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Original Contribution

The ability of renal ultrasound and ureteral jet evaluation to predict 30-day outcomes in patients with suspected nephrolithiasis

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ABSTRACT

Study objective: We sought to identify findings on bedside renal ultrasound that predicted need for hospitalization in patients with suspected nephrolithiasis.
Methods: A convenience sample of patients with suspected nephrolithiasis was prospectively enrolled and underwent bedside ultrasound of the kidneys and bladder to determine the presence and degree of hydronephrosis and ureteral jets. Sonologists were blinded to any other laboratory and imaging data. Patients were followed up at 30 days by phone call and review of medical records.
Results: Seventy-seven patients with suspected renal colic were included in the analysis. Thirteen patients were admitted. Reasons for admission included intractable pain, infection, or emergent urologic intervention. All 13 patients requiring admission had hydronephrosis present on initial bedside ultrasound. Patients with moderate hydronephrosis had a higher admission rate (36%) than those with mild hydronephrosis (24%), $P < .01$. Of patients without hydronephrosis, none required admission within 30 days. The sensitivity and specificity of hydronephrosis for predicting subsequent hospitalization were 100% and 44%, respectively. Loss of the ipsilateral ureteral jet was not significantly associated with subsequent hospital admission and did not improve the predictive value when used in combination with the degree of hydronephrosis.
Conclusions: No patients with suspected renal colic and absence of hydronephrosis on bedside ultrasound required admission within 30 days. Ureteral jet evaluation did not help in prediction of 30-day outcomes and may not be useful in the emergency department management of renal colic.

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1. Introduction

Renal colic caused by a ureteral stone is a frequent presentation to the emergency department (ED) accounting for approximately 5.7 million ED visits from 2005 to 2009 according to the National Hospital Ambulatory Medical Care Survey [1]. After the ED provider determines that a patient with abdominal or flank pain does not have a more immediate life-threatening diagnosis, management of patients with suspected nephrolithiasis revolves around pain control, ruling out infection, and determining the need for urologic intervention. Previous studies have shown that smaller, more distally located stones have a higher likelihood of spontaneous passage and lower incidence of complications [2,3]. Information on stone size and location is most accurately achieved with computed tomographic (CT) scan [4,5]. However, there are disadvantages to CT including financial and human resource costs, time, logistic infrastructure, exposure to ionizing radiation, and the risk of clinically unimportant incidental findings leading to further diagnostic testing and medical interventions with their own attendant costs and risks [6,7]. As an alternative to CT, ultrasound is a frequently used imaging modality in the workup of ureteral stones. Ultrasound can readily visualize hydronephrosis secondary to ureteral obstruction (Fig. 1), is relatively inexpensive, and can be repeated without exposure to ionizing radiation: a particular advantage in a disease, which is frequently recurrent. Such considerations have led the European Association of Urology to recommended ultrasound as "the primary diagnostic imaging tool" for urolithiasis. Widespread training of emergency physicians in bedside sonography has conferred the additional advantage of potential accelerated throughput for these patients when presenting to the ED [8-10].

A limitation of ultrasound has been its inability to identify the location and size of ureteral stones, thereby restricting its ability to predict the likelihood of spontaneous stone passage and rendering it, in the view of some, as inadequate for definitive decision making in the management of these patients [9]. Despite this, a recent large

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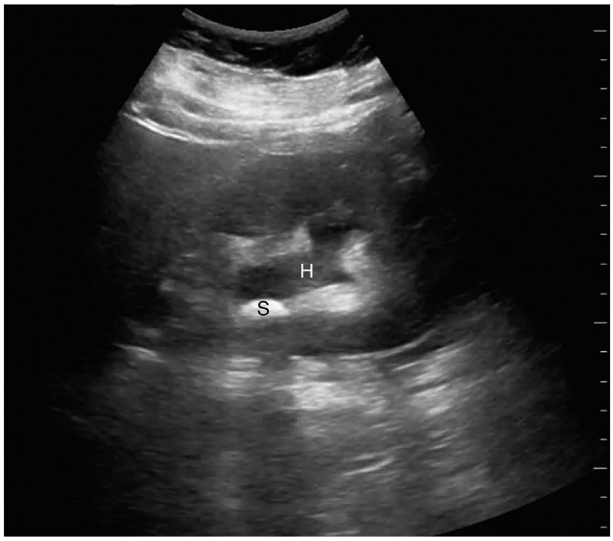

Fig. 1. Beside ultrasound showing mild hydronephrosis (H) as a result from an obstructing uretal pelvic junction stone (S).

multicenter, randomized controlled trial of ultrasound vs CT demonstrated that an ultrasound-first approach leads to a significant reduction in radiation exposure without affecting outcomes [11]. The findings of this study suggest that CT does not help risk stratify patients as previously believed, and ultrasound alone may be adequate. In addition, a large retrospective study by Edmonds et al [12] found that absence of hydronephrosis in patients with ureteral stones required urologic intervention in less than 1% of cases, suggesting that severity of hydronephrosis may predict the likelihood of subsequent complications or failure to pass spontaneously.

