Effect of Provider Experience on Clinician-Performed Ultrasonography for Hydronephrosis in Patients With Suspected Renal Colic

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Study objective: Hydronephrosis is readily visible on ultrasonography and is a strong predictor of ureteral stones, but ultrasonography is a user-dependent technology and the test characteristics of clinician-performed ultrasonography for hydronephrosis are incompletely characterized, as is the effect of ultrasound fellowship training on predictive accuracy. We seek to determine the test characteristics of ultrasonography for detecting hydronephrosis when performed by clinicians with a wide range of experience under conditions of direct patient care.

Methods: This was a prospective study of patients presenting to an academic medical center emergency department with suspected renal colic. Before computed tomography (CT) results, an emergency clinician performed bedside ultrasonography, recording the presence and degree of hydronephrosis. CT data were abstracted from the dictated radiology report by an investigator blinded to the bedside ultrasonographic results. Test characteristics of bedside ultrasonography for hydronephrosis were calculated with the CT scan as the reference standard, with test characteristics compared by clinician experience stratified into 4 levels: attending physicians with emergency ultrasound fellowship training, attending physicians without emergency ultrasound fellowship training, ultrasound experienced non–attending physician clinicians (at least 2 weeks of ultrasound training), and ultrasound inexperienced non–attending physician clinicians (physician assistants, nurse practitioners, off-service rotators, and first-year emergency medicine residents with fewer than 2 weeks of ultrasound training).

Results: There were 670 interpretable bedside ultrasonographic tests performed by 144 unique clinicians, 80.9% of which were performed by clinicians directly involved in the care of the patient. On CT, 47.5% of all subjects had hydronephrosis and 47.0% had a ureteral stone. Among all clinicians, ultrasonography had a sensitivity of 72.6% (95% confidence interval [CI] 65.4% to 78.9%), specificity of 73.3% (95% CI 66.1% to 79.4%), positive likelihood ratio of 2.72 (95% CI 2.25 to 3.27), and negative likelihood ratio of 0.37 (95% CI 0.31 to 0.44) for hydronephrosis, using hydronephrosis on CT as the criterion standard. Among attending physicians with fellowship training, ultrasonography had sensitivity of 92.7% (95% CI 83.8% to 96.9%), positive likelihood ratio of 4.97 (95% CI 2.90 to 8.51), and negative likelihood ratio of 0.08 (95% CI 0.03 to 0.23).

Conclusion: Overall, ultrasonography performed by emergency clinicians was moderately sensitive and specific for detection of hydronephrosis as seen on CT in patients with suspected renal colic. However, presence or absence of hydronephrosis as determined by emergency physicians with fellowship training in ultrasonography yielded more definitive test results. For clinicians without fellowship training, there was no significant difference between groups in the predictive accuracy of the application according to experience level. [Ann Emerg Med. 2014;64:269-276.]

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INTRODUCTION

Complaints of flank or kidney pain account for more than 2 million annual emergency department (ED) visits in the United States, and current guidelines recommend computed tomography (CT) scanning as the initial diagnostic test for acute flank pain with suspicion of stone disease.[1,2] Although accurate for detection of kidney stones, CT scanning is expensive, exposes the patient to ionizing radiation, and has not been shown to substantially alter management for renal colic despite large increases in CT use during the last 2 decades.[1,3–5]

Editor's Capsule Summary

What is already known on this topic

Bedside ultrasound scan constitutes a safe alternative to computed tomography (CT) scanning for patients with suspected renal colic.

What question this study addressed

Six hundred seventy symptomatic patients were scanned by 144 practitioners, reflecting a wide range of training and experience. Presence or absence of hydronephrosis was compared with findings on noncontrast CT.

What this study adds to our knowledge

Ultrasonography was moderately accurate in confirming or excluding the diagnosis of renal colic. Scans performed by attending physicians with fellowship training in ultrasonography more definitively ruled in or ruled out renal colic than those performed by practitioners lacking such training.

How this is relevant to clinical practice

Emergency practitioner–performed bedside ultrasonography for renal colic may require ultrasound training beyond residency to achieve accuracy adequate to guide clinical decisionmaking.

