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REVIEW ARTICLE

Overuse of CT and MRI in paediatric emergency departments

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ABSTRACT

The aim of this review is to survey CT and MRI overuse in the paediatric emergency department (ED) population. CT is one of the most important modalities employed in the ED. Not surprisingly, its high accuracy, rapid acquisition and availability have resulted in overuse. An obvious limitation of CT is ionizing radiation; in addition there are economic implications to overuse. Studies from the last two decades have shown increase in paediatric ED CT utilization in the first decade, reaching a plateau forming around 2008, followed by a decrease in the last decade. This decrease occurred in conjunction with campaigns raising awareness to the risks of radiation exposure. Although a trend of decrease in overuse have been observed, great variability has been shown across different facilities, as well as among physicians, with more pronounced overuse in non-teaching and non-children dedicated EDs. The leading types of paediatric ED CTs are head and abdominal scans. Decision rules, such as PECARN for head injury and the Alvarado score for abdominal pain, as well as using alternative imaging modalities, have been shown to reduce CT overuse in these two categories. MRI has the obvious benefit of avoiding radiation exposure, but the disadvantages of higher costs, less availability and less tolerability in younger children. Although anecdotally paediatric ED MRI usage has increased in recent years, only scarce reports have been published. In our opinion, there is need to conduct up-to-date studies covering paediatric CT and MRI overuse trends, usage variability and adherence to clinical protocols.

INTRODUCTION

CT is widely used in emergency departments (EDs) and is a vital component of rapid patient diagnostic evaluation.[1] It is an extremely informative technique which can be used in a variety of clinical applications and suits all age groups, although it can still be challenging due to a paucity of intrabdominal fat and lack of ossification (CT head, CT C-spine) in the very young. CT is characterized by short scan times and high quality of images. In addition CT is available and relatively affordable.[2]

Not surprisingly, the use of CT has been exponentially rising since its invention.[3] In the USA, CTs contribute nearly half the population's collective radiation dose from all medical X-ray examinations[4] and in the UK CT accounts for up to 68% of the population's collective radiation dose.[5]

The increase use of CT can be attributed to several factors. Advancements in technology have resulted in decreased scanning times while maintaining high image quality.[2] This is especially helpful in children, eliminating the need for sedation in many cases.[6] Additionally, over the last 20 years, CT scanner availability has rapidly increased worldwide.[7] CT is more accessible in the ED due to designated scanners.[8] In addition, low availability of other imaging modalities, such as MRI, CT is preferable by ED staff.[9,10]

Recent studies indicate that nearly a quarter of performed CT scans in the general population are inappropriate.[11] Reasons for unnecessary CT scans include lack of adherence to clinical guidelines,[12] repeated scans[13] and CT preference over other imaging modalities.[14] Specifically in children, unnecessary CT scans may result from communication barriers due to developmental age.[15] Another source for CT overuse in children is lack of competence in non-paediatric-focused facilities.[16,17] In addition, lack of standardized dosing to size variation in children can result in excessive radiation doses.[18,19] A Recent study published in 2017 found that children received a double dose of radiation in CT scans at non-paediatric hospitals in comparison to that received at paediatric trauma centres.[20] A survey conducted among ED physicians showed unwarranted scans were performed due to consultant requests, in order

to appease the patient or their family, and as a defense against malpractice suits.[21]

Together with the rise in CT use, the interest in and knowledge about the potential harmful effects of ionizing radiation exposure on health have increased. Doses of ionizing radiation administered by CT scans may cause DNA damage, and increase the lifetime risk of cancer.[1,22,23] Children are at higher risk of developing cancer, due to their higher radio-sensitivity compared to adults and due to a longer life span following exposure to radiation.[1] A study by Pearce et al demonstrated 2–3 fold increase in incidence of leukaemia and brain tumours in people who were exposed to radiation during their childhood.[22] An 11 million cohort study by Mathews et al showed a 24% increase in overall cancer incidence for people exposed to radiation from CT scans, especially when exposed at a young age.[23] Miglioretti et al found that children that have received high radiation doses from CT exhibit a small but significant increase in future cancer risk. The study estimated that more than 4800 future cancers could be induced by 1 year of paediatric CT imaging in the USA.[24]

