Trends in Computed Tomography Utilization in the Pediatric Emergency Department
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Trends in Computed Tomography Utilization in the Pediatric Emergency Department

WHAT’S KNOWN ON THIS SUBJECT: Recent studies report that overall computed tomography utilization in the emergency department has continued to rise. Increased computed tomography use is concerning because of the association with radiation exposure and the potential risk of radiation-induced malignancy, which is highest in children.

WHAT THIS STUDY ADDS: Our data showed no overall increase in computed tomography utilization through 2010. In areas where alternative non–radiation-based modalities were options, there were decreased trends in computed tomography use and increased use of potential alternative non–radiation-based modalities.

abstract

OBJECTIVE: The purpose of this study was to determine the overall trend of computed tomography (CT) utilization in the pediatric emergency department (PED) from 2003 to 2010 and to determine trends categorized by common chief complaints.

METHODS: Electronic chart records at 2 tertiary care PEDs within a large pediatric health care system were reviewed from January 2003 through December 2010. The annual CT utilization rate, by anatomic location, was determined. Annual CT utilization rates were compared with alternative imaging trends for visits with chief complaints of head injury, seizure, and abdominal pain. Analysis was performed with linear regression.

RESULTS: There was no change in overall CT utilization from 2003 to 2010 (β 0.25, 95% confidence interval [CI] [−1.61 to 2.73]) or within anatomic subgroups. Head CT utilization for the chief complaints of seizure (β −0.97, 95% CI [−1.44 to −0.90]) and head injury (β −0.93, 95% CI [−1.71 to −0.73]) showed significant declines. Although there was no change in the abdominal CT utilization rate for abdominal pain, abdominal ultrasound utilization for abdominal pain significantly increased (β 0.89, 95% CI [0.25–0.79]).

CONCLUSIONS: Our data showed no overall increase in CT utilization through 2010. In areas where alternative non–radiation-based modalities were options, there were decreased CT trends and increased use of potential alternative non–radiation-based modalities. This is the first large PED cohort study to show a decrease in CT utilization in recent years in a regional pediatric referral center and may correlate with increased awareness of radiation risk in children. Pediatrics 2012;129:e690–e697

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KEY WORDS: emergency department, emergency medicine, computed tomography, radiation reduction in children

ABBREVIATIONS
CI—confidence interval
CT—computed tomography
ED—emergency department
EM—emergency medicine
ICD-9—International Classification of Diseases, Ninth Revision
PED—pediatric emergency department
VPS—ventriculoperitoneal shunt

Drs Menoch, Hirsh, Khan, Simon, and Sturm conceived the study; Drs Hirsh, Simon, and Sturm designed the trial; Drs Simon and Khan supervised the conduct of the trial and data collection; Drs Hirsh and Menoch undertook recruitment of participating centers and patients and managed the data, including quality control; Drs Menoch and Sturm provided statistical advice on study design and analyzed the data; Dr Menoch drafted the manuscript, and all authors contributed substantially to its revision. Dr Menoch takes responsibility for the paper as a whole.

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Computed tomography (CT) is widely used in emergency departments (EDs), serving as a vital tool for rapid patient evaluation and management. Recent studies report that overall CT utilization in the ED has continued to increase.1–5 A recent study from Lee et al3 showed increased CT usage in the adult population from 2000 to 2007, with a 60% increase in head CT and 500% increase in chest CT. The most recent pediatric-specific study at a single institution from Broder et al6 also found a large increase in CT utilization in the ED from 2000 to 2006, specifically showing a 23% increase in head CT and a 49% increase in abdominal CT. National trend data from 1995 to 2008 have shown a fivefold increase in the number of child visits to the ED that included a CT scan.4 Recent overall hospital CT utilization decline has been reported at 1 pediatric institution from 2005 to 2008, but what the specific trends were in the ED during the study period was never delineated.6

This increased CT use is concerning because of the risk associated with the potential for radiation induced malignancy.7–20 Much attention in the medical community and the lay press has been paid to this in the past 10 years, especially so in the past few years. The highest risk of radiation-induced malignancy is to children, which has driven a number of pediatric studies focused on strategies for optimizing CT usage.21–31 There is a relative paucity of literature describing trends of CT utilization with other alternative imaging modalities in pediatrics. Specifically, there are few data describing trends since the increase in medical literature and public awareness on this topic in 2007. It is hypothesized that there might be potential decreased use of CTs overall in the pediatric emergency department (PED) because of this increase in awareness about risks. Furthermore, in specific areas where recommendations in the literature have been made to minimize imaging (ie, seizures),25 we hypothesize that there will be a decline in imaging rates.

