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DIAGNOSIS OF PEDIATRIC UROLITHIASIS: ROLE OF ULTRASOUND AND COMPUTERIZED TOMOGRAPHY

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ABSTRACT

Purpose: Pediatric urolithiasis is believed to be uncommon, and may present without the classic symptoms of renal colic. The objectives of this study were to describe the presenting features and radiographic evaluation of pediatric urolithiasis, and to determine the accuracy of ultrasound and unenhanced computerized tomography (CT) in detecting urolithiasis.

Materials and Methods: We retrospectively reviewed the charts of children 0 to 18 years old with urolithiasis. Data collected included age, sex, race, presenting symptoms, radiographic studies performed during initial evaluation, calculus location and family history of urolithiasis.

Results: A total of 75 patients had complete data for analysis. Of these patients 54 (72%) had urolithiasis symptoms (flank pain, gross hematuria or both). Patients with urolithiasis symptoms were older at diagnosis (median age 11.9 years vs 1.0 years, $p < 0.001$) and were more likely to have a family history of urolithiasis (54% vs 14%, $p = 0.002$). The 39 CTs performed were accurate in detecting calculi in children with urolithiasis symptoms (96% to 100%) and in those without symptoms (100%). The 36 ultrasounds performed had more variable accuracy in children with urolithiasis symptoms (33% to 100%) vs those without symptoms (89%). Ultrasound failed to detect urolithiasis in 41% of the patients with urolithiasis symptoms, compared to 5% with CT. CT was also highly accurate regardless of calculus location (89% to 100%), whereas ultrasound was again more variable (kidney 90%, kidney and ureter 75%, ureter alone 38%).

Conclusions: Ultrasound failed to detect calculi in 41% of the children with urolithiasis symptoms, whereas CT was highly accurate in all situations. Unenhanced CT should be performed in all children with persistent urolithiasis symptoms and nondiagnostic ultrasound.

KEY WORDS: urinary calculi; ultrasonography; tomography, x-ray computed; pediatrics; diagnosis

Urolithiasis is common in adults but is believed to be relatively rare in the general pediatric population. The incidence of urolithiasis in adults is 3% to 12%.[1,2] Previous studies have shown that 1 in 1,000 to 1 in 7,500 pediatric hospital admissions are due to urolithiasis.[3,4] However, since most children are not admitted to the hospital for evaluation or treatment of urolithiasis, the actual incidence in children is unknown. The presentation of urolithiasis in children also differs from that in adults. While the typical adult presentation of urolithiasis is unilateral colicky flank pain, only about 50% of pediatric patients with urolithiasis present with symptoms of pain.[4,5] Because urolithiasis may be perceived as rare in pediatric patients, the diagnosis may not be considered in children who present with symptoms other than flank pain, such as gross hematuria.

The diagnosis of pediatric urolithiasis may also be problematic. Published data reveal that unenhanced spiral computerized tomography (CT) is the gold standard for diagnosing urinary tract calculi in adults, and has been demonstrated to be more sensitive and specific than either ultrasound or excretory urography (IVP) in detecting calculi in this population.[6–9] Unenhanced CT does not expose the patient to intravenous contrast material, and provides greater detail about calculus size and location than either IVP or ultrasound. However, CT carries the risk of exposure to ionizing radiation, which can be a significant issue in children.

Because of the low clinical suspicion for urolithiasis as well as potential concerns about radiation exposure, primary care providers may choose ultrasound as the initial radiographic study for children with symptoms that can be associated with urolithiasis, such as flank pain, abdominal pain and gross hematuria. However, the accuracy of ultrasound in detecting pediatric urolithiasis has not been well studied. In our practices we noted several children who presented with urolithiasis symptoms such as gross hematuria, in whom the initial ultrasound was normal but subsequent CT showed the presence of urolithiasis. Therefore, we hypothesized that ultrasound as a first line test may fail to detect a significant proportion of pediatric urolithiasis.