In addition to the health risks involved, there are economic implications to CT overuse. Implementing decision rules for CT use could lead to substantial cost saving.[25,26] Smits et al estimated cost savings of $120 million annually in the USA.[25] CT overuse may also result in prolonged length of stay due to additional evaluation of incidental findings,[27] and false-positive results.[28]

MRI has the obvious benefit of avoiding radiation exposure, but the disadvantages of higher cost, less availability than CT and also MRI may not be tolerated in young children (especially under age 5).[29] Although, Feed and swaddle MRI is feasible without sedation up to 6 months of age.[30]

Anecdotally, MRI usage has increased in the emergency setting in recent years, perhaps due to radiation concerns raised in campaigns such as "Image Gently"[31] and "As Low As Reasonably Achievable (ALARA)",[32] and perhaps with increase in the availability of the modality, but to date, only three single centre studies describing MRI utilization in paediatric EDs[33–35] have been published, and further evidence-based research is needed.

This review aims to describe the state of the literature on the subject of CT and MRI overuse in the paediatric ED population, focusing in particular on the trends of practice in children in the ED in recent years, including the type of scans performed and factors associated with overuse.

Searches were carried out using PubMed. The search was restricted to articles in English. Key terms used were: CT, usage, overuse, paediatric, children, ED, emergency department, imaging. Articles determined to be relevant by their titles and abstract were included. References of the articles included were also reviewed for inclusion on the basis of their importance in the reviewed articles.

The meaning of the term "paediatric" and "child" in our review is patients in the age Group 0–18, excepting one of our sources that included 19-year-old patients[36] and one study with an upper limit of 17-year-old.[35]

CT UTILIZATION IN THE PAEDIATRIC EMERGENCY DEPARTMENT

Table 1 summarizes major studies that surveyed CT overuse in the paediatric ED population published in the last decade, the time frame of these studies is the past two decades, up to the year 2013.

Similarly to trends in the general population, the use of CT has increased in the paediatric population[24,44] and in paediatric EDs in the last two decades.[11,16,17,37] It is estimated that at least 4 million CT scans are conducted each year on children in the USA.[1] For example, a paediatric-specific study at a single institution found a large increase in ED CT utilization from 2000 to 2006, specifically showing a 23% increase in head CT and a 49% increase in abdominal CTs.[40]

Having said that, in the last decade CT utilization in children has begun to decline.[16, 24, 37, 38, 45] This trend correlates with increased awareness for radiation risk in children.[1,22,38] Campaigns such as "Image Gently"[31] and "ALARA"[32] were started in order to increase awareness of the risks associated with advanced imaging and to provide protocols and recommendations for reducing radiation exposure in children. While a survey of radiologists and emergency physicians from 2004 reported widespread underestimation of radiation doses, and a disbelief in increased cancer risks,[46] in a survey from 2013, 98% of responders reported a change in their clinical practice induced by concerns about radiation exposure.[10] A study from 2014 demonstrated that emergency physicians consider CT overuse to be a problem. The study further demonstrated that knowledge of past CT scans performed for the same indication affects physicians' decision to order CTs, and that emergency physicians are interested in computerized imaging decision support mechanisms.[47]

A large study by Menoch et al, of CT utilization at 2 tertiary care paediatric EDs from 2003 to 2010 registered only minimal change in overall CT use from 2003 to 2010. Following 2008, an apparent decline in CT use was seen.[38] Hoshiko et al collected data from 229 facilities in California from 2005 to 2012, and examined frequency of CT usage in paediatric patients. In the ED, CT utilization increased initially, peaked and started to decline after 2008.[16] Lodwick et al collected data of more than 12 million patients from 30 tertiary paediatric hospitals between 2009 and2013, reporting that the rate of CT imaging decreased from 69.2 to 49.6 per 1000 encounters during the study period. Both head and abdomen/pelvis CT rates showed significant decreases over the study period.[37]

