Quality of Pediatric Abdominal CT Scans Performed at a Dedicated Children's Hospital and Its Referring Institutions: A Multifactorial Evaluation

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Title

The Quality of Pre-Transfer Pediatric Abdominal CT Scans Performed at Outside Hospitals: a Multifactorial Evaluation.

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Abstract

Objective

Potential differences in how imaging is performed and interpreted at specialist pediatric centers and non-specialist centers are important when considering how and where pediatric emergency department patients are imaged. This study aims to delineate these differences with respect to pediatric abdominal CT.

Materials and Methods

Fifty consecutive abdominal CT scans performed on pediatric patients at outside institution emergency departments, prior to transfer to a tertiary care children's hospital, were selected. Fifty matched abdominal CT scans performed at the receiving children's hospital during the same period were also selected. The technical quality of each scan was assessed. The original outside report, the children's hospital reinterpretation of the outside scan, and a re-evaluation of the scan by two reviewers were analysed.

Results

Forty percent of outside scans included unnecessary anatomy, compared to 10% of children's hospital scans ($p<0.001$). Mean size-specific dose estimate was 13.29 for scans performed at outside institutions and 8.68 for scans performed at the children's hospital ($p=0.03$). Concordance between the imaging diagnosis and the clinical diagnosis was significantly lower for outside reports (38/48, 79%) than for children's hospital reviewer reports (48/50, 96%; $p=0.005$). Clinician level of confidence in the children's hospital reports was significantly higher than that in the outside reports ($p<0.001$).

Conclusion

Pediatric abdominal CT scans performed and interpreted at non-specialist centers are more likely to include unnecessary anatomy, impart a higher radiation dose to patients, and result in a lower clinician level of confidence in reported interpretations than those performed at a tertiary care pediatric hospital.

Introduction

Pediatric emergency departments (EDs) in tertiary care pediatric hospitals around the United States serve a vital role in the care pathway of pediatric patients with a range of presenting complaints. An important subset of patients presenting to these departments is initially evaluated at an outside institution (OSI) that is not pediatric-specific, with the tertiary pediatric ED subsequently providing a gateway to specialist pediatric care. Many pediatric patients who warrant transfer to a pediatric hospital also require diagnostic imaging investigations as part of their evaluation. A number of authors have evaluated whether these investigations tend to be performed at the referring non-specialist outside institution or at the receiving specialist pediatric center(1, 2). Others have assessed whether higher radiation doses are imparted to patients scanned at non-specialist centers(3, 4).

In this study we aim to further isolate and examine the differences in technical quality, radiologic interpretation, and clinical usefulness of studies and accompanying reports generated at non-specialist and specialist pediatric centers.

Materials and Methods

The study was performed at a large, urban, tertiary, free-standing children's hospital (CH). Fifty consecutive abdominal CT scans performed at OSIs and loaded to the CH picture archiving computer system (PACS) for patients transferred into the CH ED were identified and the accompanying outside reports acquired. The formal CH reports of the OSI studies, issued to the CH radiology information system (RIS) for each scan as part of normal workflow by one of the CH pediatric body radiologists, were obtained. All CH radiologists who generated these reports were fellowship-trained and held Certificates of Added Qualification in Pediatric Radiology. Fifty abdominal CT scans performed at CH during the same time period were selected and matched to the outside scans for age, sex and indication. All OSI and CH studies and reports were anonymized and given a unique study identification number. The digital imaging and communications in medicine (DICOM) overlay, including institution details, was removed during imaging review.

Scans were evaluated for study context, objective technical parameters, subjective technical parameters, imaging findings and clinical utility of the report.

Scan context was elucidated in the form of patient age and gender, referral indication, type of referring ED and American Board of Radiology (ABR) certification status of the outside radiologist. Referring EDs were classified according to whether they saw exclusively adult patients, a mix of pediatric and adult patients, or exclusively pediatric patients.

Objective technical parameters were recorded by a fellowship trained pediatric radiologist and included the appropriate use of intravenous (IV) and oral contrast administration and the number of scan phases performed. Dose reports and patient size (transverse measurement at the umbilicus) were used to calculate the size specific dose estimate (SSDE) for each scan.