The objectives of this study were to describe the presenting features and radiographic evaluation of pediatric patients with urolithiasis referred to pediatric nephrologists or pediatric urologists at a tertiary care center, and to determine the accuracy of ultrasound in detecting urolithiasis in this population.

MATERIALS AND METHODS

A retrospective chart review was performed in all patients 0 to 18 years old evaluated as outpatients and/or inpatients at our institution between October 2002 and January 2004. Patients with urolithiasis were identified by billing records, International Classification of Disease-9 codes and lists generated by individual physicians. Urolithiasis was defined as radiographic identification of a calculus or documented cal-

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TABLE 1. *Demographic characteristics of study population*

	Study Population	Urolithiasis Symptoms*	Other or No Symptoms	p Value
No. pts	75	54	21	
Median yrs age (range)	10.6 (0.08–17.8)	11.9 (3.4–17.8)	1.0 (0.08–11.6)	<0.001
No. boys	37	28	9	
No. girls	38	26	12	0.48
No. white race pts (other)	53 (22)	41 (13)	12 (9)	0.11
No. pos family history (%)	32 (43)	29 (54)	3 (14)	0.002

* Urolithiasis symptoms were defined as abdominal and/or flank pain, gross hematuria or both.

culus passage. Data collected included age, sex, race, the presence or absence of urolithiasis symptoms (gross hematuria, abdominal and/or flank pain or both) at presentation, the presence or absence of microscopic hematuria, radiographic studies performed during the initial evaluation (ultrasound, enhanced and/or unenhanced CT, excretory urography or abdominal plain film), calculus location (kidney and/or ureter or unknown) and family history of urolithiasis.

Patient demographics were described overall and by group, defined by the presence or absence of symptoms. Age was described by the median and range, and race, sex and family history by proportion of frequencies or percentages of the total. Age was compared using the Wilcoxon rank sum test, and the nominal variables were compared using chi-square analysis. Symptom and location classifications are described with frequencies and percentages. Radiographic evaluations are described as the number performed and percentage of those with positive findings. These results are stratified by symptom classification and calculus location. The level of significance was set at 0.05. All statistical analyses were done using SAS ®8.2 statistical software.

RESULTS

A total of 76 pediatric patients with urolithiasis were identified, of which 1 was excluded due to incomplete data. The demographic characteristics of the study population are summarized in table 1. Patients were further subdivided into 2 groups based on the presence or absence of urolithiasis symptoms at presentation. Patients with vs those without urolithiasis symptoms had statistically significant differences in age at diagnosis (median 11.9 years vs 1.0 years, $p < 0.001$) and the presence of a positive family history of urolithiasis (54% vs 14%, $p = 0.002$). There were no significant differences between the 2 subgroups with respect to sex or race.

A total of 54 patients (72%) had urolithiasis symptoms (abdominal and/or flank pain, gross hematuria or both), of whom 48 (89%) reported some type of pain. Among the patients 33 (61%) reported pain alone, of whom 10 also had microscopic hematuria, and 15 (28%) reported pain and gross hematuria. The remaining 21 patients (39%) did not have urolithiasis symptoms, although 3 had microscopic hematuria.

The radiographic evaluation of patients by symptom presentation is summarized in table 2. The majority of patients with pain alone or pain and gross hematuria (73%) underwent CT. The presence of microscopic hematuria in patients with pain alone appeared to have only a modest effect on whether CT or ultrasound was performed. Of the 10 patients with pain and microscopic hematuria 80% received CTs. Of the 23 patients with pain and no microscopic hematuria 65% received CTs. The 39 CTs performed were highly accurate, with a 96% to 100% detection rate in patients with or without urolithiasis symptoms. The majority of CTs performed in this study (82%) were done as unenhanced studies (ie suspected urolithiasis was the indication for the study). The remainder (18%) were enhanced and unenhanced studies performed for the indication of abdominal pain.

