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ULTRASONOGRAPHY BY EMERGENCY PHYSICIANS IN PATIENTS WITH SUSPECTED URETERAL COLIC

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□ **Abstract—We performed a prospective study of patients with suspected ureteral colic to evaluate the test characteristics of bedside renal ultrasonography (US) performed by emergency physicians (EPs) for detecting hydronephrosis, and to evaluate how US can be used to predict the likelihood of nephrolithiasis. Thirteen EPs performed US, recorded the presence of hydronephrosis, and made an assessment of the likelihood of nephrolithiasis. All patients underwent i.v. pyelography (IVP) or unenhanced helical computed tomography (CT). There were 126 patients in the study: 84 underwent IVP; 42 underwent helical CT. Test characteristics of bedside US for detecting hydronephrosis were: sensitivity 72%, specificity 73%, positive predictive value (PPV) 85%, negative predictive value (NPV) 54%, accuracy 72%. The PPV and NPV for the ability of the EP to predict nephrolithiasis after performing US were 86% and 75%, respectively. We conclude that bedside US performed by EPs may be used to detect hydronephrosis and help predict the presence of nephrolithiasis. © 1998 Elsevier Science Inc.**

□ **Keywords— emergency; bedside; ultrasonography; ureteral colic**

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INTRODUCTION

Ureteral colic is a common presenting problem in the emergency department (ED). The customary diagnostic procedure for these patients is i.v. pyelography (IVP), which has associated risks of allergic reaction and renal failure that limit its use in patients with contrast dye allergy, renal insufficiency, and diabetes mellitus (1). Furthermore, there is significant radiation exposure in pregnant women. IVP is expensive, may not be available in a timely fashion, and is time-consuming (usually 30–60 min in the radiology department). Formal renal ultrasonography (US) performed by a radiologist has been used to detect hydronephrosis (HNS) and renal calculi and is another diagnostic option. This technique is less sensitive for detecting ureteral calculi, and its use is also limited by cost and availability (2–4). The newer technique of unenhanced helical computed tomography (CT) has been shown to be accurate for detecting nephrolithiasis but is less accurate than IVP for detecting mild HNS (5–7). Although the initial reports of its use are optimistic, the technique has not been extensively studied, is also relatively expensive and time-consuming, and requires the expertise of a radiologist for interpretation. A recent study demonstrated that clinical judgment alone

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or urinalysis results were not sufficiently predictive of nephrolithiasis (8).

Recently, US has been performed by emergency physicians (EPs) with limited sonographic training to assist in the diagnosis of a wide variety of conditions. Its use has been studied in trauma patients to detect hemoperitoneum, in patients with penetrating chest trauma to detect pericardial tamponade, and in women with abdominal pain and vaginal bleeding to detect an intrauterine pregnancy (9–12). The advantage of using bedside emergency US in patients with suspected ureteral colic is that it can result in earlier diagnosis allowing more rapid administration of pain medication. Furthermore, in certain patients, it may obviate the need for IVP, which could significantly decrease cost and time spent in the ED. However, the use of emergency bedside renal US in patients with suspected ureteral colic has not been studied, and little is known about its accuracy in detecting HNS.

The present study had two objectives. The first was to evaluate the test characteristics of bedside renal US for detecting HNS shortly after the introduction of a US machine into the ED. The second objective was to evaluate how bedside renal US can be used by EPs to predict the likelihood of nephrolithiasis in patients with suspected ureteral colic.

MATERIALS AND METHODS

The study was performed at an urban university hospital with an ED that has over 66,000 annual patient visits, 3 months after the introduction of a US machine into the ED. The study was approved by the Institutional Review Board's Subcommittee on Human Studies. Oral consent was obtained after the protocol was briefly explained to the patients and before the administration of analgesia.