The purpose of this study was to determine the overall trend of CT utilization at 2 large tertiary care PEDs from 2003 through 2010 and to determine CT trends categorized by common chief complaints compared with alternative modalities with MRI and ultrasound.

METHODS

This study was a retrospective electronic medical records review, approved by the institutional review board of the health care system. The study occurred at a large pediatric health care system’s 2 tertiary care PEDs with a combined annual ED census on average of >140,000 pediatric patients per year. Both sites are staffed with pediatric emergency medicine physicians and urgent care pediatricians. All patient visits from January 2003 through December 2010 were eligible for review, because this was when all records were in electronic form. Visits that were transfers in or those in which the transfer status could not be determined (regardless of whether imaging was obtained at the referring facility) were excluded because these encounters would have had the potential to have a CT scan before arrival.

During the study period, the ordering of CT scans was at the sole discretion of the ordering physician, because there were no formal clinical guidelines or protocols for CT usage at the study sites. There were no screening or approvals processes from the radiology department regarding orders for CT scans. The radiology department was staffed by board-certified pediatric radiologists and pediatric ultrasonographers. The study sites did not use rapid MRI for ventriculoperitoneal shunt (VPS) evaluation. CT imaging was located immediately adjacent to the PED at both facilities. All imaging modalities were available throughout the study period.

The electronic medical record was queried to determine the presence of a CT, MRI, or ultrasound order for patients during the PED encounter. Data were extracted from the electronic medical record and organized by specific demographics: patient age, gender, patient medical record number, triage acuity, mode of arrival, chief complaint, type of CT performed, if an alternative imaging modality such as MRI or ultrasound was performed, and patient disposition. For study purposes, acuity levels were dichotomized into high (critical and emergent) and lower acuity. Acuity was defined on the Emergency Services Index 5-point scale with the highest 2 acuity levels defined as high acuity and the remaining categories defined as low acuity. The dispositions of admission, intensive care, and operating room were grouped in a disposition category of Admit.

CT, MRI, or ultrasound orders were categorized anatomically: head (an order including the terms "head" or "brain"), abdomen (an order for a CT of the abdomen alone, the pelvis alone, or both the abdomen and the pelvis), cervical spine (an order including the term "c-spine"), and other. The other category includes CT scans of the orbit, face, chest, thoracic or lumbar spine, soft tissue, neck, and extremity. Whether a CT scan was ordered with or without contrast did not change the categorizations. CT, MRI, and ultrasound rates were normalized per 1000 patient annual visits.

PED visits were also analyzed by common presenting chief complaints and concerns. Visits were categorized into the following groups by chief complaint: International Classification of Diseases, Ninth Revision (ICD-9) codes: head injury, abdominal pain, seizure, and patients with a possible VPS problem. ICD-9 coding was performed by professional
coders at the study institutions, and chief complaints were coded after the visit. Head CT for patients with a suspected VPS malfunction was chosen as an internal control group in this study. The rates of imaging for these patients were not expected to change during the study period, because head CT is part of the standard evaluation for VPS malfunction at both PEDs studied. The other complaints were chosen because they were considered the most common anticipated reasons for CT utilization and represented both medical and surgical concerns. If a visit involved more than 1 imaging technique, each was counted separately. For example, there may be patients who had both an abdominal ultrasound and a CT scan of the abdomen on the same visit; for consistency, we have decided to present these as separate studies.

Orders for CT, MRI, or ultrasound were identified for each patient visit and organized into anatomic location as previously described. Imaging rates were normalized per 100 patient annual visits for that complaint.

The primary outcome measures were the trends for the annual CT and alternative imaging modality utilization rates of all visits, for each anatomic area, and within common chief complaint groupings. All statistical analyses were done by using SPSS 18. Linear regression techniques were used to analyze the trends over the study period.

