefit from having a longitudinal and complete medical record for patients included in the study.

CONCLUSIONS

The use of CT and ultrasound imaging for the diagnosis of pediatric nontraumatic abdominal pain did not significantly change between 2007 and 2014. An increased likelihood of CT imaging was demonstrated in general EDs compared with pediatric EDs, in which ultrasound was more likely.

ABBREVIATIONS

aOR: adjusted odds ratio
CI: confidence interval
CT: computed tomography
ED: emergency department
NHAMCS: National Hospital Ambulatory Medical Care Survey
OR: odds ratio

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