The emergency sonographers (ESs) were 13 full-time attending EPs in the Department of Emergency Medicine. To be able to enter patients into the study, the ES first had to complete an orientation course. This consisted of a 2-h didactic session and 3 h of hands-on, supervised training which included basic ultrasound principles, technical use of the equipment, probe positioning, and identification of the kidney, a normal collecting system, and hydronephrosis.

The patient population was a convenience sample of patients ≥18 years old who presented to the ED from September 11, 1995 to November 30, 1996 with a history of flank or abdominal pain. Patients were eligible if an IVP or an unenhanced helical CT scan was ordered to determine the presence or absence of nephrolithiasis. For the first 7 months of the study, IVP was the primary diagnostic study used by the radiology department to evaluate patients with suspected ureteral colic. Thereafter, unenhanced helical CT became the primary diagnostic modality used to evaluate these patients at our institution. The decision to order the IVP or CT scan was made by the attending EP based on the clinical history and physical examination. At our institution, almost all patients with suspected ureteral colic undergo a diagnostic study. Entry into the study was determined by the ES.

Once the patient was entered, the ES made an initial assessment of the likelihood that the patient had nephrolithiasis. This probability was estimated using an analogue scale that ranged from 0% to 100%. When making this assessment, the ES was aware of the patient's clinical presentation and urinalysis results. The ES then performed an examination of the kidney using an Aloka Echo Camera SSD-500 US machine and recorded whether or not hydronephrosis was present. This was based on dilatation of the collecting system. After performing the bedside renal US, the ES made a second assessment as to the likelihood of nephrolithiasis based on the US results. Patients then underwent either IVP or unenhanced helical CT scan. These imaging studies were interpreted by staff radiologists who were blinded to the results of the emergency US. Each patient had the following information recorded: age, sex, time of emergency US, time of definitive imaging study, the presence or absence of hematuria (>2 RBC/hpf), and the results of the IVP or helical CT scan. A random sample of eligible patients (matched by the type of formal imaging study) who were not enrolled in the study were compared with study patients to investigate possible selection bias caused by a non-consecutive study sample. Student's t test or χ^2 test was used to compare patient demographics and the incidence of nephrolithiasis, HNS, and hematuria in the two groups.

Based on the post-test likelihood of nephrolithiasis, patients were placed into three groups: Group I had a post-test probability of 0%–24%, Group II had a post-test probability of 25–74%, and Group III had a post-test probability of 75%–100%.

Chart review and telephone follow-up were performed in all study patients when the etiology of the abdominal or flank pain remained indeterminate at the time of discharge from the ED.

Test characteristics (sensitivity, specificity, positive predictive value, negative predictive value, accuracy) of emergency US to detect HNS were calculated. IVP was designated as the only gold standard for HNS because of its superior accuracy compared with helical CT. Test characteristics of the ES's prediction as to the likelihood of nephrolithiasis before formal imaging studies were also calculated. For this part of the study, IVP and helical CT were both considered to be gold standards.

Table 1. Operator Experience before the Start of the Study

Operator	Prior Experience (# of Abdominal Exams Performed)	Prior Training	Number of Patients Entered in Study
1	7	None	9
2	8	None	13
3	9	None	6
4	10	None	1
5	20	None	3
6	22	None	11
7	35	None	9
8	45	None	9
9	50	None	5
10	50	Course 1	11
11*	110	Course 1	19
12*	175	Course 2	23
13*	450	Course 2	7

* Denotes investigator.

RESULTS

During the study period, 500 patients underwent helical CT scan or IVP for suspected ureteral colic. Of these, 126 patients were entered into the study; 79 were male and 47 were female. The mean age was 44 years. Hematuria was present in 98 patients (78%). Eighty-four patients underwent IVP as the formal imaging study and 42 patients underwent unenhanced helical CT scan. Sixty-three patients (75%) had nephrolithiasis by IVP and 33 (79%) had nephrolithiasis by helical CT scan. One patient was excluded from further analysis because the kidney could not be visualized as the patient was obese. There was an average delay of 147 min (standard deviation of 70 min) between the emergency US and the IVP or helical CT scan. We compared the demographics (mean age, sex, time of presentation in the ED, and side of pain) and the incidence of ureteral colic, HNS, and hematuria between eligible patients entered into the study and a random sample of those not enrolled. There were no significant differences except for the incidence of hematuria and the percentage of patients who were cared for by one of the study investigators. The incidence of hematuria was 64% in the not-enrolled group and 78% in the enrolled group ($p = 0.02$). The percentage of patients evaluated by one of the primary investigators (CLR, REW, DFMB) was 39% in the enrolled group and 11% in the not-enrolled group ($p < 0.001$).