Two fellowship trained pediatric radiologists with Certificates of Added Qualification in Pediatric Radiology were selected from the CH cohort of body radiologists. The reviewers performed a structured subjective review of technical factors and clinical findings for all outside and CH scans, in a pre-determined randomized order. In order not to bias the reviewers with additional clinical information not available to OSI radiologists, the reviewers were provided only with the referral information as given in the OSI report and were not permitted to access the CH electronic medical record (EMR), to view prior or subsequent imaging studies or to read the CH re-interpretation report of the OSI studies that is performed as standard practice by the CH site. The review included evaluation of anatomic coverage, appropriateness of contrast if administered, appropriateness of the phases of imaging performed, presence or absence of an abnormality and overall adequacy of the imaging performed.

Subjective quality of the OSI studies was also recorded in the form of a Workflow Quality Score provided by a staff CH radiologist at the time of standard OSI CT re-read. Scores are assigned according to a pre-determined rating system; 1 = technically adequate, 2 = technically limited but adequate for the specific clinical indication provided, 3 = non-diagnostic.

The diagnosis listed in the relevant EMR discharge summary was compared to the findings of the original OSI or CH reports, the findings of the CH re-interpretation of OSI studies, and the findings of the CH reviewers.

Two board-certified pediatric emergency medicine (EM) physicians were provided with anonymized versions of the OSI reports and the CH re-interpretation of OSI studies . They evaluated these in a prescribed, randomized order, providing sliding scale scores for completeness, ease of understanding, degree to which the clinical question was answered, and level of confidence in the report. They were also asked to state whether the report would be likely to benefit decision-making and whether, based on the report alone, they would seek further discussion with the radiologist or request further imaging.

Study data were collected and managed using REDCap electronic data capture tools hosted at our institution. (http://www.sciencedirect.com/science/article/pii/S1532046408001226). Data were analyzed using the R statistical package version 6.1.0.

Demographic, clinical and referral institution characteristics are presented as mean (SD) for continuous variables and frequency (percent) for categorical variables. Differences between CH and the OSI demographics and between clinical variables were tested using the signed-rank test for continuous variables and Cochran Mantel-Haenzsel test for categorical variables to account for matching between CH and OSI scans. Similarly, differences between CH and OSI scans on technical performance and presence of abnormality were tested using the signed-rank test for continuous variables and Cochran Mantel-Haenzsel test for categorical variables. Physician reviewer analyses of CH and OSI reports (completeness, ease of understanding, etc.) are reported as percents and compared between CH and OSI using chi-squared tests. All tests were performed in SAS (v9.4; Cary, NC) at an alpha-level of 0.05.

Results

Patient characteristics and scan context are summarized in Table 1. Right lower quadrant pain was the most common indication for imaging (38%), followed by non-specific abdominal pain (28%) and blunt abdominal trauma (24%). The remainder of scans was performed for post-operative evaluation of appendicitis (2%), renal colic (2%) and other indications (6%).

The technical parameters assessed for CH and OSI studies are summarized in Table 2. Calculation of SSDE was possible for 31/37 scans performed at OSI adult-focused EDs, 11/13 scans performed at OSI pediatric-specific EDs and 48/50 scans performed at CH; dose reports were not present for the remaining scans. Median evaluable SSDE was 13.29 for scans performed at OSI EDs and 8.68 for scans performed at CH (p=0.03). Median SSDE was significantly lower for all CH scans compared to all OSI adult-focused ED scans (p=0.02) (Figure 1). There was no significant difference in SSDE between OSI pediatric ED and CH scans (p=0.85). The difference between SSDE for OSI scans performed at adult-focused (n=31) and pediatric-specific (n=11) EDs was larger than that between CH and pediatric-specific OSI scans but not did not reach significance (p=0.19). The most significant difference between CH and OSI median SSDE was for studies performed for right lower quadrant pain or appendicitis; for these studies the median SSDE for CH studies (n=18) was 6.36 (IQR 5.4, 6.7), compared to 15.0 (6.9, 20.5) for outside studies (n=17), p=0.004.