In addition to evaluating for hydronephrosis, ultrasound can also identify the ureteral jet of urine flowing into the bladder (Fig. 2). Previous study has demonstrated ureteral jet asymmetry in cases of ureterolithiasis, with an absent or weaker jet lateralizing to the side with obstruction [13]. Studies have not elucidated whether this additional sonographic bedside test could also provide prognostic information.

Currently, unless a CT is obtained, the management of renal colic is based on clinical data (eg, pain control, ability to tolerate oral intake, concomitant urinary infection, etc). Identification of sonographic findings that predict complications of ureteral colic such as need for hospitalization or urologic intervention would be of value in the management of these patients. Conversely, identifying patients with a high rate of spontaneous passage and low rate of complications could decrease utilization of CT.

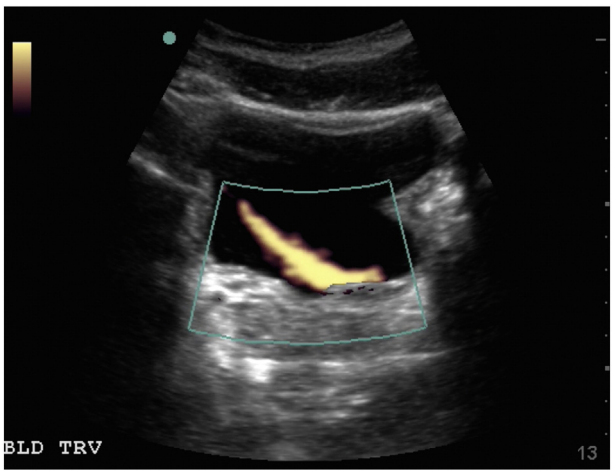

Fig. 2. Power Doppler of a bladder demonstrating a normal left ureteral jet.

We hypothesized that severity of hydronephrosis and a decreased or absent ureteral jet on the side of the patient's symptoms would be associated with an increased need for hospitalization for pain, infection, or urologic intervention within 30 days in patients with suspected nephrolithiasis.

2. Methods

2.1. Study design

This prospective, observational study enrolled a convenience sample of ED patients presenting with symptoms of renal colic during 2008 to 2011. The facility's institutional review board approved the study, and all patients provided informed consent.

2.2. Setting and population

The study was performed at a single-center urban teaching ED with an annual census of 55 000. Adult patients with symptoms consistent with renal colic (eg, flank or abdominal pain, hematuria, etc) were included. Exclusion criteria included presence of ureteral stent or percutaneous nephrostomy, history of end-stage renal disease or renal transplant, and pregnancy. In addition, patients who had a diagnosis other than nephrolithiasis as the most likely cause of their symptoms (as determined by the caring ED attending physician) were excluded from analysis. Study personnel consisted of seven emergency physicians who all met the 2008 American College of Emergency Physician's Emergency Ultrasound Guidelines with at least 25 renal studies [14]. In addition, sonographers were given a standard didactic and hands-on training for assessment of ureteral jets. Study personnel were blinded to laboratory and radiology data of enrolled patients and were not involved in the clinical care of the patient.

2.3. Methods and measurements

Ultrasound examination of both kidneys and the bladder was performed in longitudinal and transverse planes. The sonologist graded the presence of hydronephrosis for each kidney as none, mild (any nonvascular and noncystic fluid collection in the renal sinus), moderate (renal sinus dilatation resulting in confluence of calices), or severe (grossly dilated renal sinus with cortical effacement). At the discretion of the sonologist, color or power Doppler ultrasound was used to confirm or exclude hydronephrosis in equivocal cases. Bilateral simultaneous ureteral jet evaluation was performed in the transverse plane at the level of the ureterovesical junctions using color or power Doppler with a pulse repetition frequency set to detect low flow. The power Doppler field size was set to include the entire posterior wall of the bladder and was visualized for 3 minutes. Ureteral jets were considered normal if present at least once on each side. Ureteral jets were considered nondiagnostic when neither side was visualized during the 3 minutes. A ureteral jet was considered abnormal when visualized on the contralateral side but was either absent or comparatively diminished on the ipsilateral side. Patients with an empty bladder were excluded from ureteral jet analysis. All ultrasounds were obtained with either a Sonosite M-Turbo or a Siemens Accuson X-300 using a curvilinear 2- to 5-MHz probe depending on sonologist preference and machine availability. The time spent performing each study was determined by machine timestamps of study start and finish.