Thirteen emergency physicians were eligible to enter patients. Table 1 shows the characteristics of the ESs and includes investigator status, a personal estimate of the number of abdominal USs performed before the start of the study, prior training, and the number of examinations performed by each operator during the study. Prior additional training varied among ESs, some having taken courses such as the 2-day (21.25-h) course developed by the Society for Academic Emergency Medicine's (SAEM) Ultrasound Task Force and the Medical College of Wisconsin (Course 1) or the Advanced Health Education Center's 3-day (27-h) course (Course 2). Ten of the attendings had experience with 50 or fewer abdominal US examinations before the study. Only the three investigators, who entered 39% of the patients, had extensive previous experience with US (>100 examinations).

Table 2. Emergency Ultrasonography Results for Hydronephrosis

	IVP		
Emergency US	Positive	Negative	Total
Positive	41	7	48
Negative	16	19	35
Total	57	26	83

Table 2 shows the emergency US results for hydronephrosis for the 84 patients who had IVP as the formal imaging study. The test characteristics for the ability of emergency US to detect HNS, using IVP as the gold standard, were as follows: sensitivity 72% (95% C.I. 59–83%), specificity 73% (95% C.I. 52–88%), positive predictive value (PPV) 85% (95% C.I. 71–94%), negative predictive value (NPV) 54% (95% C.I. 37–71%), and accuracy 72% (95% C.I. 61–82%). We also looked at the influence of prior experience, as defined by the number of US exams performed by the ESs prior to the start of the study. Table 3 demonstrates how prior experience of the ES influenced the test characteristics of RUS for detecting HNS. Emergency physicians with previous experience performing 50 US examinations or fewer before the study had lower test characteristics for detecting HNS; however, this difference did not reach statistical significance. Table 4 shows a comparison of the test characteristics of emergency US for detecting

Table 3. A Comparison of the Test Characteristics of Emergency US for Detecting HNS Compared with IVP Results for ESs with Previous Experience ≤50 Examinations vs. ESs with >50 Examinations before the Study

		Prior Experience	
	Overall	ESs With ≤50 Examinations	ESs With >50 Examinations
Sensitivity	72	70	75
Specificity	73	65	89
PPV	85	81	93
NPV	54	50	62

$p > 0.05$ in all cases.

Table 4. Comparison of the Test Characteristics of Emergency Ultrasound for HNS When Pain Was on the Right Side vs. the Left Side

	Side	
	Left	Right
Sensitivity	60	81
Specificity	64	83
PPV	75	93
NPV	47	63

$p > 0.05$ in all cases.

HNS when the patient's pain was on the right side vs. the left side. Although the test characteristics were better if the pain was on the right, the difference was not statistically significant.

Table 5 shows the ESs' assessments of the probability of nephrolithiasis made after performing emergency US compared with the results of formal imaging studies. After emergency US was performed, 102 patients (82%) who eventually underwent IVP or CT scan were felt to have a likelihood of nephrolithiasis that was greater than or equal to 75%. Of these, nephrolithiasis was confirmed by IVP or CT scan in 88 cases. For patients with a high probability (≥75%) of nephrolithiasis after emergency US, the PPV for the ability of the ES to correctly predict the presence of nephrolithiasis was 86% (95% C.I. 78–92%). After US was performed, the probability of nephrolithiasis was less than 25% in eight patients; six of these patients did not have nephrolithiasis confirmed by IVP or CT scan. This yielded an NPV of 75% (95% C.I. 35–97%).

