Published in final edited form as:

J Urol. 2015 May ; 193(5 Suppl): 1848–1853. doi:10.1016/j.juro.2014.09.115.

Patient and Institutional Characteristics Associated with Initial CT Use for Children Presenting to the Emergency Department with Kidney Stones

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Abstract

Purpose—Professional associations recommend ultrasound as the initial imaging study for children with suspected nephrolithiasis; however, computed tomography (CT) remains frequently utilized. We sought to identify patient and institutional characteristics associated with use of CT as the first imaging study for children with nephrolithiasis diagnosed in the emergency department (ED).

Materials and Methods—We performed a cross-sectional study of children with nephrolithiasis aged 2-18 years referred to a free-standing children's hospital from 2003-2012 and identified the imaging modality first used to evaluate the child. ED medical directors where children were first evaluated were sent a questionnaire to ascertain ED characteristics. Multivariate hierarchical logistic regression models were used to determine patient and institutional characteristics associated with initial CT utilization.

Results—Of 536 eligible children, 323 (60.2%) were evaluated at EDs who returned surveys. Two hundred thirty-eight (71%) underwent CT as the first imaging study. All EDs had ultrasound. Older age was associated with higher initial CT utilization (OR 1.09; 95% CI 1.04-1.16). A more recent year of diagnosis (OR 0.80; 95% CI 0.72-0.88) and a clinical care pathway that uses ultrasound as the initial imaging study (OR 0.29; 95% CI 0.01-0.38) were associated with lower initial CT utilization.

Conclusions—A clinical care pathway in the ED was the only institutional characteristic associated with lower CT utilization. Future studies are needed to determine if care pathways that use ultrasound as the initial imaging study for children with suspected nephrolithiasis decrease inappropriate CT utilization and improve adherence to national guidelines.

Keywords

nephrolithiasis; computed tomography; ultrasound; emergency care; children

Introduction

The incidence of nephrolithiasis among adolescents has increased approximately 10% per year over the last 20 years.¹⁻³ During this time period, computed tomography (CT) use for children diagnosed with nephrolithiasis at children's hospitals has increased 26% to 45%.⁴ Increasing CT utilization is concerning because of the risk of malignancy associated with ionizing radiation, which may be higher in children than in adults because of a longer life expectancy and greater sensitivity of developing tissues to the effects of radiation.⁵ In response to this potential harm from radiation, the American Urological Association in 2012 and the European Association of Urology in 2013 developed imaging guidelines for children with suspected nephrolithiasis.^{6, 7} Both groups recommend ultrasound as the first-line imaging modality with non-contrast CT reserved if ultrasound is non-diagnostic.^{6, 7}

Currently, CT is the most frequently utilized modality for the evaluation of abdominal pain and for children with suspected nephrolithiasis in the emergency department (ED).^{8, 9} This is concerning because children with stones often undergo multiple CTs during a single stone episode and many have recurrences.^{4, 10} There is substantial variability in CT usage across hospitals participating in the Pediatric Hospital Information System (PHIS) after controlling for demographic and socioeconomic factors, which suggests other factors affect CT utilization.⁴ However, our knowledge of institutional characteristics associated with CT use is limited because prior studies were conducted in administrative databases.^{2, 4, 8, 9, 11}

The purpose of this study was to determine the patient and institutional characteristics associated with use of CT as the first imaging study for children with nephrolithiasis diagnosed in the ED at both children's and non-children's hospitals. We hypothesized that institutional factors would have the strongest association with initial CT use. Our secondary aim was to characterize the patterns of diagnostic imaging at these hospitals.

Materials and Methods

Study Population

We performed a cross-sectional study of all children aged 2-18 years who were diagnosed with symptomatic kidney stones and were referred to the Division of Urology at the Children's Hospital of Philadelphia, a 480-bed free-standing children's hospital in Philadelphia, Pennsylvania. The Division of Urology has a prospectively maintained database for patients with nephrolithiasis initially evaluated at, or referred to the hospital for continued management. We queried this database for patients with either renal or ureteral calculi who underwent initial evaluation in the ED from 2003-2012. We excluded patients with neuropathic bladder and anatomic urinary tract abnormalities. The kidney stone episode was defined as the time from initial symptomatic presentation in the ED to stone passage or surgical management. All CTs and ultrasounds performed during a kidney stone episode were retrospectively reviewed. Since all patients had one of these 2 studies, additional imaging such as a plain radiograph or intravenous pyelography was not reviewed. Review of the ED visit note for each child was not performed, as these records were not available. This study was approved by our institutional review board.