Ultrasonography offers a safe imaging alternative for renal colic that has been shown to be accurate when performed by experienced users and is often a first-line test outside of the United States.[6–8] Point-of-care, clinician-performed ultrasonography provides a tool that may be used easily at the bedside and is increasingly available in the emergency department setting.[9]

However, ultrasonography is a user-dependent modality. Previous studies have shown that emergency physicians can accurately detect hydronephrosis, an indirect sign of ureteral obstruction. However, these studies have been criticized for including a predominance of studies performed by emergency physicians who are very experienced or motivated to perform bedside ultrasonography.[10–12] In 2 of these studies, the ultrasonography was in most cases performed by a separate investigator not directly involved in the care of the patient,[11,12] and the other study included a preponderance of subjects enrolled and cared for by study investigators.[10] This does not accurately represent actual practice, in which bedside ultrasonography is typically performed by the practitioner caring for the patient.

In terms of training, although the Accreditation Council on Graduate Medical Education lists ED bedside ultrasonography as one of 15 core procedural competencies to be obtained during emergency medicine residency, the test characteristics of emergency physicians at different levels of training, as well as other clinicians in the ED, have not been studied.[13] We sought to determine the test characteristics of clinician-performed ultrasonography to detect hydronephrosis when performed by emergency clinicians with a wide range of experience, using noncontrast CT as a reference standard, and to determine whether there was an association between formal ultrasound training and these test characteristics. We also sought to determine whether test characteristics differed according to whether the sonographer was directly involved in the care of the patient.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted between July 19, 2010, and November 1, 2012. The 2 study sites were the Yale–New Haven Hospital Emergency Department, an urban Level I trauma and teaching center with an annual ED census of greater than 80,000 adult patients, and the Shoreline Medical Center, a freestanding ED associated with Yale–New Haven Hospital. All emergency medicine attending physicians are board eligible or board certified through the American Board of Emergency Medicine. This study was approved by the Yale University Human Investigation Committee (part of Yale Institutional Review Board), and all patients enrolled provided written informed consent. This study was begun as an independent project but was folded into data collected as part of research funded by the Agency for Healthcare Research and Quality. The Agency for Healthcare Research and Quality study did not alter the eligibility for enrollment in the original study.

The Department of Emergency Medicine in the Yale School of Medicine has an active emergency ultrasound program, including an emergency ultrasound fellowship that has been in place for the last 10 years and residency training guidelines that meet or exceed American College of Emergency Physicians emergency ultrasound guidelines.[14] Although renal ultrasonography is an integral part of this training program, no additional training in it was provided as part of this protocol.

Selection of Participants and Methods of Measurement

During predefined shifts representing all hours of the week, consecutive ED patients aged 18 years and older for whom the clinician intended to obtain a CT scan for suspected renal colic were approached by a research assistant or investigator for enrollment. The research assistants circulated during their shifts to find patients and carried a dedicated pager that all clinicians were encouraged to call when considering a CT for renal colic. As a backup, a system was set up that generated an automated page whenever a CT scan for renal colic was ordered. Patients were excluded from enrollment if CT had already been performed and results were known, they had known renal disease (chronic kidney disease, renal transplant, polycystic kidney disease, etc), had undergone trauma, were non-English speaking, were incarcerated, or were otherwise unable or unwilling to consent. Consenting subjects for whom the ultrasonography was rated as uninterpretable or those who did not undergo CT after consent were excluded from analysis. Subjects could be enrolled more than once, with each ED visit considered a separate observation.

After written informed consent, an emergency clinician performed bedside ultrasonography with a curvilinear probe from any of 6 compact cart-based ultrasonographic machines: GE Logiq P5 Scanner (GE Inc, Milwaukee, WI), Philips HD11XE, EnVisor, or Sparq (Philips Medical, Andover, MA), Sonosite Turbo (Sonosite Inc, Bothell, WA), or Zonare z.one (Zonare Medical Systems Inc, Mountain View, CA). Dynamic images (cineloop clips) were obtained and recorded with the Digital Imaging and Communications in Medicine standard. Presence or absence of hydronephrosis was categorized as none observed, mild, moderate, or severe, as determined subjectively by the primary operator. No visual point of reference was included in the study packet and no specific training was offered in connection with participation in this study. Specifically, "moderate" hydronephrosis was a subjective determination. Standard teaching by Yale's Section of Emergency Ultrasound is that mild hydronephrosis is defined as dilatation of the renal pelvis, moderate hydronephrosis as dilatation of the renal pelvis and calyces, and severe hydronephrosis as ballooning of the calyces and ultimately thinning of the renal cortex. These interpretations were documented by one of the investigators or a research assistant before CT results, along with level of training of the primary operator at the time of the ultrasound. Similarly, the radiologist was blinded to the results of the bedside ultrasonography before interpreting the CT. The research assistants were present for the ultrasonography and specifically asked the clinician to categorize the presence and degree of hydronephrosis. If the kidney on the side of suspected symptoms could not be adequately visualized, the ultrasonography was noted as indeterminate and the encounter was excluded from the analysis.