However, both Menoch et al[38] and Lodwick et al[37] conducted their studies in a paediatric-specific facilities, while most of CT imaging performed in children occurs at non-paediatric-specific facilities. In the USA, it is estimated that 85% of paediatric CT imaging performed in the ED is done at primarily adult facilities.[2] This is noteworthy, since variability in CT usage across different types of facilities has been demonstrated. Table 2 lists

Table 1. Summary of major studies concerning CT usage in paediatric emergency departments in the last two decades

	Number of participants	Type of facility	Important findings	Indication for CT	Type of CT	Study period
Lodwick et al, 2015[37]	12,531,184	30 tertiary paediatric hospitals	Between 2009 and 2013, overall, head and abdomen CT use has decreased. Significant variability in CT usage across tertiary paediatric EDs was found, even when controlling for case-mix and hospital volume.	All	All types	2009–2013
Hoshiko et al, 2014[16]	3,606,022	229 EDs and PEDs	An increase in CT utilization was observed, peaking in 2008 and declining afterwards. The decline appeared earlier and was more pronounced in teaching hospitals.	All	All types	2005–2012
Menoch et al, 2012[38]	987,932	two tertiary care PEDs	No significant change in overall CT use was observed from 2003 to 2010, however following 2008 a decline is apparent.	All	All types	2003–2010
Mannix et al, 2012[39]	161,319	40 paediatric hospitals	Significant variation in practice across paediatric facilities, with no correlation to rates of significant head injury.	Head trauma	Head CT	2005–2009
Larson et al, 2011[2]	103,250	General and paediatric EDs	Overall CT use has registered a 5-fold increase during the study period. CT scans were primarily performed at non-paediatric facilities.	All	All types	1995–2008
Broder et al, 2007[40]	78,932	Paediatric EDs	During the study period, CT scan rates increased by dozens of percentage points (with differing increases for different scan types), while triage acuity remained stable.	All	All types	2000–2006
Shahi et al, 2015[11]	9763 unweighted observations for a total of 32,432,686	EDs across USA	The study period was marked by an overall 2-fold increase in CT utilization, peaking at 2009, and followed by a decline in 2010. The increase was also observed when controlling for demographics and clinical variables.	Fall injuries	All types	2001–2010
Fahimi et al, 2012[41]	5516	General and paediatric EDs	During the study period, abdominal CT scan rates in children increased 17-fold. Ultrasound and radiograph rates remained constant. From 2006 to 2008, CT use plateaued.	Abdominal pain	Abdomen CT	1998–2008
Miescier et al, 2015[42]	5340	Tertiary paediatric hospital's EDs	CT ordering rates varied significantly between physicians over a 3-fold range.	Head trauma	Head CT	2011–2013
Adelgais et al, 2014[17]	5148	Paediatric trauma centres and referral general EDs	A significant increase in CT use was observed during the study period, from 6.8 to 42.0%. General EDs were marked with a more pronounced increase relative to PEDs.	Trauma injuries	Cervical spine CT	2002–2011
Neff et al, 2011[43]	546	Paediatric and referral hospitals	Children who initially presented to referral hospitals were more likely to undergo CT scan. There was no connection between Alvarado scores and CT usage.	Abdominal pain	Abdomen CT	1999–2010

Table 2. Studies addressing the effect of the type of facility and physician training on CT usage in children in emergency departments