Survey Instrument

We developed a survey to identify the current characteristics of the ED where children were diagnosed with nephrolithiasis. The questionnaire took approximately 5 minutes to complete and consisted of a maximum of 29 questions (see Supplement). The questionnaire assessed hospital characteristics with answer choices for ED size and volume determined by reviewing national ED data.^{12, 13} The questionnaire also assessed the availability of imaging resources and consultants. To determine the presence of quality initiatives designed to deliver evidence-based therapy to patients, we asked about the presence of a clinical care pathway in the ED for the management of children with suspected nephrolithiasis. If a pathway was present, the directors were asked to indicate the first-line imaging modality.

The survey was pre-tested by administering it to a focus group of ED physicians to ensure that the questions comprehensively and accurately ascertained all ED characteristics potentially associated with imaging utilization. We revised the questionnaire based on the feedback received.

A list of local hospitals within the geographical referral base of our hospital was compiled (n=110). Each hospital was contacted via telephone to obtain the ED medical director's contact information, which was then used to distribute the survey via email. A reminder to complete the survey was sent one and two weeks following the initial invitation. Survey data was developed, collected, and managed using REDCap hosted at the University of Pennsylvania. REDCap is a secure, web-based application designed to support data capture for research studies.¹⁴

Outcome Definition

The primary outcome was use of CT as the initial imaging study during the ED visit when the stone was diagnosed. The secondary outcome was the order of imaging during the ED visit. We determined the frequency of ultrasound and CT use during the stone episode and identified the first imaging study obtained for each patient by the date and timestamp on the radiology report.

Predictor Variables

Predictor variables assessed for inclusion in the regression model included patient demographics and institutional characteristics identified in the survey.

Statistical Analysis

Differences in the ages of patients who underwent CT versus ultrasound as the initial imaging study were determined using the rank-sum test after confirming non-parametric distribution. Chi-square tests were used to evaluate for differences in all categorical patient and institutional characteristics between patients who first underwent CT versus ultrasound.

We used hierarchical logistic regression models to estimate the association between patient and institutional characteristics and initial CT utilization. Regression models were built using manual backwards selection of covariates. We included in the final model all covariates associated with CT at $p < 0.2$ on univariate analysis, and those with *a priori*

defined face validity, and those that exhibited significant confounding of CT use in the final multivariate model. Confounding was defined as a change of 15% between the unadjusted and adjusted odds ratio for CT utilization. Independent variables included *a priori* were age, gender, year of diagnosis, CT availability in the ED, 24-hour availability of ultrasound, number of pediatric beds in the ED, number of annual ED pediatric visits, and a clinical care pathway for children with suspected nephrolithiasis. Age was modeled as continuous variables. All other variables were categorical. This random intercept model included fixed effects for the aforementioned predictor variables and random effects for the hospital at which the patient presented. This model thus controlled for clustering of practice patterns at the hospital level, which previous studies in PHIS demonstrated were common.⁴ Analyses were completed on subjects with complete data. To assess for response bias, a sensitivity analysis was performed to determine differences in patient and imaging characteristics between hospitals which did and did not complete the survey. To explore multicollinearity within our data, we constructed a correlation matrix and eliminated covariates with a correlation coefficient $>|0.4|$ and then refit the model. There were no significant changes in the results. Tests were 2-sided, and the threshold of statistical significance was defined at $p < 0.05$. Analyses were performed with Stata 13 (StataCorp, College Station, TX).

Results

Cohort Demographics

539 children met eligibility criteria. Three were excluded due to missing imaging information, leaving 536 in the eligible population. For the entire cohort, the median age was 13.9 years, most were female (54.2%) and Caucasian (77.9%). When comparing children who had CT as opposed to ultrasound, there was no difference in gender, race/ethnicity, or a prior episode of nephrolithiasis (Table 1). However, there was a difference in age and stone size with children undergoing CT more likely to be older and with smaller stones (Table 1).