Operators performing the ultrasonography were either the clinical emergency provider responsible for that patient or an emergency physician rotating on his or her ultrasound rotation in the ED. Clinicians who were caring for the patient directly were encouraged to perform the ultrasonography, although a separate clinician could perform it if the initial provider was not able to do it (typically because of time limitations from other patient care responsibilities). Whether the clinician performing the ultrasonography was directly involved in the care of the patient was noted.

The level of the clinician performing the ultrasonography was categorized as "attending physicians with fellowship training," "attending physicians without fellowship training," "ultrasound experienced non–attending physician clinicians," and "ultrasound inexperienced non–attending physician clinicians." Attending physicians with fellowship training (N=8) were attending emergency physicians who were currently participating in or who had completed a fellowship in emergency ultrasonography. Attending physicians without fellowship training (N=39) were attending emergency physicians who had completed residency and were board certified or board prepared in emergency medicine but had not completed an emergency ultrasound fellowship. Ultrasonographically experienced non–attending physician clinicians (N=47) were clinicians who had completed at least 2 weeks of an ultrasound rotation (including all post graduate year to 4 emergency medicine residents and post graduate year 1 residents who had finished the first half of their ultrasonographic rotation, which would typically include more than 50 total ultrasonographic tests and at least 8 hours of dynamic image review). Ultrasonographically inexperienced non–attending physician clinicians (N=50) were providers who typically had some basic ultrasonographic training but had not completed more than 2 weeks of an ultrasonographic rotation (physician assistants, nurse practitioners, and ultrasonographic rotators who had completed fewer than 2 weeks of their ultrasonographic rotation). The physician assistants and nurse practitioners were typically directly involved in the care of the patient and in most cases had participated in some basic workshops on bedside ultrasonography but had experience levels we judged to be similar to that of the novice rotators. None of the operators were ultrasonographic technicians. If an operator progressed to a different level during the term of the study (typically residents or rotators completing more than 2 weeks of the rotation, or residents graduating and staying as attending physicians), the level when the ultrasonography was performed was used.

The data collected included basic patient demographics, patient history, physical examination findings, and laboratory testing, along with the bedside ultrasound findings. This was initially recorded on a paper data sheet and entered into a database, although as the study evolved data were collected on a tablet computer that was linked directly to a centralized database (Filemaker Pro; Filemaker Inc., Santa Clara, CA).

CT data about the presence and degree of hydronephrosis, as well as the presence, size, and location of ureteral stones, were abstracted from the dictated radiology report by an investigator blinded to the bedside ultrasonographic results. Hydronephrosis was considered to be present if any dilatation of the renal collecting system was noted in the dictated CT report, with the exception of isolated hydroureter. Ureterolithiasis was considered present if a stone was identified from the renal pelvis to the ureterovesical junction. Parenchymal or bladder stones were noted but not included in the analysis. Data abstraction of CT results adhered to the methods described by Gilbert et al[15] and included research assistants specifically trained in chart abstraction, a detailed manual and practice chart abstractions, discrete definitions of variables, and standardized abstraction forms. To determine interrater reliability of presence of hydronephrosis on CT scan, one of the primary authors (SL) blindly re-extracted data from 50 randomly selected CT scans and compared this with data extracted by the research assistants.