Teaching hospitals vs non-teaching facilities	
Hoshiko et al[16]	An earlier and more considerable decline in CT rates was demonstrated in teaching hospitals during the study period (2005–2012).
Marin et al[48]	Non-academic non-paediatric EDs had higher odds of using any type of CT during injury-related visits [OR = 1.51, 95% CI (1.16 to 1.96)].
Saito et al[49]	Children who were initially evaluated for appendicitis in a community hospital were about 4.5 times more likely to have a CT scan and were less likely to have an abdominal ultrasound as compared to an academic centre.
Blackwell et al[50]	This study demonstrated no differences in CT use between teaching and non-teaching facilities (21% CT usage rate in each).
Paediatric-specific facilities vsgeneral hospitals	
Adelgais et al[17]	Cervical spine CT usage has increased particularly in children originally assessed at general EDs (from 6.8 to 42.0%), as compared to patients in paediatric specific facilities (from 3.5 to 16.1%) between 2002 and 2011.
Wylie et al[10]	Paediatric training and higher paediatric volumes were associated with less frequent use of head CT.
Blackwell et al[50]	CT was used more frequently in general EDs (22%) than in paediatric-specific EDs (13%) during the study period (1995–2003).
Neff et al[43]	Patients who initially presented at a referral hospital were more likely to undergo CT scan for presumed acute appendicitis than patients presented at a children's hospital. In addition, the Alvarado score has been effective in preventing unneeded CT scans in the children's hospital, but was not taken into account in the referral hospitals.
Michailidou et al[51]	Children that presented at a referral institution with acute abdominal pain had a 5-fold larger likelihood to receive a CT scan, compared to children presented at a paediatric ED.
Physician training type	
Stanley et al[52]	Physician training type was associated with variability in CT use, with the greatest overall rate of CT use in physicians with emergency medicine training alone, and the lowest overall rate of CT use in paediatric residents.
Miescier et al[42]	Overall CT use at a specific paediatric hospital ED varied over a 3-fold range, with a significant variation even among the paediatric emergency medicine physicians group.
Grim et al[53]	Emergency medicine physicians who saw adults and children used CT significantly more frequently (37% of children) in the evaluation of abdominal pain in children compared to paediatricians (15%).

and summarized studies that have addressed the effect of the type of facility and physician training on CT usage in children in emergency departments.

For instance, in Hoshiko et al study, CT rates varied between types of facilities, with an earlier and more considerable decline in teaching hospitals.[16] Adelgais et al showed that CT usage has increased in particular in children originally assessed at general EDs, as compared to patients in paediatric specific facilities.[17] Another study estimated higher odds for CT ordering rates during injury related visits in non-paediatric trauma centres and non-academic EDs.[48] Similar results are exhibited in a survey conducted by Wylie et al. Paediatric training and higher paediatric volumes were associated with less frequent use of head CT, and community hospital practice was associated with frequent CT use.[10]

The typical injury pattern in children is usually confined to an isolated anatomical area rather than multiple sites; hence, the British RCR paediatric trauma guidelines advocate judicious use of targeted CT with relevant paediatric protocols. According to these guidelines, whole-body CT trauma protocols, which are used in adult patients, are not appropriate as a routine investigation in children. Only 3% of children undergone CT scan in a paediatric major trauma centre had a full body CT scan, compared with 9% undergone CT in an adult unit, demonstrating the practice variation between these types of facilities.[54]

Explanatory factors that have been suggested include differences in evidence-based protocol implementation between academic and non-academic EDs, the application of adult guidelines to children in mixed population EDs, and greater comfortability of physicians with their diagnosis of children in EDs with large paediatric volumes.

Still, significant variability in CT use exists also across major paediatric hospitals, as demonstrated In Lodwick et al in their large-scale study. In this study, a significant inverse relationship between CT scan rate and hospital volume was found. Even after controlling for case-mix and hospital volume, 36% of the variability remain unexplained.[37]

Variability in CT related practices also exists between physicians in the same facility. Shahi et al reported a wide variation in all types of CT ordering among emergency medicine physicians that was not associated with patient factors.[11] These findings are congruent with a previous study that demonstrated significant variation in physician use of common ED resources.[55]

The vast majority of CT scans performed in the ED are of the head and abdomen.[2,37,38] One study estimated head CT scans as constituting 60%, and abdomen CT scans a further 20%.[37] In this review we will concentrate on head and abdomen data, since they constitute the bulk of CT scans administered.