DISCUSSION

The present study is the first to describe the test characteristics of emergency US in the detection of HNS in patients with ureteral colic. It demonstrates that a positive bedside US for HNS may predict that HNS will be present on the IVP. This is a preliminary study that was performed 3 months after a new US machine was introduced into the ED. The sensitivity and specificity reported in this study are slightly lower than those reported in the radiology literature. In these studies, the reported sensitivity of US for HNS ranges from 87 to 98%, and the specificity ranges from 74% to 92% (13–15). However, in many of these studies, the experience and training of the operators and the entry criteria were not well-defined. Table 6 shows the sensitivities and specificities of the various diagnostic modalities for HNS and for nephrolithiasis.

Table 5. Likelihood Assessments of Nephrolithiasis Made by the Emergency Sonographers after Performing US Compared with Formal Imaging Studies

	Posterior Probability		
IVP or CT Scan	Low (<25%)	Moderate (25–74%)	High (≥75%)
Nephrolithiasis Present	2	5	88
Nephrolithiasis Absent	6	10	14

Patients with suspected ureteral colic may benefit significantly from the use of emergency bedside US. There is a potential for emergency bedside US to facilitate early treatment with analgesia and decrease the time spent in the ED by obviating the need for further studies in a subset of patients. The actual time it takes to perform an emergency renal US examination is 30 s to a few minutes. The other advantage to using bedside emergency US in patients with flank and abdominal pain is that it may be useful in excluding other life-threatening disorders such as abdominal aortic aneurysms.

There are several limitations to the study. We used a convenience sample since we could not ensure that all eligible patients would be entered, which raised the possibility of selection bias. Our comparison of the study population with a random sample of patients who were not enrolled demonstrated that patients who were enrolled did not have a significantly higher incidence of nephrolithiasis or HNS. In the study population, the percentage of patients treated by one of the principal investigators was significantly higher than in the group of patients not enrolled. The incidence of hematuria was also significantly higher in the study population. In addition, we did not compare the two groups for differences in weight, body habitus, or fasting status, which all affect the ease of the US examination.

Another limitation is the choice of "gold standards." Although IVP and helical CT do not have accuracies of 100% for detecting HNS or nephrolithiasis, in many institutions, these are the standard tests performed in the evaluation of patients with suspected ureteral colic. In consideration of this, the records of all study patients were reviewed to determine if a patient returned to the ED with continued symptoms and underwent another diagnostic test that revealed HNS or nephrolithiasis. This did not occur in any of the patients. We did not use helical CT as a gold standard for HNS since it is not as accurate for this purpose (5–7).

The results that we obtained are specific to the device used, which is relatively inexpensive and has limited resolution. The use of newer generation US machines with higher resolution should improve the accuracy of the test.

In this study, we did not account for the time delay

Table 6. Comparison of the Sensitivity and Specificity of the Various Diagnostic Modalities for HNS and Nephrolithiasis

Test	HNS		Nephrolithiasis	
	Sensitivity	Specificity	Sensitivity	Specificity
IVP	—	—	64–90%	94–100%
Helical CT	—	—	97%	96%
Formal US (interpreted by a radiologist)	87–98%	74–92%	64–95%*	100%
Bedside emergency US	72%	73%	—	—

From References 3, 7, 13–25, 22–24.
* The higher sensitivity is for renal calculi; US is less sensitive for ureteral calculi.

between the bedside US and the IVP or CT scan. The average delay was 147 min with a standard deviation of 70 min. This may have contributed to the low NPV and sensitivity of emergency US for detecting HNS. Patients with ureteral obstruction who did not yet have HNS at the time of the US could have developed HNS with i.v. fluid administration while awaiting IVP. It has been previously demonstrated that administration of i.v. fluids before US will increase the number of patients with ureteral obstruction who will have collecting system dilatation by US (16). Conversely, patients who had HNS by US could have passed the stone and decompressed the collecting system by the time of the IVP, which might help account for the high "false positive" rate of 27%.