Survey Results

Twenty-three (21%) medical directors completed the questionnaire. 323 children (60.2%) were evaluated at hospitals that returned surveys. Of these, 238 (71%) underwent CT as the first imaging study. Most EDs had pediatricians (83%) and urologists (83%) available for consultation. All EDs had ultrasound available, and 83% had ultrasound available all the time. One ED (4%) had a clinical care pathway for the evaluation of children with suspected nephrolithiasis. This pathway was used to care for 66 (20%) patients. Full responses to the questionnaire are listed in Table 2. There were no differences in patient characteristics (data not shown), but children evaluated at EDs who did not complete the questionnaire had a smaller stone size (3 v 4 mm) and a higher rate of CT use (83% v 71%) compared to those evaluated at EDs who did complete the questionnaire.

Predictors of initial CT utilization

The final regression model, which contained data on the 323 (60.2%) children for whom complete patient and institutional data were available, included variables shown in Table 3. On multivariate regression adjusting for clustering of practice patterns between hospitals,

two patient characteristics were associated with initial CT utilization. Older age (OR 1.09; 95% CI 1.04-1.16) was associated with higher odds of CT utilization and a more recent year (as compared to 2003) of diagnosis (OR 0.80; 95% CI 0.72-0.88) was associated with lower odds of CT utilization. The only institutional characteristic associated with initial CT utilization was a clinical care pathway that used ultrasound as the initial imaging study for children with suspected nephrolithiasis. Children evaluated at an ED with a pathway were 71% less likely to undergo CT as the first diagnostic imaging modality than children evaluated at an ED without a pathway (OR 0.29; 95% CI 0.01-0.38) (Table 3).

Imaging Patterns

Of the eligible population, 407 (75.9%) children underwent CT and 129 (24.1%) underwent ultrasound. 298 (55.6%) underwent either 1 ultrasound or 1 CT. 238 (44.4%) underwent more than 1 imaging study with 174 (32.4%) children having both an ultrasound and CT and 54 (10.0%) undergoing 2 or more CTs.

Discussion

In this cross-sectional study of children with nephrolithiasis, we observed that patient and institutional characteristics were associated with initial CT use in the ED. Despite variability in ED volume and academic affiliation, the only ED characteristic associated with decreased initial CT use was the presence of a clinical care pathway that used ultrasound as the initial imaging study for children with suspected nephrolithiasis.

The American Urological Association and the European Association of Urology published imaging guidelines for children with suspected nephrolithiasis in 2012 and 2013, respectively.^{6, 7} Both groups recommend ultrasound as the first-line imaging modality with CT reserved if ultrasound is non-diagnostic, and clinical suspicion remains high.^{6, 7} Additionally, the Image Gently Alliance began its campaign in 2007 to lower radiation exposure among children who need diagnostic imaging.¹⁵ These recommendations were based on the harms of CT and the acceptable diagnostic performance of ultrasound. Although less sensitive and specific than CT,^{16, 17} ultrasound identifies most stones in children. In a recent prospective cohort study using CT as the gold standard, the sensitivity and specificity of ultrasound for kidney stones in children was 76% and 100%, respectively.¹⁷ Importantly, the discrepancy between ultrasound and CT was clinically important in a minority of cases.^{17, 18}

Given the variability in diagnostic imaging utilization for nephrolithiasis observed amongst PHIS hospitals,⁴ we hypothesized that significant variability would exist among EDs where children were first diagnosed with kidney stones prior to referral to a urology clinic at a PHIS hospital. We found that ultrasound was universally available and almost all EDs had both a pediatrician and urologist available for consultation. This suggests that lack of availability of ultrasound or specialist consultants is not a significant factor in determining CT use.