Primary Data Analysis

Sensitivity, specificity, and positive and negative likelihood ratios of bedside ultrasonography for hydronephrosis (dichotomized as present or absent) were calculated, using the presence of hydronephrosis and the presence of ureteral stone as mentioned in the CT scan report as the reference standard. Sensitivity and specificity of any hydronephrosis on ultrasonography and moderate hydronephrosis on ultrasonography for hydronephrosis on CT were estimated, with confidence intervals (CIs) assessed with a logistic regression model accounting for clustering by operator. Transformations were made by following the methods of Coughlin et al.[16] Clustered data were analyzed with Stata (version 13.1; StataCorp, College Station, TX). The operators performing the ultrasonography were categorized into 4 subgroups: attending physicians with fellowship training, attending physicians without fellowship training, ultrasonographically experienced non–attending physician clinicians, and ultrasonographically inexperienced non–attending physician clinicians, as described above.

A post hoc analysis was performed to detect any significant differences in test characteristics according to whether the clinician performing the ultrasonography was directly involved in the care of the patient. A sensitivity analysis was performed to determine the effect of any indeterminate scans on test characteristics. Interobserver reliability of CT data extraction is expressed as a κ with 95% CI. Data were analyzed with JMP 8 (SAS Institute, Inc., Cary, NC), R (http://www.r-project.org), and vassarstats.com.

RESULTS

From July 2010 to November 2012, there were 679 ED visits by 672 unique subjects who were enrolled and underwent both CT and clinician-performed ultrasonography before CT results, of which 670 ultrasonographic results were interpretable for presence or absence and degree of hydronephrosis. Subjects had an average age of 46 years, 51.5% were women, and ureteral stone was described as present in 47.0% of CT reports (Table 1). Hydronephrosis was described as present in 47.4% of CTs, nearly the same as the prevalence of ureteral stone; however, ureteral stone without hydronephrosis was noted in 5.5% of CTs and hydronephrosis without ureteral stone was noted in 6.0% of CTs. κ For interobserver agreement on presence of hydronephrosis on CT was 0.87 (95% CI 0.73 to 1.00), indicating excellent agreement. There were 144 unique sonographers, with each one performing a median of 4 ultrasonographic tests (interquartile range 5). Of the 679 ED visits, clinician-performed ultrasonography was performed by a clinician directly involved in the patient's care in 542 of the visits (80.9%) (Table 2). Hydronephrosis was described as present on clinician-performed ultrasonography in 48.5% of subjects and was rated as moderate or greater in 36.3% of subjects when hydronephrosis was present (17.6% of all subjects). The prevalence of hydronephrosis and ureteral stone was not significantly different between sonographer groups.

Table 1. Patient demographics and prevalence of CT findings in the study cohort.

Demographics and Prevalences	No. (%) Unless Otherwise Specified (Total n=670)
Age, y (SD)	46.0 (14.8)
Female sex	345 (51.5)
Race	
White	538 (80.3)
Black	101 (15.1)
Other	31 (4.6)
Ethnicity	
Hispanic	134 (19.9)
Non-Hispanic	545 (80.1)
Ureteral stone present on CT	315 (47.0)
Ureteral stone without hydronephrosis on CT	37 (5.5)
Hydronephrosis present on CT	318 (47.4)
Hydronephrosis without ureteral stone on CT	40 (6.0)

A diagram of test characteristics of any hydronephrosis on ultrasonography compared with any hydronephrosis on CT, using the Standards for Reporting of Diagnostic Accuracy (STARD) format,[17] is shown in Figure 1. The detailed results of each study (true positives, false positives, true negatives, and false negatives) by each sonographer stratified by the group are available in Figure 2.

Overall, hydronephrosis detected on clinician-performed ultrasonography was 72.6% sensitive and 73.3% specific, with a positive likelihood ratio of 2.72 (95% CI 2.25 to 3.27) and a negative likelihood ratio of 0.373 (95% CI 0.31 to 0.44), using hydronephrosis on CT as the criterion standard (Table 3). There was no significant difference in test characteristics between attending physicians without fellowship training, ultrasonographically experienced clinicians, and ultrasonographically inexperienced clinicians. Attending physicians with fellowship training when compared with all other users had significantly better sensitivity, 92.7% (95% CI 83.8%

Table 2. Breakdown of clinicians performing bedside sonography, along with whether they were directly involved in care of the patient.