RESULTS

There were 1,023,300 total visits to the PEDs during the 8-year study period; 35,386 (3.4%) visits were classified as transfers or the transfer status could not be determined, leaving 987,932 visits that met the study criteria. A CT scan was performed in 54,797 visits (5.5%) to the PED during this time frame. Head CTs made up 65% of the total, abdomen/pelvis CTs accounted for 20%, c-spine for 3%, and the remaining 14% were categorized as other. The demographics of these patients who had a CT performed are listed in Table 1. There was a statistically significant increase in high-acuity visits (β 0.9, 95% confidence interval [CI] [0.76–2.2]) and admission disposition (β 0.87, 95% CI [0.63–2.3]) over the study period.

During the study period, there was no statistical change in the rate of CT utilization overall or within the anatomic subgroups. The overall CT and anatomic subgroups had peak rates in 2008 and a decline by 2010; however, these changes were not statistically significant (overall CT: β 0.25, 95% CI [−1.61 to 2.73]) (Fig 1).

The distribution of patients presenting for 1 of the 4 study complaints is listed in Fig 2. CT, MRI, and ultrasound utilization within the 3 ICD-9 chief complaint categories are described in Figs 3, 4, and 5. CT utilization within the chief complaint categories of seizure and head injury showed significant declines, with no significant change in the rate of head MRI (Figs 3 and 4).

Demographics for visits with a CT organized by study chief complaint are represented in Table 1. There was a significant increase in high-acuity patients in both the head injury and seizure groups during the study period. There was a significant decrease in the percentage of patients admitted for head injury.

During the study period there was no significant decline in abdominal CTs for the chief complaint of abdominal pain (β −0.64, 95% CI [−0.83 to 0.08]); however, the rate of abdominal ultrasound steadily increased (β 0.89, 95% CI [0.25–0.79]) (Fig 5).

There was no change in the number of head CTs for the chief complaint of a VPS problem. Head MRI utilization in this group showed no significant change in trend (Fig 6).

DISCUSSION

A large amount of data regarding radiation-induced malignancy from CT scans has been produced in the past decade.17–18 Commonly viewed sources in the lay press have covered this issue including Time magazine, ABC news, CBS news, NPR, US News and World Report, and the New York Times.32–37 In the medical community, a widely publicized review article in the New England Journal of Medicine from 2007

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<tr>
<th>Overall CT</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>β*</th>
<th>95% CI*</th>
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<tbody>
<tr>
<td>High acuity, %</td>
<td>44.4</td>
<td>42.0</td>
<td>49.4</td>
<td>47.8</td>
<td>47.8</td>
<td>51.8</td>
<td>52.4</td>
<td>53.7</td>
<td>0.9</td>
<td>(0.76 to 2.2)</td>
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<tr>
<td>Median age, y</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>0.6</td>
<td>(−0.04 to 0.3)</td>
</tr>
<tr>
<td>Male gender, %</td>
<td>55.3</td>
<td>57.7</td>
<td>55.3</td>
<td>54.6</td>
<td>56.7</td>
<td>55.6</td>
<td>56.5</td>
<td>56.1</td>
<td>0.1</td>
<td>(−0.38 to 0.44)</td>
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<td>Admission, %</td>
<td>27.8</td>
<td>28.5</td>
<td>28.2</td>
<td>29.7</td>
<td>31.1</td>
<td>29.7</td>
<td>37.1</td>
<td>38.4</td>
<td>0.9</td>
<td>(0.63 to 2.5)</td>
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</table>