Each CH reviewer's responses were analyzed and a consensus opinion was generated for each discordant answer. The reviewers found anatomic coverage to be significantly different between CH and OSI studies; 20/50 (40%) of OSI scans were found to include unnecessary anatomy, compared to 5/50 (10%) of CH studies (p<0.001). Thin section images sufficient to allow multiplanar reconstruction at the reporting workstation were provided in 46/50 (92%) of OSI cases and were available on PACS for all CH cases (p=0.08). Phases of imaging were deemed to be optimal in 47/50 (94%) of CH studies and 44/50 (88%) of OSI studies (p=0.32). Frequency of administration of intravenous contrast did not differ significantly between the OSI and CH groups (88% and 92% respectively, p=0.48) and all were deemed appropriate. The frequency of administration of oral contrast differed significantly between CH and OSI studies and was lower for all CH studies (26%) than for all OSI studies (63%; p=0.002). The percentage of scans for which IV contrast was administered was not significantly different for the CH and OSI cohorts (92% and 88% respectively, p=0.48). Oral contrast was administered in 13 (26%) of CH studies and 31 (63%) of OSI studies. The administration of oral contrast was in line with CH scan protocols for 100% of CH studies and 26% of OSI studies. CH CT scan protocols, based on current best practice, are summarized in Table 3 (5) (6) (7).

The CH reviewers' findings are compared with the findings of the OSI radiologists in Table 2. The CH consensus interpretation review found an abnormality to be identified on 36% of CH studies and 64% of OSI studies (p=0.004). Two OSI reports were incomplete. OSI radiologists noted an abnormality in a total of 81% of OSI studies for which complete reports were available (n=39). CH reviewers disagreed with the OSI radiologist in 25% of these cases. OSI radiologists were more likely to indicate the presence of an abnormality when, according to the CH reviewers, none was present (Figure 2); 10/39 studies were reported as abnormal in the OSI report but deemed to be normal by the CH reviewers (p=0.02 from McNemar chi-square test). An additional 2/39 studies were reported as normal in the OSI report but reported as abnormal by the CH reviewers (Figure 2). Findings of bowel and 'other' abnormalities were not significantly different for CH reviewers and OSI radiologists. There were significant differences in the findings of appendiceal (p<0.001), solid-organ (p=0.01) and soft tissue abnormalities (p=0.03) between CH reviewers and OSI radiologists, with OSI radiologists more likely to determine these abnormalities to be present.

Concordance between the imaging diagnosis and the clinical discharge diagnosis was significantly lower for OSI reports (38/48, 79%) than for CH reviewer reports (48/50, 96%; p=0.005). There was no significant difference between CH reviewer and CH re-interpretation concordance with the discharge summary (p=0.56). For CH studies there was concordance between the imaging diagnosis and the clinical discharge diagnosis for 47/50 (94%) CH reviewer reports and 48/50 (96%) CH original reports (p=0.56). OSI reports, CH re-interpretation of OSI studies and CH reviewers were concordant in all cases in which surgical correlation was available (n=21).

Evaluation of board certification of OSI radiologists revealed that all were board certified in diagnostic radiology. Six (12%) held a Certificates of Added Qualification in interventional radiology, three (6%) in neuroradiology, and one (2%) in pediatric radiology.

CH Workflow Quality Scores were available for 44/50 (88%) OSI studies. 27/44 (61%) were assigned a score of 1 (technically adequate), 16/44 (36%) were assigned a score of 2 (technically limited), and 1/44 (3%) was assigned a score of 3 (non-diagnostic). CH Workflow Quality Scores are not routinely assigned to CH-performed studies and were therefore not available for comparative analysis.

The pediatric EM physician reviewers found CH re-interpretations of OSI studies to have higher levels of completeness than OSI reports (Table 4) (p<0.001). They also found that CH re-interpretations of OSI studies were more frequently easy to understand (p<0.001) and that they more frequently answered the stated clinical question well ($p<0.001$). The EM reviewers' level of confidence in the CH re-interpretations of OSI studies was significantly higher than their level of confidence in the OSI reports ($p<0.001$). The reviewers indicated that they would seek further discussion regarding the CH re-interpretation of an OSI study in 48% of cases and seek to repeat imaging in 9% (56% ultrasound and 44% x-ray). By comparison they felt it would be necessary to seek further discussion regarding OSI reports in 62% of cases ($p=0.05$ compared to CH) and to seek repeat imaging in 31% ($p<0.001$ compared to CH) (10% CT, 3% MRI and 22% ultrasound, 3% x-ray and 10% other). The CH re-interpretations of OSI studies were felt to benefit clinical decision-making in 98% of cases, compared to 93% of OSI reports ($p=0.09$).