The accuracy of the 36 ultrasounds performed was more variable. For patients presenting with pain alone or pain and gross hematuria the detection rate was low (33% and 57% of studies were positive, respectively). For the 4 patients with gross hematuria alone who underwent ultrasound all studies were positive. In patients with other symptoms or no symptoms the ultrasound detection rate was high (89% of studies were positive). Ultrasound was performed in these patients because of urinary tract infection (8 patients), prematurity with chronic diuretic therapy (3), microscopic hematuria (3), followup of a known urological disorder (2), urgency/frequency (1), hypercalciuria following treatment with high dose calcium and phosphorus (1), and screening ultrasound in association with Turner syndrome (1). CT was performed in 2 patients without urolithiasis symptoms in whom ultrasound revealed hydronephrosis but no calculus. Two additional patients without urolithiasis symptoms did not undergo ultrasound or CT. These patients were diagnosed by an incidental finding on an abdominal plain film during inpatient evaluation for respiratory distress, and passage of a calculus in association with a known family history of urolithiasis.

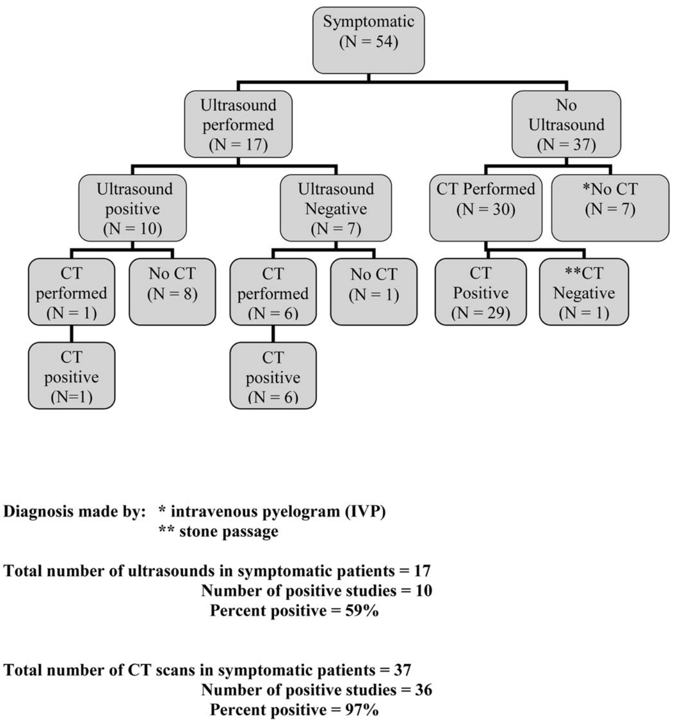
To determine if the presenting symptom(s) could have influenced the choice of the initial diagnostic evaluation(s) in patients with urolithiasis symptoms, we examined the sequence and accuracy of diagnostic studies performed in that subgroup, including the choice of initial diagnostic study (ultrasound vs CT). As demonstrated in the figure, 56% of patients with urolithiasis symptoms underwent CT as the initial diagnostic study, with a high detection rate (97% of studies were positive). There was 1 patient in whom initial CT was negative. That patient subsequently had recurrence of urolithiasis symptoms and was diagnosed by calculus passage.

Only 31% of patients with urolithiasis symptoms underwent ultrasound as the initial diagnostic test. In this population the detection rate was lower (59% of studies were positive). Therefore, ultrasound failed to detect urolithiasis in 41% of patients with urolithiasis symptoms. Six patients with negative ultrasound subsequently underwent CTs, all of which were positive. One patient with a negative ultrasound was diagnosed by calculus passage. There were 7 patients with urolithiasis symptoms who did not undergo ultrasound or CT, all of whom were diagnosed by IVP.