HEAD CT

Head trauma is the most common indication for CT in paediatric patients.[2,24,38] Traumatic brain injury (TBI) is a leading cause of morbidity and mortality among paediatric patients,[56] thus requiring prompt evaluation. Although paediatric head trauma is common, most children with head trauma suffer from only mild TBI,[57] and the vast majority of CT scans are without evidence of brain injury.[58,59] While mitigating overuse of CT is difficult due to the interplay of, on the one hand, the efficacy of CT in diagnosing life-threatening head injuries, and on the other hand, the low frequency of such injuries, overuse may be reduced by acknowledging the significance of history, physical examination and a period of observation to exclude severe head injuries.[36,60]

Head CT ordering rates in children exhibits great variability across a variety of factors.[61, 62] A large study by Marin et al, which included 848 EDs, recorded significant variability among general EDs in CT use for paediatric head trauma, indicating the need for strategies to reduce variation and improve ED imaging practices for this population.[61]

The type of hospital that patients present to was found to be a contributing factor for variation in head CT practice. A higher CT scan rate of 2–2.4 fold was shown in general hospital EDs.[39, 50]

Stanley et al[52] demonstrated a substantial variation in the use of head CT in children presenting to the ED with minor TBI, across 25 general EDs in the USA. This variation was not explained by the rate of positive CT scans, or by the severity clinical findings, implying overuse of CT. Children with low to middle risk received head CT scans at higher rates in suburban hospitals and non-children hospitals. In addition, the physician training type was associated with variability, with the greatest overall rate of CT use in physicians with emergency medicine training alone, and the lowest overall rate of CT use in paediatric residents.

A recent study by Miescier et al[42] evaluated the variation in CT use for examination of head injury between physicians at a specific paediatric hospital ED. Overall CT use varied over a 3-fold range from 12.4 to 37.3%. CT use rate varied significantly even among the paediatric emergency medicine physicians group. Less than 1% of patients who didn't undergo CT scan had return visits to the ED, implying that lack of a CT scan did not result in high rates of misdiagnosis.

Several conjectures have been made regarding the underlying reasons for the variation in head CT usage. One explanation is better familiarity with up-to-date evidence-based studies in teaching hospitals, leading to decreased use of head CT. Another is variability in practices between purely paediatric EDs and general population EDs, in which there is a tendency to approach children in the same manner as adults, which are known to undergo imaging more frequently.[63]

For example, repeated CT scans once TBI is identified, a practice based on experience with adult patients, may not be justified in children.[13, 64–66] There is evidence supporting the elimination of further imaging when paediatric patients are appropriately monitored with neurologic examination and intracranial pressure monitoring.[67] Yet, repeated CT scans are frequently performed.[68, 69]

In recent years, efforts have been made to develop validated clinical decision rules specifically for paediatric head trauma in an attempt to decrease CT use and decrease the variation in use among hospitals and physicians, without compromising patient care.[59,70] The Paediatric Emergency Care Applied Research Network (PECARN) prospectively derived and validated a clinical prediction rule,[59] identifying patients at low risk of clinically important njury who can be evaluated without a CT scan. This prediction rule has a very high, bordering on 100%, negative predictive value for clinically important TBIs, and is widely adopted.

Publication of the PECARN prediction rule resulted in numerous quality improvement projects, which led to considerable reduction in head CT use for paediatric head injury in academic paediatric EDs,[71, 72] and also in a community hospitals.[73] Nigrovic et al demonstrated that the reduction in cranial CT rates was not associated with an increase in missed clinically important TBIs.[72] Jennings et al evaluated a QI project in a community ED, and showed an improvement in CT usage in most providers, although the variation among providers persisted.[73]

However, achieving reduction in CT overuse in the general medical community is probably hindered by the decreased likelihood of paediatric head trauma clinical guideline adoption in non-paediatric hospitals,[39] and the general lack of consistency in applying evidence-based decision instruments among physicians.[74–77]

ABDOMINAL CT

Abdominal pain is a common complaint among children presenting to the ED. It is challenging to make a diagnosis in children with acute abdominal pain, due to the wide spectrum of differential diagnoses,[78] ranging from emergent surgical causes to benign self-limiting conditions, in combination with difficulties to obtain complete history from a young patient or interpret findings from physical examination. In particular, acute appendicitis which is the most common surgical emergency in children, is difficult to diagnose, and is also one of the most common reasons for malpractice litigation.[79] Considering this, it is not surprising that imaging is frequently used for the evaluation of acute abdominal pain in children.