A technical factor that we did not account for in our analysis that may have affected the results is the fact that the left kidney is more difficult to visualize. This occurs because of overlying bowel gas or air in the stomach that reflects sound waves, the more-superior location of the left kidney, and the absence of the liver to provide an acoustic window. In fact, the test characteristics were better when the right kidney was examined. However, these differences were not statistically significant. The ESs may not necessarily have compared US images of the affected side to the unaffected side. The sensitivity and specificity may have been higher if these factors had been addressed.

Another limitation is that interobserver variability among the different ESs could not be assessed because of the small sample size per ES. If there were significant interobserver variability, it could have biased the results of the study.

A final limitation is that the ESs had varying degrees of experience at the start of the study. Ten of the ESs had minimal experience ($\leq$50 examinations) before they started entering patients. Only three ESs had previous experience performing greater than 100 examinations. However, we feel that this distribution reflects the US experience of an academic department of emergency medicine starting to use US in the ED. The test characteristics of emergency US for detecting HNS were lower in the hands of ESs who had previous experience with 50 examinations or fewer. However, these differences did not reach statistical significance.

This study examines only the early phase of US in the ED and cannot predict changes in physician accuracy with increased use and experience. We anticipate that the accuracy will be significantly higher with increased experience. The influence of training also was not assessed. Learning curves documenting how many emergency US examinations should be performed before the operator achieves a reasonable accuracy have yet to be determined. Credentialing emergency physicians in ultrasound remains controversial. The American Institute of Ultrasonographic Medicine has defined this as "being involved with the evaluation and interpretation of at least 500 diagnostic examinations." (17) Realizing that few emergency physicians could hope to meet these criteria, the Ultrasound Task Force of the Society for Academic Emergency Medicine has suggested a more-realistic goal of a minimum of 50 abdominal examinations (18). However, these criteria are not evidence-based, and few data are available to determine actual test characteristics of emergency US as a function of training or experience. A number of studies assessing emergency US for detecting hemoperitoneum have shown promising results despite minimal training by emergency sonographers (10,19,20). The reliability of the study is almost certain to vary based on the type of examination performed. To be valid, criteria need to be established for each indication. For example, visualization of hemoperitoneum may be easily achievable with minimal training, yet assessment of hepatic ducts may be difficult without considerable training and experience.

In this study, we assessed the use of bedside US performed by EPs with minimal experience and training for detecting HNS and for predicting the presence of nephrolithiasis in patients with ureteral colic. This is a preliminary report. However, we found that even in the initial phase, this technique may be useful in the management of patients with ureteral colic. Future studies are needed to define a subgroup of patients with ureteral colic who will benefit most from bedside US. The accu-

racy of this technique when performed by operators with different levels of experience and with newer US machines with higher resolution also needs to be studied. Based on these results, a study investigating an algorithm using urinalysis and bedside US results is warranted. In the radiology literature, Svedstrom reported a sensitivity of 93% and a specificity of 79% for detecting nephrolithiasis using a clinical algorithm in which IVP was performed only if the US was negative. In this study, clinical follow-up was used as the "gold standard" (21). Similar studies are needed to assess the consequences of incorporating emergency US into a clinical pathway for patients with suspected ureteral colic. These may lead to a reduction in the cost of care by a decrease in the use of formal imaging studies and a decrease in the total time spent in the ED. Emergency US may also improve the quality of care and patient satisfaction by decreasing the time from presentation to the ED to institution of analgesia.

Despite the relative inexperience of the emergency sonographers (most of whom would not have met the SAEM criteria for credentialing), emergency renal ultrasonography performed by EPs may be helpful in detecting hydronephrosis and predicting the presence or absence of nephrolithiasis. Further studies incorporating this diagnostic tool into clinical pathways are needed to assess its role in the management of patients with suspected ureteral colic.

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