Operators	Examinations Performed (%)	Examinations by Provider Directly Involved in Patient Care (%)
All operators	670 (100)	542 (80.9)
Attending physicians with fellowship training	114 (17)	79 (69.3)
Attending physicians without fellowship training	182 (27.2)	180 (98.9)
Ultrasonographically experienced non–attending physician clinicians	217 (32.4)	156 (71.9)
Ultrasonographically inexperienced non–attending physician clinicians	157 (23.4)	127 (80.9)

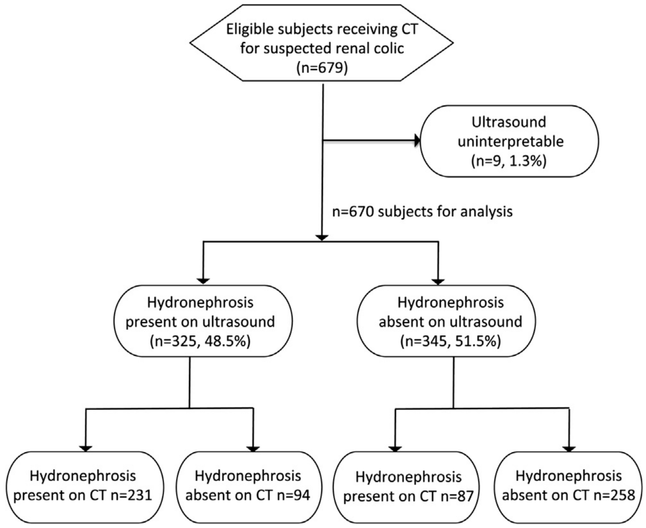

Figure 1. Enrollment using the Standards for Reporting of Diagnostic Accuracy,[17] comparing any hydronephrosis on ultrasonography with any hydronephrosis on CT scan.

to 96.9%) versus 68.4% (95% CI 59.1% to 76.5%), with positive likelihood ratio 4.97 (95% CI 2.90 to 8.51) versus 2.42 (95% CI 1.98 to 2.95) and negative likelihood ratio 0.08 (95% CI 0.03 to 0.23) versus 0.44 (95% CI 0.37 to 0.53), respectively. When moderate or greater hydronephrosis was considered positive, the overall specificity of clinician-performed ultrasonography for hydronephrosis observed on CT was 94.6%, but sensitivity decreased to 31.3% and was not significantly different between operator groups. The test characteristics for providers who were directly involved in the care of the patients are included in Table 3. There was no statistically significant difference in test characteristics between ultrasonography performed by providers directly involved in the care of the patient and those not directly involved.

Test characteristics for the presence of hydronephrosis detected on clinician-performed ultrasonography were similar (not significantly different) when ureterolithiasis on CT was used as the criterion standard. For nonfellowship-trained clinicians, hydronephrosis on ultrasonography compared with ureterolithiasis on CT yielded sensitivity of 67.4% (61.3% to 73.0%), specificity of 70.9% (65.3% to 76.0%), positive likelihood ratio 2.32 (1.90 to 2.82), and negative likelihood ratio 0.46 (0.35 to 0.50), whereas for fellowship-trained clinicians sensitivity was 92.2% (80.4% to 97.1%), specificity 76.2% (52.7% to 90.2%), positive likelihood ratio 3.87 (2.47 to 6.06), and negative likelihood ratio 0.10 (0.03 to 0.26). Moderate hydronephrosis (as determined by any user) compared with ureteral stone on CT yielded specificity of 91.3% (86.2% to 94.6%) and positive likelihood ratio 3.16 (2.16 to 4.63).

There were 9 scans (1.3%) rated as indeterminate for the presence or absence of hydronephrosis, and a sensitivity analysis of the potential contribution of these scans did not substantially alter the results.