Discussion

The main findings in our study are that pediatric abdominal CT scans performed and interpreted at non-specialist centers are more likely to include unnecessary anatomy, impart a higher radiation dose to patients, and result in less-useful reports to clinicians than those performed at a tertiary care pediatric hospital. This study adds weight to existing literature on the effect of sub-specialty performance and interpretation of imaging studies. Two prior studies document higher effective radiation doses delivered to pediatric patients in facilities that are not primarily focused on pediatric care (20, 21). Higher dose levels in non-specialists centers in these two studies were attributed to lack of compliance with pediatric-specific protocols that limited both exposure parameters and the size of the region scanned. It is likely that institutional policies, radiologist and technologist training, and clinician sub specialization all had an impact on this finding. As we have shown, pediatric radiology subspecialist training is not common among radiologists at non-specialist centers that image children. Non-pediatric focused EDs have also been demonstrated to be less equipped for treating pediatric patients, with significantly fewer pediatric-specific supplies and round the clock pediatric ED attending coverage (8).

Primary evaluation of appendicitis with ultrasound, reserving CT or MRI for clarification in equivocal cases, has been proven to be an effective imaging strategy, but one that may require strong clinical and radiology leadership to instigate (9)(10). Notably, higher levels of clinical experience have been shown to moderate the use of CT among ED physicians, even if they have limited knowledge of the risks associated with radiation (11). Several studies have shown an increased utilization of CT in centers that do not specialize in pediatric care. Eakins et al (22) found that overall CT utilization was also much higher in children with suspected appendicitis initially evaluated at a community hospital compared to initial evaluation at a children's hospital. Neff et al also documented a higher CT rate in the evaluation of suspected appendicitis in centers not specializing in pediatric radiology (12). Townsend et al showed that from 2003 to 2007 there was an overall decrease in the number of CT scans performed at children's hospitals in the United States, however it is less apparent if this trend for reduced CT use in children being imaged in specialist centers is also the case in non-specialist centers that image children (13)(14). Russell et al showed that implementation of a clinical practice guideline for appendicitis can result in reduced use of CT while maintaining diagnostic accuracy (15).

With respect to technical quality, the majority of OSI studies in our cohort were complete and included thin section images suitable for multiplanar reconstruction. However, when compared to standard pediatric protocols, a significant number were suboptimal with regard to the field of view selected, the use of contrast media, as well as the dose of radiation imparted.

We could not find any studies addressing the overall accuracy of imaging interpretations at non-specialty hospitals compared to pediatric-specific facilities. However, Saito et.al showed lower diagnostic accuracy between community hospitals and pediatric-focused hospitals in children being evaluated for suspected appendicitis (12). Eakins et al (22) evaluated the frequency of discrepancies between imaging interpretations of radiologists at outside referring institutions and those of radiologists at a tertiary care children's hospital. This group found that major disagreements occurred in 32.6% of body imaging cases. One important limitation of their study is that the authors did not control for the impact of the availability of the electronic health record and additional imaging at the pediatric referral center. Having blinded our reviewers to additional information available on PACS, RIS or the EMR we are able to add weight to the findings of Eakins et al by demonstrating that the differences in how scans are interpreted are not simply attributable to the added clinical and radiologic patient information commonly available at tertiary care centers. The higher rate of abnormal findings on OSI CTs than CH CTs in our study is likely to be due to the increased likelihood that patients with positive findings would require transfer to a tertiary care center.

Analysis of the pediatric EM physician reviewers' opinions regarding the OSI reports and CH re-interpretations of OSI studies showed that CH reports were deemed superior for all evaluated parameters. Although the EM reviewers did not have access to the patient, the EMR or any clinical context other than the scan indication, they still indicated higher levels of confidence in the CH re-interpretations of OSI studies than in the OSI reports. This aspect of the variability of the quality of scans performed at general and specialist centers has not previously been clearly delineated.