Indeed, a significant increase has been observed in CT utilization for the diagnosis of acute appendicitis in the last two decades.[38, 41, 80, 81] Broder et al found a 49% increase in abdominal CT in the ED from 2000 to 2006.[40] However, similarly to rates of general CT use, abdominal CT rates have plateaued between 2006 and 2008.[41]

Overuse of CT scans for abdominal pain may be due to applying adult medical practices to children.Grim et al showed that emergency medicine physicians who saw adults and children used

CT significantly more frequently in the evaluation of abdominal pain in children.[53]

In order to mitigate the long-term problems associated with radiation exposure in children, protocols for limiting CT scan use in favour of ultrasound imaging have been developed, such as the Alvarado score—an established scoring system for acute appendicitis.[82, 83]

Ultrasound was found to be sufficient to confirm or rule out a surgical condition in approximately 97% of cases.[84] Using ultrasound as the primary imaging modality in children with suspected acute appendicitis has been shown to be cost-effective and to reduce the number of CT scans ordered[82,85,86] without resulting in inferior outcomes.[87,88] However, in some situations a definitive diagnosis cannot be made by ultrasound, requiring further evaluation with CT or MRI.[15]

Blumfield et al[89] evaluated the effect of an initiative to reduce radiation exposure by adjustment of paediatric CT protocols, utilizing ultrasound instead of CT as the first modality to evaluate acute appendicitis, increasing the availability of paediatric radiologist and establishing frequent teaching sessions that emphasize the ALARA ("As Low As Reasonably Achievable") principle.[32] This resulted in a reduction of 62.7% in the rate of abdominal CT phases per visit during the study period, concurrently with a rise in the number abdominal ultrasoundS scans ordered by the ED. A poll of ED physicians in this facility found that the most important factor in this CT usage reduction was communication with the paediatric radiologists.

Abdominal CT overuse is also related to variation in practice between facilities and physicians.[43,49,51] Neff et al reviewed a cohort of 546 children who underwent appendectomy for presumed acute appendicitis.[43] Patients who initially presented at a referral hospital were more likely to undergo CT scan than patients presented at a children's hospital. In addition, the Alvarado score has been effective in preventing unneeded CT scans in the children's hospital, but was not taken into account in the referral hospitals.

Similar findings were shown by Michailidou et al:[51] children that presented at a referral institution had a 5-fold larger likelihood to receive a CT scan, compared to children presented at a paediatric ED, after controlling for patient's characteristics and Alvarado scores. Similarly, Saito et al reported that children who were initially evaluated for appendicitis in a community hospital were about 4.5 times more likely to have a CT scan and were less likely to have an abdominal ultrasoundS as compared to an academic centre.[49] Potential explanation for these observations might be a lack of ultrasound availability and adequately trained ultrasound technicians at community hospitals, especially at night.[14]

PATIENT-RELATED FACTORS ASSOCIATED WITH CT UTILIZATION

The significant variation in CT utilization across various types of EDs and even among major paediatric EDs suggests that additional factors, not merely clinical ones, may play a role in the decision to obtain CT imaging. However, only few studies have gone beyond basic trend analysis and tried to evaluate patient-related characteristics that may influence CT usage in paediatric patients.

Age

Among 10 studies that examined age, eight studies found that older age groups were more likely to undergo a CT scan.[2,17,40,41,50,53,90,91] Possible explanations include ease of imaging in older patients, reduced concern about radiation risk and greater concern due to the common mechanisms of injury in adolescents. By contrast, two studies have reported greater utilization rate in younger paediatric patients,[11,48] suggesting difficulty in obtaining reliable physical examinations and anamneses in young infants as a possible explanation.