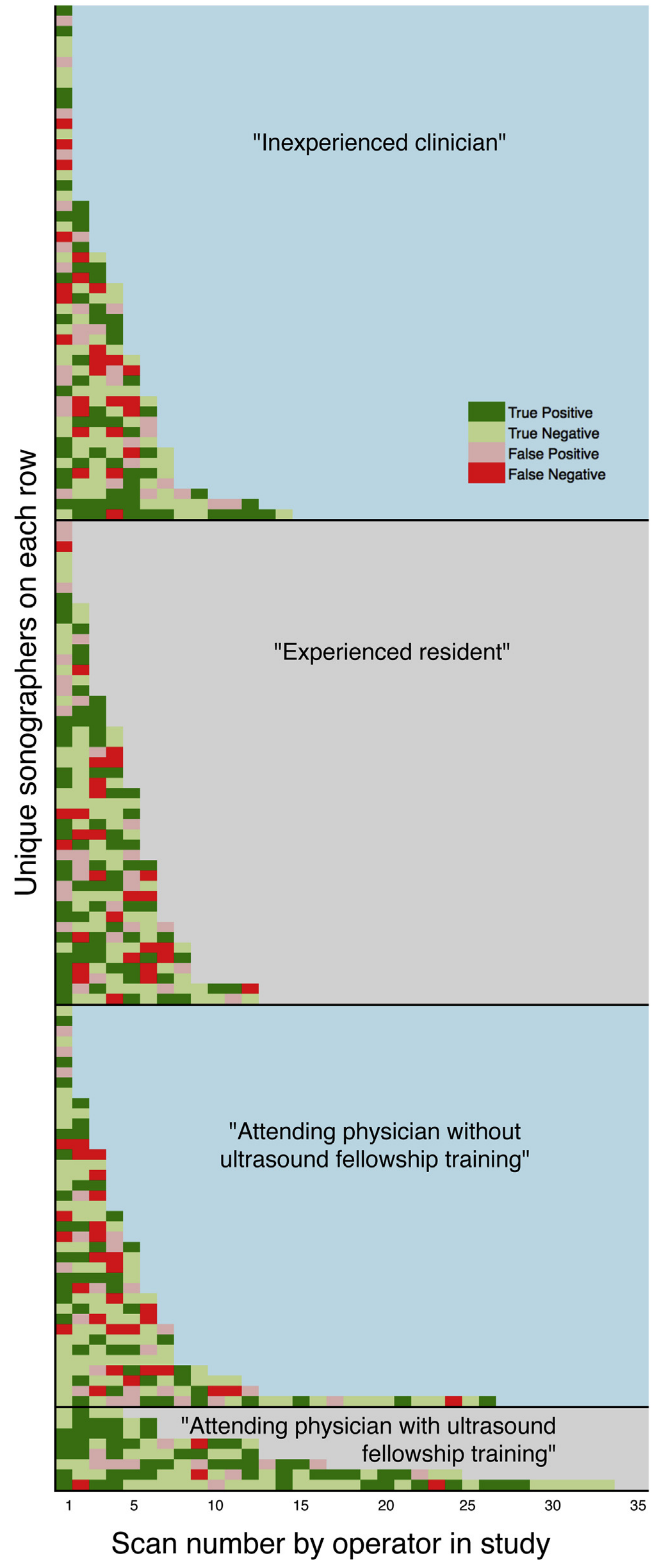

Figure 2. Results of each ultrasonographic test performed (presence of any hydronephrosis on ultrasonography compared with any hydronephrosis on CT), shown with each sonographer representing a row, stratified by group. For this figure, sonographers were placed in the group in which they started the study (because a small number moved to different groups during the study).

Table 3. Sensitivity and specificity (with 95% CIs estimated by using results clustered by operators), and likelihood ratios, with 95% CIs for the presence of hydronephrosis: all hydronephrosis and moderate or greater hydronephrosis compared with any hydronephrosis on CT.*