All patients received a follow-up phone-call 30 days after the ED visit for information regarding repeat ED visits, need for admission, or urologic intervention. The primary outcome was any subsequent urologic intervention or hospitalization related to the diagnosis of ureterolithiasis at the time of presentation or within 30 days after initial ED presentation.

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2.4. Data analysis

Summary statistics with 95% confidence intervals was calculated. All variables were tested for normality, and summary statistics are reported in means with SD, medians with interquartile ranges, or frequencies. Comparisons were performed using χ^2 or Fisher exact test where appropriate. All statistics were performed using Stata (StataCorp 2009, Stata Statistical Software: Release 11; StataCorp LP, College Station, TX).

3. Results

One hundred eleven patients were screened for enrollment. Thirty-four patients had an alternative leading diagnosis, leaving 77 patients with suspected nephrolithiasis. Demographic information is presented in Table 1. Thirty-day follow-up was completed in 95% (73/77) of patients. Four patients were unable to be reached by phone and did not have a primary care physician. No patients died during the follow-up period. Twenty-three patients (29%) reported visualizing a stone pass at home, and 61 (79%) reported resolution of symptoms. Thirteen patients (17%) had a subsequent hospitalization for a ureteral stone (Table 2). Of the 13 hospitalized patients, 10 were admitted during the initial ED visit, and 3 returned to the ED within 72 hours of the initial ED visit and were admitted at that time. Reasons for hospital admission were intractable pain (8) and evidence of infection (5). Seven patients underwent an inpatient urologic intervention during admission. No alternative diagnoses were discovered during the follow-up period.

Bedside ultrasound evaluation for hydronephrosis was successfully completed in all patients; however, ureteral jet evaluation could not be performed in 7 (9%) cases due to an empty bladder. The rate of hospitalization for a urologic complication (pain or infection) in patients with renal colic was 0% (0/28) of patients with no hydronephrosis, 24% (9/38) of patients with mild hydronephrosis, and 36% (4/11) of patients with moderate hydronephrosis, $P < .01$. There were no patients with severe hydronephrosis in the sample. The rate of admission in patients with decreased or absent ipsilateral ureteral jet was 19% and in patients with normal ureteral jets was 14%, $P = .6$. Test characteristics of various ultrasound and CT findings for prediction of subsequent hospital admission are presented in Table 3. Overall, hydronephrosis was found to have a receiver operator area under the curve of 0.72 (95% confidence interval, 0.66-0.78). In the subset of patients who underwent CT scan, a stone size of 5 mm or greater yielded an area under the curve of 0.77 (0.62-0.93) for prediction of subsequent admission. Loss of the ipsilateral ureteral jet did not significantly improve sensitivity or specificity when combined with findings of hydronephrosis for predicting the need for hospital admission.

4. Discussion

An optimal strategy for working up renal colic identifies those cases likely to have complications (prolonged pain or infection) and avoids unnecessary ionizing radiation from CT. The current study shows that, in patients with suspected nephrolithiasis, severity of hydronephrosis on bedside ultrasound is associated with an increased risk of hospitalization. Patients without hydronephrosis had a 0% rate of subsequent hospitalization. The findings suggest that, in patients with an ED diagnosis of renal colic, ultrasound provides some prognostic information on the likelihood of spontaneous stone passage without having to directly visualize stone size or location. The current study also found that ureteral jet evaluation does not improve the predictive value for determining 30-day hospitalization rates in patients with acute renal colic.

Previous evidence has also suggested that the degree of hydronephrosis (identifiable on ultrasound) may be an alternative to the pathologic and anatomic information available from CT. In a 2010 study by Goertz and Lotterman [15], the negative predictive value of no or mild hydronephrosis vs moderate or severe hydronephrosis for predicting ureteral stones greater than or equal to 5 mm was 0.876. Along similar lines, Moak et al [16] determined that emergency bedside ultrasound had a sensitivity of 90% for detecting hydronephrosis in patients with a stone of greater than 5 mm. A study by Eisner et al [17] demonstrated that the degree of ureteral dilation is greater with proximal stones compared with distal stone. In a large, retrospective study, patients with renal colic and no hydronephrosis had a 0.6% incidence of urologic intervention [12]. Our study prospectively corroborates that patients with renal colic and an absence of hydronephrosis are unlikely to require subsequent hospitalization or urologic intervention.