We also examined whether the symptoms at presentation were associated with the location of the calculus (ie kidney, ureter or both). As shown in table 3, half of the patients with kidney calculi alone had no urolithiasis symptoms. In contrast, of the 32 patients with ureteral calculi alone the overwhelming majority (91%) had 1 or more urolithiasis symp-

TABLE 2. *Radiographic evaluation and symptoms*

Diagnostic Study	Urolithiasis Symptoms			Other or No Symptoms
	Pain Only	Gross Hematuria Only	Pain + Gross Hematuria	
No. pts	33	6	15	21
No. ultrasound (% pos)	6 (33)	4 (100)	7 (57)	19 (89)
No. CT (% pos)	23 (96)	2 (100)	12 (100)	2 (100)



Radiographic evaluations in 54 patients with urolithiasis symptoms. Flow chart depicts sequence of radiographic studies. Ultrasound was positive in 10 of 17 patients with symptoms (59%), while computerized tomography (*CT*) was positive in 36 of 37 patients with symptoms (97%). Asterisk indicates cases diagnosed by IVP. Double asterisk indicates cases diagnosed by stone passage.

toms, primarily pain (88%). Of the 9 patients with calculi in the kidney and ureter 6 (67%) had urolithiasis symptoms. In the remaining 6 patients the calculus location was unknown because of calculus passage or because the precise location of the calculus was not noted in the chart records. Four of these patients (67%) also had urolithiasis symptoms.

Table 4 outlines the accuracy of each diagnostic study performed in relation to calculus location. CT was highly accurate regardless of calculus location, with a detection rate of 89% to 100%. This finding was particularly true for the 32 ureteral calculi, in which 100% of studies were positive. In contrast, ultrasound accuracy was highly variable. For the 28 kidney calculi the detection rate was comparable to that of CT (90%). In contrast, the detection rate for ureteral calculi was markedly lower than that of CT (38% vs 100%).

DISCUSSION

Unenhanced CT has been proposed as the method of choice in diagnosing urinary tract calculi due to its high sensitivity and specificity, and detail.[4–7] In this study CT was accurate in detecting calculi regardless of the location, with 89% to 100% of studies being positive. It is noteworthy that for ureteral calculi the detection rate was 100%. In contrast, the accuracy of ultrasound, which may be the initial study performed in children presenting with abdominal pain, flank pain and/or gross hematuria, was more variable. Renal calculi were readily detected by ultrasound, with 90% of studies being positive. However, ureteral calculi detection rates with ultrasound were low, with only 38% of studies being positive. Our results are consistent with published reports on adults.[6–8] In a study of 112 adults with renal colic who were diagnosed with ureteral calculi and underwent ultrasound and CT Yilmaz et al reported a sensitivity of 94% with CT vs only 19% with ultrasound.[6]

Few published studies have examined the accuracy of ultrasound vs CT in diagnosing urolithiasis in the pediatric population. Eshed and Witzling retrospectively studied 20 unenhanced CTs performed in patients 1 to 15 years old who presented with a variety of symptoms, including flank pain, abdominal pain, hematuria, nausea and vomiting.[10] Eight of these patients had previously undergone ultrasound. Only 3 patients in this group had urolithiasis, of whom 1 had a positive CT finding and had not previously undergone ultrasound, and 2 had an abnormal ultrasound finding (hydronephrosis) without evidence of the actual calculus, which was subsequently revealed on CT. The authors concluded that CT did not provide significant information if performed after a normal ultrasound. They proposed using ultrasound as the first line screening tool in children suspected of having urinary tract calculi, and reserving CT for those patients in whom ultrasound results were "uncertain or abnormal."[10]

In contrast, in our current study 7 of 17 patients (41%) with urolithiasis symptoms who underwent initial ultrasound had negative studies. Six patients subsequently underwent unenhanced CT, and all 6 studies were positive. There are several potential reasons why our findings differ from those of Eshed and Witzling.[10] First, our study had a larger cohort of patients (75 vs 20). Also, our study population comprised patients with documented urolithiasis, with or without urolithiasis symptoms, who underwent CT and/or ultrasound. In the study by Eshed and Witzling the population was made up of symptomatic pediatric patients who had undergone CT to evaluate for possible calculi.[10]

Ultrasound may still be the appropriate initial study for the majority of children presenting with symptoms suggestive of urolithiasis, such as abdominal and flank pain. However, in contrast to Eshed and Witzling,[10] we clearly demonstrate that a subset of patients with urolithiasis symptoms and normal ultrasound will subsequently exhibit urolithiasis on unenhanced CT. It is noteworthy that newer unenhanced CT protocols suggest that a decreased radiation dose results in a comparable detection rate for urolithiasis to the currently used conventional doses.[11] Similarly, newer pediatric CT protocols have also been reported to decrease radiation exposure by 60% to 90%.[12] Less exposure to ionizing radiation may make pediatric practitioners more willing to order unenhanced CT for suspected urolithiasis. In addition, advances in ureteroscopic equipment and techniques have allowed the pediatric urologist to treat calculi endoscopically in children,[13,14] thereby decreasing the need for invasive procedures once urolithiasis is identified.