Test and Reference Standard	Sensitivity (95% CI), %	Specificity (95%CI), %	Positive Likelihood Ratio (95% CI)
Hydronephrosis on ultrasonography vs hydronephrosis on CT			
All	72.6 (65.4–78.9)	73.3 (66.1–79.4)	2.72 (2.25–3.27)
Attending physician with fellowship training	92.7 (83.8–96.9)	81.4 (63.8–91.5)	4.97 (2.90–8.51)
Attending physician	61.5 (40.5–79.0)	77.9 (59.9–89.2)	2.78 (1.86–4.15)
Experienced resident	70.4 (59.3–79.5)	70.6 (59.6–79.7)	2.39 (1.74–3.28)
Inexperienced clinician	72.7 (54.4–85.7)	65.0 (45.3–80.6)	2.07 (1.49–2.88)
Moderate hydronephrosis on ultrasonography vs any hydronephrosis on CT			
All	31.3 (19.3–46.1)	94.6 (90.3–97.1)	5.76 (3.61–9.19)
Attending physician with fellowship training	38.2 (4.9–88.2)	98.3 (82.8–99.9)	22.52 (3.13–161.8)
Attending physician	23.1 (7.2–53.7)	97.1 (89.7–99.2)	8 (2.44–26.2)
Experienced resident	37.0 (19.6–58.7)	90.8 (80.4–96.0)	4.03 (2.12–7.65)
Inexperienced clinician	26.0 (10.4–51.6)	93.8 (83.2–97.9)	4.15 (1.64–10.51)
Hydronephrosis on ultrasonography vs hydronephrosis on CT: clinician directly involved in care of the patient			
All	72.3 (61.8–80.8)	73.9 (63.8–82.1)	2.78 (2.25–3.42)
Attending physician with fellowship training	95.2 (85.8–98.5)	86.8 (66.5–95.6)	7.24 (3.19–16.4)
Attending physician	61.0 (39.9–78.7)	77.7 (59.5–89.2)	2.73 (1.83–4.09)
Experienced resident	70.4 (57.3–80.8)	70.7 (57.7–81.0)	2.40 (1.64–3.50)
Inexperienced clinician	73.3 (51.0–87.9)	64.7 (41.0–82.9)	2.08 (1.46–2.97)

*Test characteristics of studies conducted by sonographers directly involved in the care of the patient are also shown.

LIMITATIONS

There were several limitations to this study. First, bedside ultrasonography was not always performed contemporaneously with CT. A delay of greater than 1 hour from order entry to the actual CT scan was not uncommon and potentially allowed the opportunity for hydronephrosis to develop with time and hydration, or alternatively for the patient to pass the stone and for hydronephrosis to resolve. Fourteen CT reports stated "signs of passed stone," 2 of which were interpreted as the patient's having had hydronephrosis hours earlier on bedside ultrasonography, with no significant hydronephrosis on the subsequent CT, and 2 with moderate hydronephrosis observed on bedside ultrasonography and mild hydronephrosis on the subsequent CT, showing likely stone passage.

Noncontrast CT was the reference standard for this study, but its sensitivity and specificity for hydronephrosis and ureterolithiasis are not 100%. Noncontrast CT has been shown to have a sensitivity of 83% and specificity of 94% for collecting system dilatation in the presence of ureteral stone when patients were followed and the diagnosis was confirmed with excretory urography, retrograde or antegrade pyelography, stone movement or passage seen on serial radiographs, sonography, contrast-enhanced CT, and follow-up unenhanced CT.[18]

Finally, this study was conducted at a single academic medical center with a strong emphasis on bedside ultrasonography. Determination of any and of moderate hydronephrosis was subjective and may differ between institutions or users. Although training in bedside ultrasonography is now an Accreditation Council on Graduate Medical Education mandate and is included to some degree at all academic centers, there is variation in the extent of these programs and these results may not be generalizable to academic or community centers with less developed bedside ultrasonographic programs.

DISCUSSION

Our data show that in an actual situation (in which most bedside ultrasonography is performed by clinicians taking care of the patient), emergency clinicians overall had moderate sensitivity (72.6%) and specificity (76.9%) for detecting hydronephrosis as seen on CT. Although using a cutoff of moderate hydronephrosis improved specificity among all users (to 94.6%), data for attending physicians with fellowship training in ultrasonography were much more sensitive (92.7%) for the presence of hydronephrosis. To our knowledge, this is the largest study on this topic, the most realistic, and the only study to demonstrate the effect of fellowship training in ultrasonography on diagnostic performance.