Older age and an earlier year of diagnosis were associated with an increased odds of initial CT. This might reflect an increased willingness to obtain CT for older patients and temporal

trends of decreasing CT use.⁴ We also observed that an ultrasound-first pathway in the ED was associated with a 71% lower odds of undergoing an initial CT scan for nephrolithiasis. Although only 1 hospital had a clinical care pathway, this was the only institutional characteristic associated with decreased CT use even when accounting for other measures of care such as academic affiliation and ED volume and size. However, given the study design, and that only 1 clinical care pathway was present we cannot attribute causality to this association. It is possible that a pathway that uses ultrasound as the initial imaging study for children with suspected kidney stones decreases CT utilization by directly influencing physician decisions. Alternatively, it is possible that a pathway is a surrogate for other processes and quality initiatives that affect imaging utilization. Future randomized trials should assess whether clinical pathways decrease inappropriate CT utilization, as they do for other surgical diseases of childhood such as appendicitis.¹⁹

Previous investigations in PHIS have demonstrated that over 50% of children with nephrolithiasis have at least 2 studies during a kidney stone episode.⁴ We observed similar imaging patterns in a broader sample of EDs, which included free-standing children's hospitals and local hospitals. In the present study, 44% of children underwent more than one imaging study, 32% had imaging using multiple modalities, and 10% had 2 or more CT scans. Repeated CT use during a single kidney stone episode is disturbing because a single pediatric stone protocol CT is estimated to result in 2-3 radiation-induced cancers for every 1000 naturally occurring cancers.⁵ Although this rate is low, the recurrent nature of nephrolithiasis and the likelihood of future scans compounds the adverse effects of the radiation.

We acknowledge the limitations of this study. It was performed at a single referral hospital and thus may not be generalizable to other areas of the country. However, we included children who were first evaluated at local hospitals, which provides insight into practices and determinants of imaging not possible through analysis of administrative databases.

We were not able to determine imaging utilization for children in whom kidney stones were suspected, but who were ultimately found to have an alternative diagnosis. It is possible that the choice of imaging study was influenced by the child's presenting symptoms, vital signs, and laboratory values, which influenced the pre-test probability of nephrolithiasis.²⁰ We also did not assess the technologist's or radiologist's comfort in performing and interpreting imaging in children, and if there were barriers to obtaining a study, such as calling in a technologist from home. Furthermore, although the majority of EDs had a pediatrician and urologist available for consultation, we do not know if these resources were utilized for a given child. Future prospective studies will need to take these variables into consideration.

This study has the limitation of any self-report survey, including response bias. Although all EDs were initially contacted via telephone, only 21% completed questionnaires representing the majority of eligible patients. However, it is possible that the 79% of hospitals which did not respond to the survey may have significantly different ED characteristics. We did observe a greater use of CT (83% v 71%) in children from hospitals which did not complete the survey. Therefore, the addition of institutional characteristics from these non-responders, especially with regards to the presence of a clinical care pathway could modify the

association with CT use. Finally, the survey only assessed the current state of ED characteristics, which may have changed over the time course of our study.

Conclusions

Although ultrasound is widely available in the ED, it is utilized less frequently than CT as the initial imaging study for children with nephrolithiasis. A clinical care pathway in the ED was the only institutional characteristic associated with lower CT utilization. Future studies are needed to determine if care pathways that use ultrasound as the initial imaging study for children with suspected nephrolithiasis decrease inappropriate CT utilization.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Dr. Tasian was supported by NIH grant T32HD060550.

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Table 1
Characteristics of Children with Nephrolithiasis Evaluated in the Emergency Department between 2003 and 2012

		Ultrasound (n=129)	CT (n=407)	Total (n=539) ^a	P Value
Median age, years (IQR)		13 (7-16)	14 (11-17)	14 (10-16)	<0.001
Gender	Male (%)	59 (46)	188 (46.2)	247 (45.8)	0.93
	Female (%)	70 (54)	219 (53.8)	292 (54.2)	
Race/Ethnicity	Caucasian (%)	96 (74)	321 (79.0)	420 (77.9)	
	Black (%)	10 (8)	29 (7.1)	39 (7.2)	
	Hispanic (%)	4 (3)	16 (3.9)	20 (3.7)	0.43
	Asian (%)	0 (0)	5 (1.2)	5 (0.9)	
	Other (%)	13 (10)	25 (6.1)	38 (7.1)	
	Unknown (%)	6 (5)	11 (2.7)	17 (3.2)	
Prior Episode of Nephrolithiasis	Yes (%)	105 (81)	349 (85.7)	454 (84.2)	
	No (%)	23 (18)	57 (14.0)	80 (14.8)	0.38
	Unknown (%)	1 (1)	1 (0.3)	5 (1.0)	
Median stone size, mm (IQR)		5 (2-7)	3 (2-5)	3 (2-5)	<0.001