The true incidence of pediatric urolithiasis is unknown but it is thought to be relatively low. Although the goal of this

TABLE 3. *Calculus location and symptoms*

Stone Location	Total No. Pts	No. Urolithiasis Symptoms (%)			No. Other or No Symptoms (%)
		Pain Only	Gross Hematuria Only	Pain + Gross Hematuria	
Kidney	28	6 (21)	4 (14)	4 (14)	14 (50)
Ureter	32	21 (66)	1 (3)	7 (22)	3 (9)
Kidney + ureter	9	3 (33)	1 (11)	3 (33)	2 (22)
Unknown	6	3 (50)	0 (0)	1 (17)	2 (33)

TABLE 4. *Calculus location and radiographic study*

Calculus Location	Total No. Pts	No. Ultrasound (% pos)	No. CT (% pos)
Kidney	28	21 (90)	9 (89)
Ureter	32	8 (38)	24 (100)
Kidney + ureter	9	4 (75)	6 (100)

study was not to establish the incidence of the disease, it is noteworthy that in a period of less than 2 years our single center evaluated and diagnosed 76 children with urolithiasis. This finding suggests that pediatric urolithiasis may be more common that previously thought. It is also noteworthy that children with urolithiasis symptoms were far more likely than those without symptoms to have a positive family history (55% vs 22%, $p < 0.01$). Therefore, we speculate that the apparent increase in pediatric urolithiasis could be due to environmental factors such as diet (particularly sodium intake) "unmasking" a genetic tendency at an earlier age.

Our study is limited by its retrospective design and the fact that all of the patients were evaluated at a tertiary care center. However, it is noteworthy that although the patients were evaluated at hospital based specialty practices, many had already undergone 1 or more diagnostic studies before the initial evaluation by a pediatric nephrologist or pediatric urologist. Because of the retrospective design, we were unable to compare directly the sensitivity and specificity of ultrasound and unenhanced CT for all patients in the study. In addition, color Doppler of ureteral jets, which may improve detection of ureteral calculi,[15] was not performed in the ultrasounds included in this report. Our study also did not examine the results of all unenhanced CTs performed at our institution during the study period. Finally, we did not have the ability to confirm the radiographic diagnosis in each patient by calculus retrieval. However, the possibility of false-positive results is extremely low, given that the radiographic appearance of calculi (particularly on CT) is fairly unique.

CONCLUSIONS

This study of 75 pediatric patients shows that ultrasound failed to detect calculi in 41% of patients with urolithiasis symptoms who were ultimately found to have urolithiasis. Furthermore, the calculus location influences the accuracy of ultrasound but not that of unenhanced CT in detecting pediatric urolithiasis. In particular, ultrasound has a high detection rate for renal calculi but a low rate for ureteral calculi. Therefore, a negative ultrasound should not be considered sufficient to rule out the diagnosis of urolithiasis in pediatric patients with urolithiasis symptoms such as flank pain and/or gross hematuria. Based on the findings of this study, we recommend that children with a negative ultrasound and persistent symptoms of flank or abdominal pain and/or gross hematuria undergo unenhanced CT. In the subset of older patients with pain and a positive family history of urolithiasis it may be appropriate to proceed directly to unenhanced CT. Furthermore, unenhanced CT may be considered in patients with persistent microscopic hematuria, a family history and negative ultrasound. The findings of this study highlight the importance of maintaining a high index of suspicion for pediatric urolithiasis, which may not be as uncommon as previously thought.

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