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<tr>
<th>Chief complaint</th>
<th>Head injury</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>β*</th>
<th>95% CI*</th>
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<tbody>
<tr>
<td>High acuity, %</td>
<td>39.5</td>
<td>43.2</td>
<td>50.2</td>
<td>48.0</td>
<td>51.3</td>
<td>56.9</td>
<td>52.6</td>
<td>52.9</td>
<td>0.8</td>
<td>(0.61 to 3.14)</td>
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<tr>
<td>Admission, %</td>
<td>11.2</td>
<td>13.9</td>
<td>14.1</td>
<td>9.7</td>
<td>11.0</td>
<td>7.1</td>
<td>7.9</td>
<td>8.5</td>
<td>−0.8</td>
<td>(−1.52 to −0.12)</td>
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<table>
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<tr>
<th>Seizure</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>β*</th>
<th>95% CI*</th>
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<tbody>
<tr>
<td>High acuity, %</td>
<td>42.8</td>
<td>41.6</td>
<td>49.9</td>
<td>47.0</td>
<td>45.0</td>
<td>49.7</td>
<td>50.5</td>
<td>55.3</td>
<td>0.8</td>
<td>(0.52 to 2.56)</td>
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<tr>
<td>Admission, %</td>
<td>27.7</td>
<td>33.0</td>
<td>36.2</td>
<td>28.1</td>
<td>24.8</td>
<td>21.4</td>
<td>33.9</td>
<td>35.2</td>
<td>0.2</td>
<td>(−1.58 to 2.22)</td>
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<table>
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<th>Abdominal pain</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>β*</th>
<th>95% CI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>High acuity, %</td>
<td>25.0</td>
<td>20.3</td>
<td>27.0</td>
<td>23.4</td>
<td>22.8</td>
<td>23.6</td>
<td>22.9</td>
<td>20.7</td>
<td>−0.4</td>
<td>(−1.15 to 0.49)</td>
</tr>
<tr>
<td>Admission, %</td>
<td>28.4</td>
<td>33.4</td>
<td>31.6</td>
<td>34.5</td>
<td>28.5</td>
<td>28.3</td>
<td>30.1</td>
<td>26.0</td>
<td>−0.5</td>
<td>(−1.62 to 0.43)</td>
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<th>2003</th>
<th>2004</th>
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<th>2006</th>
<th>2007</th>
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<th>2010</th>
<th>β*</th>
<th>95% CI*</th>
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<tr>
<td>High acuity, %</td>
<td>99.2</td>
<td>92.2</td>
<td>95.6</td>
<td>91.9</td>
<td>96</td>
<td>97.7</td>
<td>98.2</td>
<td>98.4</td>
<td>0.4</td>
<td>(0.61 to 1.58)</td>
</tr>
<tr>
<td>Admission, %</td>
<td>56.4</td>
<td>59</td>
<td>68.4</td>
<td>72.8</td>
<td>72.2</td>
<td>77.3</td>
<td>80.3</td>
<td>95.2</td>
<td>1.0</td>
<td>(3.39 to 6.23)</td>
</tr>
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* β and CI represent trends with linear regression techniques.
* Admission is disposition to the inpatient ward, ICU, or operating room.
by Brenner et al\textsuperscript{10} summarized this knowledge with supporting evidence and predicted that, regardless of the knowledge about risk, CT usage in pediatrics would continue to increase from 2007 to the ongoing few years. The CT utilization rates presented in our study are similar to those published elsewhere on this topic, with $\sim 5\%$ of total PED visits having a CT scan performed.\textsuperscript{1,4,5} Before this study, the most recently published CT utilization data are from 2008, showing increased utilization in pediatric ED visits.\textsuperscript{4} However, in contrast, our data present new information on a large cohort of pediatric ED patients with CT utilization rates since 2003, reporting that overall CT utilization has not increased over this 8-year period at our large pediatric health care system. Our data show a peak in 2008 similar to previously published studies. What makes this study unique is the apparent decline in CT rates seen since 2008, which followed enhanced public awareness and studies regarding radiation risks.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{CT_rate_graph.png}
\caption{Annual CT rate by anatomic site per 1000 patient visits.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{chief_complaints.png}
\caption{Distribution of visits with a CT, MRI, and ultrasound for each chief complaint. If a visit had more than 1 image it was counted separately for each image. ICD-9 codes were used to define each chief complaint: head injury, 959.01, 801, 800, 803.4, 801.4, 803, 804, 850, 310.2, 850, 851, 852, 853, 854; seizure, 345.9, 780.39, 780.32, 345.8; abdominal pain, any code starting with 789, 787.3, 787.9; possible complications of a ventriculoperitoneal shunt, 996.2 for mechanical complication of nervous system device, implant, and graft.}
\end{figure}
FIGURE 3
Annual CT and MRI rate (%) for evaluation of head injury compared with annual visits for head injury.