Abbreviations: CT, computed tomography; IQR, interquartile range

^aTotal includes 3 additional patients who were excluded from the CT or ultrasound group due to missing radiographic information

Table 2
Survey Responses from Referring Emergency Departments

Question		Response (n=23)
Time to a children's hospital (%)	<30 Min	13 (57)
	>30 Min	10 (43)
Practice location (%)	Urban	8 (36)
	Suburban	14 (64)
Practice environment (%)	Academic	10 (44)
	Non-Academic	13 (56)
Children's hospital affiliate (%)	Yes	8 (35)
	No	15 (65)
Trauma center (%)	Yes	6 (26)
	No	17 (74)
Total number of ED beds (%)	<30	11 (48)
	>30	12 (52)
Dedicated pediatric ED (%)	Yes	11 (48)
	No	12 (52)
Total number of pediatric ED beds ^a (%)	<5	2 (18)
	>5	9 (82)
General pediatrician available for consultation (%)	Yes	19 (83)
	No	4 (17)
General urologist available for consultation (%)	Yes	19 (83)
	No	4 (18)
Pediatric urologist available for consultation ^b (%)	Yes	4 (21)
	No	15 (79)
CT available in the ED (%)	Yes	16 (70)
	No	7 (30)
Ultrasound available in the ED (%)	Yes	23 (100)
	No	0 (0)
Ultrasound available 24 hours per day in the ED (%)	Yes	19 (83)
	No	4 (17)
Radiologist reads ED films (%)	Yes	22 (96)
	No	1 (4)
Radiologist available 24 hours per day ^c (%)	Yes	15 (71)
	No	6 (29)
Annual total patients evaluated in the ED ^d (%)	<50,000	12 (55)
	>50,000	10 (45)
Annual pediatric patients evaluated in the ED ^d (%)	<10,000	10 (45)
	>10,000	12 (55)
Presence of a clinical care pathway for the evaluation of suspected nephrolithiasis (%)	Yes	1 (4)

Question		Response (n=23)
	No	22 (96)

Abbreviations: ED, emergency department; CT, computed tomography

^a Only includes respondents with a dedicated pediatric emergency department (n=11)

^b Only 19 respondents

^c Only 21 respondents

^d Only 22 respondents

Table 3
Final Multivariate Logistic Regression Model for Initial CT Use in the Emergency Department

Predictor Variable	OR	95% CI	P Value
Age at diagnosis (year)	1.09	1.04-1.16	0.001
Gender	0.98	0.56-1.69	0.94
Year of diagnosis (ref. 2003)	0.80	0.72-0.88	<0.001
Pediatric ED size (no. beds)	0.48	0.52-4.45	0.52
Presence of an ED CT scanner	0.38	0.02-5.87	0.49
Ultrasound available 24 hours per day	0.54	0.35-8.46	0.66
Pediatric ED clinical volume (no. visits per year)	1.99	0.84-4.72	0.12
Presence of a nephrolithiasis clinical care pathway	0.29	0.01-0.38	0.007

Abbreviations: OR, odds ratio; CI, confidence interval; ED, emergency department; CT, computed tomography

Table 4
Frequency of CT and Ultrasounds Performed during a Kidney Stone Episode

	Number of studies obtained during episode	CT (%) ^b					
		0	1	2	3	4	Total
Ultrasound (%) ^b	0	N/A ^a	223 (41.6)	34 (6.3)	4 (0.7)	0 (0)	261 (48.7)
	1	75 (14.0)	132 (24.6)	12 (2.2)	0 (0)	1 (0.2)	220 (41.0)
	2	20 (3.7)	19 (3.5)	3 (0.6)	0 (0)	0 (0)	42 (7.8)
	3	4 (0.7)	5 (0.9)	0 (0)	0 (0)	0 (0)	9 (1.7)
	4	0 (0)	2 (0.4)	0 (0)	0 (0)	0 (0)	2 (0.4)
	5	2 (0.4)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.4)
Total		101 (18.8)	381 (71.1)	49 (9.1)	4 (0.7)	1 (0.2)	536 (100)

Abbreviations: CT, computed tomography

^a A total of 3 patients had no available radiographic information and were excluded from analysis

^b All % calculated out of the total number of patients (n=536)