The current study also shows that degree of hydronephrosis (at least mild and moderate) is related to urologic complications (infection, intractable pain, and hospitalization). A study by Papa et al [3] examined 18 predictor variables for urologic intervention within 4 weeks of symptom onset and found that stone size greater than 6 mm, location above the mid ureter and higher severity of pain at ED discharge yielded a 92% sensitivity and 63% specificity (degree of hydronephrosis was not included as a variable in the analysis). A limitation to this prediction rule is that it necessitates a CT with its burdensome financial, manpower, and infrastructural costs in addition to the bioeffects of ionizing radiation and the potential for equivocal or incidental findings that require further evaluation and workup with ensuing expense, risk, and inconvenience to the patient (and health care system). Our study found that the overall area under curve for hydronephrosis was similar to a cut point of a stone size of 5 mm or greater for predicting subsequent admission suggest that, given its immediate availability, low cost, and lack of ionizing radiation, bedside ultrasound may be an acceptable alternative to CT in the prognostic evaluation of renal colic. The findings of our study are supported by a recent large multicenter study in which performing CT as the initial choice of imaging modality in patients with suspected nephrolithiasis did not lead to a decrease in complications from nephrolithiasis [11].

The current study is the first to investigate how bedside ureteral jets affect patient outcomes in patients with renal colic in the ED. Ureteral jets are present in normal patients occurring approximately every 2 to 45 seconds from each ureteral orifice, which can be visualized using power Doppler [18]. In complete ureteral obstruction, the ureteral jet is absent. A variety of findings have been reported with incomplete ureteral obstruction including a continuous or more frequent stream with asymmetry of jet velocity as well as some patients with a ureteral jet of normal volume and velocity [19]. In this study, ureteral jets do not appear to be useful in predicting urologic complications. In addition, ureteral jets were not obtainable in 9% of our cases. Ureteral jets have also been found to be of limited utility in another study [20].

The current study supports the idea that, in cases of renal colic, there is a low incidence of complications in patients without hydronephrosis, and CT is unlikely to change management. The study does not tell us when a patient with hydronephrosis should undergo CT. This should be at the discretion of the ED provider; however, an increasing severity of hydronephrosis appears to be associated with an increased incidence of subsequent complications and may help target patients who will benefit from emergent CT scan. Further investigations may help further elucidate which patients with renal colic truly require an ED CT scan.

Table 1
Demographics

	All (n = 77)	Hospitalization within 30 d		*P*
		Yes (n = 13)	No (n = 64)	
Age, median (IQR)	38 (27-49)	38 (29-53)	40 (27-49)	.96
Sex, (% female)	56%	69%	39%	.05
History of kidney stones, %	60%	62%	59%	.89
Hematuria, %	75%	92%	72%	.12
CT performed	74%	85%	72%	.34
Stone size ≥5 mm if CT was performed (n = 57)	41%	80%	26%	<.01

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Table 2
Patients with ureterolithiasis requiring hospitalization at initial ED visit or within 30 days

Case	Hydronephrosis	Ureteral jet	Stone size (mm)	Initial ED disposition	Outcome/interventions
18	Mild	ND	9	Discharged	Returned 2 d later for infected stone. Ureteral stent placed.
22	Mild	Normal	13	Admitted	Admitted for concern for infection. No urologic intervention done.
48	Moderate	Normal	8	Discharged	Discharged. Patient returned to the ED with prolonged pain. Ureteral stent placed.
51	Mild	Normal	–	Admitted	Staghhorn calculus. Patient admitted for percutaneous nephrostomy drain.
53	Moderate	Normal	9	Admitted	Patient febrile with presumed infected stone. Stent placed.
64	Moderate	Absent or diminished	9	Admitted	Patient admitted for stent placement.
68	Mild	Absent or diminished	9	Admitted	Admitted for concern for infection. Urine culture negative. No intervention.
71	Mild	Absent or diminished	9	Admitted	Admitted for concern for infection. No stent placed, urine culture without growth.
89	Mild	Normal	7	Admitted	Admitted for intractable pain. Ureteral stent placed.
107	Mild	Normal	–	Discharged	Discharged. Admitted later for ureteral stents.
109	Mild	Absent or diminished	3	Admitted	Admitted for intractable pain. Lithotripsy performed.
110	Moderate	ND	2	Admitted	Admitted for intractable pain. Stent placed.
111	Mild	ND	4	Admitted	Admitted for intractable pain and elevated creatinine.