Race

Among four studies that examined race, three studies found that white children were more likely to undergo a CT scan.[41,90,91] Race disparity was present, however, only in low risk patients, and was not observed for high risk patients,[91] suggesting that CT overuse may also be racially motivated. However, one study reported no significant difference in CT use between patients of different races.[2]

Gender

Among five studies that examined gender, three studies found that males were more likely than females to undergo a CT scan,[41,48,92] one study reported increased CT ordering rates for females,[11] and another study did not find any correlation between gender and CT ordering rates.[2]

Table 3 lists and summarizes studies that have addressed the effect of demographic variables on CT usage in children in emergency departments.

MRI UTILIZATION IN THE PAEDIATRIC EMERGENCY DEPARTMENT

Anecdotal evidence suggests that MRI use has increased due to the recent decrease in CT utilization, and due to the principles of ALARA and the desire to Image Gently.[31,32] Although present in the literature in an adult context, very little is recorded in the literature on MRI utilization in paediatric EDs.

Ramirez et al reported on MRI usage rates of 0.96% of visits in paediatric EDs.[33] Their work suggests that there is an increasing trend in MRI utilization in the paediatric ED setting. In a report for a mixed adult and paediatric ED, MRI was performed during 0.51% of ED visits.[34]

A retrospective study performed at a single-site urban PED conducted by Scheinfeld et al[35] collected data of MRI usage in the PED between 2011 and 2015. They found a small but statistically significant utilization increase trend during the study period, with MRI being performed during 0.23% of visits in 2011 and 0.49% of visits during 2015. Of the MRI examinations performed, 90% were neuroradiology examinations, 6% were of the chest, abdomen or pelvis, and 4% were musculoskeletal.

Table 3. Summary of studies addressing the effect of demographic characteristics on CT usage in children in emergency departments

Age	
Larson et al[2]	CT use in the ED was greater in adolescents and school-aged children than in preschool-aged children and infants or toddlers during the entire study period (1995–2008).
Adelgais et al[17]	Children 8 years and older were 1.5 times more likely to have a Cervical spine CT than younger children.
Broder et al[40]	Increases in CT utilization were most pronounced in adolescents ages 13 to 17 years (62–731% increase across CT types in adolescents compared to 8–283% increase in children aged 3–12).
Blackwell et al[50]	CT was used more frequently in the older age groups: 11–13% order rate in children up to 4 years, in comparison with 32% order rate in children aged 10 to 18 years.
Fahimi et al[41]	The youngest age group (aged 0–3 years) had no significant change in the proportion undergoing CT scanning, whereas the 4- to 12-year-old and 12- to 18-year-old groups exhibited significant increases in CT use (about 6-fold and 4-fold increases, respectively).
Grim et al[53]	CT use was almost 2-fold greater in 12- to18-year-old children compared to 6- to 12-year-old children.
Mannix et al[90]	Older age was associated with higher CT use in paediatric head trauma [OR = 1.3, 95% CI (1.1 to 1.5)].
Marin et al[48]	Compared with infants, all age groups had decreased odds of any CT type.
Shahi et al[11]	Patients aged 0–1 years had higher odds of CT utilization than patients aged 13–17 years [OR = 2.27; 95% CI (2.26–2.27)].
Race	
Fahimi et al[41]	Black children were one-half as likely to undergo a CT scan compared with white children [OR = 0.50, 95% CI (0.31–0.81)].
Mannix et al[90]	White race was associated with higher CT use in paediatric head trauma [OR = 1.5, 95% CI (1.02 to 2.1)].
Natale et al[91]	White children were more likely to undergo a CT scan. This race disparity was present, however, only in low risk patients, and was not observed for high risk patients.
Larson et al[2]	There was no significant difference in CT use between patients of different races from 1995 to 2008, excepting 2007.
Gender	
Marin et al[48]	Male patients were more likely than female patients to undergo CT scan among all EDs [OR = 1.25, 95% CI (1.20 to 1.31)].
Fahimi et al[41]	Male patients were overall more likely than females to undergo CT scan [OR = 1.46, 95% CI (1.11–1.92)].
Shahi et al[11]	Male patients had lower odds of CT utilization than females [OR = 0.86; 95% CI (0.86–0.86)].
Larson et al[2]	There was no significant difference in CT use between male and female patients from 1995 to 2008, excepting 2000.