Efforts to optimize the use of CT for pediatric patients must include an awareness of all aspects of radiologic care of children. Where shortcomings in that care exist, such as those that have been highlighted by this study, there are opportunities for pediatric radiologists to advocate for, and to facilitate, improvements. These may include optimization of pediatric training of radiology residents, outreach training of clinical trainees and attendings, continued professional education of CT technologists, radiologists' involvement in the implementation of clinical care pathways, and dose reduction strategies. The findings in this study support the assertion that, when possible, there is a significant benefit to both performing and reporting pediatric abdominal CT scans in a specialist center.

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Tables and Figures

Table 1. Patient and referral institution characteristics of patients presenting for abdominal CT.

	n (%)		
	Children's Hospital (n=50)	Outside Institution (n=50)	p-value[a]
Age (years; mean; SD)[b]	12.3 (5.2)	12.8 (6.0)	0.28
Female	23 (46%)	23 (46%)	0.99
Indication for CT			
Trauma	12 (24%)	12 (24%)	0.99
Pain – Non-Specific	14 (28%)	14 (28%)	
RLQ Pain/Appendicitis	19 (38%)	19 (38%)	
Renal Colic	1 (2%)	1 (2%)	
Post Op Appendicitis	1 (2%)	1 (2%)	
Other	3 (6%)	3 (6%)	
Type of Institution			
General ED	0 (0%)	37 (74%)	<0.001
Pediatric ED	50 (100%)	13 (27%)	

a p-value from Cochran Mantel-Haenzsel test accounting for matched pairs unless otherwise noted

b p-value from signed-rank test

Table 2. Technical assessment and radiologist interpretation of abdominal CT scans performed at a pediatric referral center relative to those performed at non-specialist outside institutions.

	n (%)		
	Children's Hospital Studies (n=50)	Outside Institution Studies (n=50)	p-value[a]
Size-Specific Dose Estimate (SSDE) (median; IQR)[b]	8.68 (6.44, 15.0)	13.29 (8.33, 15.6)	0.03
Anatomic Coverage			
Insufficient	0 (0%)	1 (2%)	<0.001
Sufficient	45 (90%)	29 (58%)	
Over coverage	5 (10%)	20 (40%)	
Thin Section Images Sufficient for Multiplanar Reconstruction			
Yes	50 (100%)	46 (94%)	0.08
No	0 (0%)	3 (6%)	
Optimal Phases			
Yes	47 (94%)	44 (88%)	0.32
No	3 (6%)	6 (12%)	
Unnecessary Phases Performed			
Yes	1 (2%)	1 (2%)	0.99
No	49 (98%)	49 (98%)	
IV Contrast Administered	46 (92%)	43 (88%)	0.48
IV Contrast was Indicated (N=89)	46 (100%)	43 (100%)	0.99
Oral Contrast Administered	13 (26%)	31 (63%)	0.002
Oral Contrast was Indicated (N=44)	13 (100%)	8 (26%)	0.05

	n (%)		
	Children's Hospital Reviewers (n=50)	Outside Institution Radiologist (n=50)	p-value[a]
Abnormality Reported			0.004
Yes	18 (36%)	32 (64%)	
No	32 (64%)	18 (36%)	
Type of Abnormality			
Bowel	7 (14%)	6 (12%)	0.76
Solid Organ	8 (16%)	3 (6%)	0.10
Appendix	3 (6%)	2 (4%)	0.65
Soft Tissue	1 (2%)	2 (4%)	0.56

Bone	1 (2%)	1 (2%)	0.99
Other	4 (8%)	0 (0%)	0.05

a p-value from Cochran Mantel-Haenzsel test accounting for matched pairs unless otherwise noted

b p-value from signed-rank test

Table 3. Children's Hospital abdominal CT protocols for common indications.

Indication	IV Contrast	Oral Contrast	Number of phases	Field of view	Notes
Right lower quadrant pain/? appendicitis	Yes	No	1	Bottom of L3 though symphysis pubis	
Non-Specific Abdominal Pain	Yes	Yes	1	Lower thorax through symphysis pubis	
Post-operative pain	Yes	Yes	1	Lower thorax through symphysis pubis	
Blunt abdominal trauma	Yes	No	1	Lower thorax through symphysis pubis	Delayed phase considered in some cases of suspected trauma of the genitourinary tract
Renal colic	No	No	1	Just superior to kidneys through bottom of urinary bladder	

Table 4. Emergency Medicine physician reviewer analysis of Children's Hospital and outside institution abdominal CT reports.