Abbreviation: ND, nondiagnostic ureteral jets due to empty bladder.

4.1. Limitations

The current study enrolled a convenience sample of patients and may be subject to an inherent selection bias from convenience sampling. This was necessary, as patients could only be enrolled when research personnel were available. Misclassification bias may have occurred, as nephrolithiasis was not definitely proven in all cases but based on the ED provider's clinical gestalt. However, given that patients in real practice will often be dispositioned based on the ED provider's clinical judgement, the outcome data are meaningful and applicable to real-world practice instead of a diagnostically perfect theoretical one. Ultrasounds were performed by sonologists either pursuing or having completed a fellowship in emergency ultrasound, which may limit the generalizability of results. Four patients were lost to follow-up and may have had a subsequent need for hospitalization and/or urologic intervention, which could have affected the final results of the study. There were no patients with severe hydronephrosis in this study, also limiting its generalizability, although this degree of hydronephrosis is uncommon in the setting of acute renal colic. It was decided to evaluate for ureteral jets for up to 3 minutes based on the a priori pragmatical considerations of typical time constraints in a busy ED. Other studies evaluated ureteral jets for longer periods [19,21,22]. In one study of patients with unilateral obstructing kidney stone proven by CT, there was a difference found in ureteral jet frequency, duration, and peak velocity in the obstructed vs nonobstructed side; however, the ureteral jet evaluation lasted for 10 minutes and took place 15 to 30 minutes after subjects had been given 750 to 1000 mL of oral hydration [23]. These parameters would be difficult to perform in a busy ED but, if possible, may have affected our results. In contrast, data from at least one study evaluating patients with renal colic suggest that 3 minutes is enough time to reliably detect a ureteral jet in a nonobstructed ureter [19] and is supported by typical ureteral peristalsis rates in humans. We classified a ureteral jet as abnormal if it was either absent or diminished on the ipsilateral side of the suspected colic. It is possible that a subanalysis of absent vs diminished ureteral jets may have revealed some prognostic predictive value of one of these abnormal subtypes in isolation.

5. Conclusion

Renal colic patients without sonographic hydronephrosis have a low incidence of subsequent hospitalization. In addition, patients with moderate hydronephrosis had a higher 30 day admission and intervention rate than those with mild hydronephrosis. Bedside ureteral jet evaluation did not significantly contribute to prediction of patient outcomes. Information derived from bedside ultrasound may help the clinician determine which patients with renal colic will benefit from additional advanced imaging, and it may also help determine ultimate patient disposition.

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Table 3
Sensitivity, specificity, positive likelihood ratio, negative likelihood rate, and odds ratio for various findings on bedside ultrasound for predicting 30-day hospitalization in patients with renal colic

	Sensitivity	Specificity	+LR	−LR	OR
Any hydronephrosis	100% (75-100%)	44% (31-56%)	1.8 (1.4-2.2)	0	Infinite
Mild hydronephrosis	100% (66-100)	49% (36-63)	2.0 (1.5-2.5)	0	Infinite
Moderate hydronephrosis	31% (9-61%)	89% (79-96%)	2.8 (1.0-8.2)	0.8 (0.5-1.1)	3.6 (0.9-14)
Abnormal UJ	36% (11-69)	71% (58-82)	1.3 (0.5-3.0)	0.9 (0.6-1.4)	1.4 (0.4-5.2)
Stone ≥5 mm[a]	80% (44-98%)	74% (54-89%)	3.1 (1.5-6.3)	0.3 (0.1-1.0)	11.4 (2.1-59.1)
Any hydronephrosis + abnormal UJ	36% (11-69%)	81% (69-90%)	2.0 (0.8-5.0)	0.8 (0.5-1.2)	2.5 (0.7-9.6)
Moderate hydronephrosis + abnormal UJ	9% (0-41%)	95% (86-100%)	1.8 (0.2-15.7)	1.0 (0.8-1.2)	1.9 (0-14.9)

Abbreviations: +LR, positive likelihood ratio; −LR, negative likelihood rate; OR, odds ratio; UJ, ureteral jet.
[a] In the subgroup (n = 57) of patients who underwent CT scan.

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