Gadolinium contrast was used for 42% of examinations. MRI availability did not change during the study period, and therefore increase in MRI utilization rates cannot be attributed to higher availability. The increase was most notably in females, on weekdays, and after-hours. During the study period, neurological CT scan rates decreased significantly for PED, but a corresponding decrease was not found for musculoskeletal or trunk CT scans.

A small increase in abdomino-pelvic MRI rates was recorded in the final year of the study, with appendicitis as the most common indication for MRI imaging of the trunk. This may be related to increased desire to expose children to as little radiation as possible, and in light of publications emphasizing the use of abdominal MRI in children for appendicitis evaluation.[93,94]

As information on MRI utilization in children is scarce, more research is required to determine an overall picture with some confidence. If, however, the works cited here are an indication, a further increase in MRI utilization may become a reality, necessitating on the one hand increasing off-hour employment of MRI radiologists, in response to growing demand, and on the other hand development of clinical protocols that may limit over usage of this expensive resource.

DISCUSSION

CT scan rates have increased significantly in the last two decades, in the general population and in paediatric patients, due to higher availability and greater efficiency of available CT technologies. The availability of this technology has resulted in increased CT usage in paediatric emergency departments. There has not been a corresponding increase in children presenting to the EDs, or in positive findings and admission rates, suggesting that CT imaging is overused.

While a steady increase in CT utilization in children at the emergency department has been observed for the past 20 years, with some estimates as high as 5-fold increase, a considerable body of evidence indicates this trend has changed, with a plateau forming around 2008, followed by a decrease. This decrease occurred in conjunction with campaigns raising awareness to the long-term risks of radiation exposure. Indeed, use of other imaging modalities such as ultrasound and established decision rules have been shown to reduce CT imaging rates and were not associated with inferior outcomes.

The leading types of CT scans performed on children in the ED are head and abdominal scans, with utilization rates displaying the same trend as overall CT, including a decrease since 2008.

Decision rules, such as PECARN for head injury and the Alvarado score for abdominal pain, as well as using alternative imaging modalities, have been shown to be effective in reducing CT overuse in these two categories.

CT ordering rates exhibit great variability across facilities, facility types and even among paediatric focused facilities as well as among physicians. In addition to clinical factors, patient characteristics may also influence the decision to administer a CT scan. Age, race and gender disparities in CT scan rates have been demonstrated; however, only a few studies have investigated such factors, and more work is needed along these lines.

MRI usage rates in paediatric emergency departments have scarcely been studied. The available evidence does suggest a small increase in MRI usage in recent years, which may be related to the desire to decrease exposure of paediatric patients to ionizing radiation. More studies are needed on this subject.

It should be noted that major studies surveying CT overuse in the paediatric ED population describe trends up to the year 2013, as can be seen in Table 1. As CT overuse has high medical implications, especially in children, and important economical implications, it is our opinion that there is a need to conduct up-to-date studies covering paediatric CT and MRI overuse trends, usage variability and adherence to clinical protocols.

To summarize, CT is an important modality employed in the ED, but its high accuracy, rapid acquisition and availability have resulted in overuse. Studies from the last two decades have shown increase in paediatric ED CT utilization in the first decade, followed by a decrease in the last decade. Although overuse decreased in the last decade, variability has been shown across different facilities, as well as among physicians, with more pronounced overuse in non-teaching and non-children dedicated EDs. The leading types of paediatric ED CTs are head and abdominal scans. Decision rules, such as PECARN for head injury and the Alvarado score for abdominal pain, have been shown to reduce CT overuse in these two categories. MRI has the benefit of avoiding radiation, but the disadvantages of higher costs, less availability and less tolerability in younger children. Although anecdotally paediatric ED MRI usage has increased in recent years, only scarce reports have been published.

In conclusion, although a decrease in paediatric CT use has been registered, rates are still very high and still suggestive of overuse. The high degree of variability in CT ordering rates suggests places where overuse can be reduced by the introduction of decision rules and other imaging modalities, which have been shown to be effective.

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