FIGURE 4
Annual CT and MRI Rate (%) for evaluation of seizure compared with annual visits for seizure.
There were statistically significant downward trends in the rate of head CTs within the chief complaint of head injury and seizure. Although these results reflect a subgroup of the total head CTs performed, they reflect a significant portion of the overall imaging performed (34% overall). Although the reasons for the overall decline in CT utilization within these chief complaints cannot be fully determined, increased CT radiation risk awareness may have
made caregivers potentially choose to do no imaging, avoid radiation, and use observation instead. This could be a potential reason for the increase in admission rates for children presenting with seizures. In these cases, there may be an increase in overall health care utilization if the period of hospitalization or extended observation exceeds the cost of the deferred CT scan. It is also noteworthy that the decreased frequency of CT use is not due to a decrease in the number of PED visits or a decrease in acuity during the time period. Although the decline in CT utilization rates may be related to increased awareness of radiation risks, this may not reflect causality. Other possible reasons for the noted decline in CT utilization rates may be parent preference or refusal of radiologic studies or the willingness of families and providers to observe patients in the PED or in the hospital for longer periods of time.

Although the decline for abdominal CT utilization rates for the chief complaint of abdominal pain is not significant, it is of greater importance that there is no increase in utilization, which may become significant over time. Again, the cause of this decline cannot be determined because of study design; however, the declining trend could be due to the increase seen in imaging with abdominal ultrasound. This is an important finding because ultrasound is a valuable tool for gaining information without exposing patients to radiation. During the study period these changes in ultrasound utilization rates for a chief complaint of abdominal pain do not appear to be due to changes in patient acuity. Furthermore, there was no change in admission rate during this period. Observing trends in the next few years will help yield more information on this topic.

Because this is a retrospective study, the reasons for the decline in head CT utilization and increase in abdominal ultrasound cannot be fully determined. However, some combination of providers and families being more cognizant of the risks of CT radiation, the recent studies guiding more efficient CT utilization for seizure and head injury, as well as increased awareness of the alternative imaging with MRI and ultrasound has likely contributed to these trends. Importantly, there is a downward trend in the most recent time period that perhaps is a reflection of provider practice changes and family preferences in response to recent literature on this topic. No previous studies have presented this recent data or showed recent trends in CT utilization as well as utilization of potential alternative modalities in the PED. Whereas these trends are anticipated to continue and not represent common cause variation, ongoing monitoring of these trends is part of our continued investigation into CT utilization.

The majority of CT imaging performed in children nationwide occurs at non–pediatric-specific facilities. In fact, it is estimated that >85% of CT imaging performed in children in the ED is done at primarily adult facilities. Although our data represent trends at a pediatric-specific health care system and 2 separate free-standing pediatric EDs, it does not address the trends where the majority of imaging is performed, community-based and non–pediatric-specific EDs. However, the results of this study are encouraging because much of our knowledge base and teaching of future providers at these alternative centers starts at such free-standing tertiary care centers. Our data show that ordering behaviors at our large study site are declining over time, perhaps because of increased awareness of the risks. Translating this increased awareness to nonpediatric facilities on a nationwide level is of paramount importance.

This study has several potential limitations. The medical coders standardized the ICD-9 codes for the free text chief complaint. When the chief complaint does not match an ICD-9 code, they consider other factors that vary by each chart. It is possible that the ICD-9 discharge code may not accurately map to the chief complaint. However, this coding was independent of the clinical providers and was done in a standard fashion, minimizing bias and error. Furthermore, the data do not include patients transferred from outside facilities, potentially missing a group of CT scans done on pediatric patients. However, the goal of our study was to evaluate CT trends in the PED obtained by pediatric emergency medicine–trained or pediatric urgent care physicians. This analysis is retrospective and has all of the inherent data retrieval concerns. However, the nature of the study allowed us to evaluate large-scale general practice of CT utilization without a predetermined guideline or protocols impacting trends. Because this study only evaluates imaging ordered in the PED, we may be underestimating alternative imaging modalities such as MRI scans in stable patients who are deferred to the outpatient setting.

**CONCLUSIONS**

In this study population, the overall CT utilization has not increased. In addition, there is a decrease in CT utilization of the highest-volume CTs for patients who enter with the chief complaints of head injury and seizure. Although there was not a statistically significant decrease in abdominal CT’s for the chief complaint of abdominal pain, there was an increase in abdominal ultrasound use, representing a potential alternative nonradiation modality. This is the first large-cohort study to show a decrease in CT utilization in recent years and may correlate with increased awareness of radiation risk in children. Evaluation of continued trends concerning long-term impact and causality are ongoing.
REFERENCES


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