	Level of completeness		Ease of understanding		Answers stated clinical question		Level of confidence	
	CH	**OSI**	**CH**	**OSI**	**CH**	**OSI**	**CH**	**OSI**
1 (best)	19.8%	5.2%	28.1%	18.6%	34.4%	14.5%	27.1%	15.4%
2	40.6%	19.6%	32.3%	15.4%	39.6%	30.9%	51.0%	28.9%
3	29.2%	34.0%	30.2%	40.2%	22.9%	27.8%	16.7%	35.1%
4	9.4%	30.9%	8.3%	21.7%	2.1%	17.5%	5.2%	15.5%
5 (worst)	1.0%	10.3%	1.1%	4.1%	1.0%	9.3%	0.0%	5.1%

Figure 1.-Size-specific dose estimate for pediatric abdominal CT scans by type of emergency department.

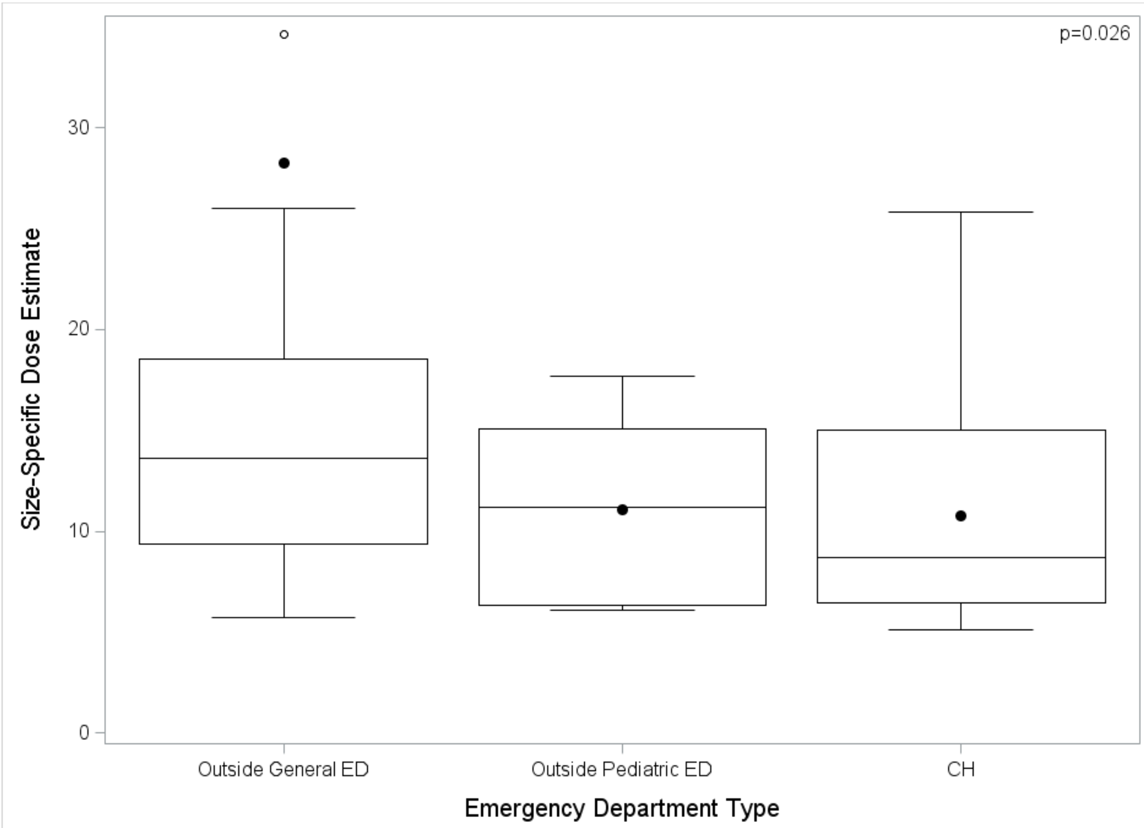

Figure 2.-Rate of detection of abnormalities on abdominal CT by specialist center reviewers and non-specialist outside institution radiologists.