Our results about overall sensitivity and specificity are comparable to those of one of the first studies in this area, which was published in 1998 and found a sensitivity of 72% and specificity of 73% for hydronephrosis on ultrasonography compared with CT.[10] More recent articles have shown higher sensitivities and specificities, likely because ultrasonography is being performed by a small group of experienced and motivated clinicians. A 2007 study of 57 patients compared emergency physician ultrasonographic findings to CT and found a sensitivity of 80%, specificity of 83%, and accuracy of 81% of ultrasonography for hydronephrosis.[19] The study authors performed 60% of the ultrasonography, whereas 12 other emergency physicians performed the remainder. A 2005 study enrolled 104 subjects with suspected renal colic and found a bedside ultrasonography sensitivity and specificity of 86.8% and 82.4%, respectively, for hydronephrosis on CT.[12] There were a total of 6 emergency physician operators performing ultrasonography, and more than two thirds had extensive ultrasonographic experience. In 2008, Moak et al[20] looked at 107 patients with flank pain and found the presence of hydronephrosis on emergency ultrasonography to have a sensitivity and specificity for the presence of kidney stone on CT of 76.3% and 78.3%, respectively, which was comparable to but slightly higher than our overall sensitivity (71.4%) and specificity (71.8%) of hydronephrosis for ureteral stone. Although ultrasonography was interpreted by one of 24 emergency physicians credentialed (more than 25 renal scans conducted) in performing and interpreting renal ultrasonography, the numbers interpreted by each physician were not reported, and nearly half (43%) of subjects enrolled had the primary investigator (an ultrasonographic fellowship–trained emergency physician) as the attending physician. The present study differs from previous similar studies by observing a large number of emergency clinicians with varied experience in standard practice.

In grouping clinicians by experience to compare test characteristics, we used broad categorizations based on level of training that may have included individual practitioners with substantial variation in experience. Previous guidelines have often focused on numbers of ultrasonographic tests performed, which was not available for all practitioners and would have been difficult to analyze because it changed during the study. However, numbers alone have been criticized as an imperfect measure of competency, and we believed that these levels of training represented actual practice. Previous studies have also typically included a large proportion of subjects undergoing ultrasonography by a clinician not directly involved in the care of the patient, or a disproportionate number of subjects enrolled by study investigators.[10–12] Although our study included about 80% of ultrasonographic studies conducted by the clinicians directly involved in the care of the patient, this appeared to have had minimal influence on test performance (Table 2).

To our knowledge, this is the first study to demonstrate a statistically significant difference in test characteristics of hydronephrosis as determined by attending physicians with fellowship training in emergency ultrasonography. Although this study does not delineate the point (in terms of quantity of experience or number of scans) at which improved test characteristics occur, it does show improvement with concentrated training devoted to emergency ultrasonography. The user dependence of ultrasonography includes skill in obtaining quality images and in interpreting them. This study did not attempt to discern which of these factors had the greatest effect on test characteristics, though it is likely that increased experience in clinician-performed ultrasonography affects both areas.

Bedside ultrasonography has the advantage of being a noninvasive test without ionizing radiation that can be performed rapidly at the bedside. However, our results show that bedside ultrasonography alone for the presence of hydronephrosis, performed by physicians without fellowship training, adds only modestly to diagnostic certainty. This suggests that bedside ultrasonography (particularly when performed by clinicians without fellowship training in ultrasonography on a patient deemed to have only moderate prevalence of disease) may not bring the clinician to an acceptable diagnostic certainty to treat the patient. For example, if you begin with a "typical" patient for whom you are considering a CT, the prevalence of ureteral stone was about 50% in our population. A clinician without ultrasonographic fellowship training would thus have a postultrasonographic probability of hydronephrosis of 70% if hydronephrosis were observed and 32% if hydronephrosis were not observed, and this may not obviate the need for further testing (Table 4).[21] However, the absence of hydronephrosis as determined by a fellowship-trained attending physician would yield a posttest probability of 7% for hydronephrosis and 9% for ureteral stone, which may be below the threshold at which the clinician (or the patient) believes that further testing is needed.

Table 4. Influence of ultrasonographic results by provider level on posttest probability of hydronephrosis or ureteral stone, given a pretest probability of 50% (actual prevalence in our population: hydronephrosis 47.4%, ureteral stone 47.0%).[21]

	Posttest Probabilities (95% CI)	
Test and Result	**Hydronephrosis**	**Ureteral Stone**
No hydronephrosis present by ultrasonographic fellowship–trained provider	7 (3–19)	9 (4–21)
No hydronephrosis present by non–ultrasonographic fellowship–trained provider	31 (27–35)	32 (28–35)
Any hydronephrosis present by ultrasonographic fellowship–trained provider	83 (74–89)	80 (71–86)
Any hydronephrosis present by non–ultrasonographic fellowship–trained provider	71 (66–75)	70 (66–74)
Moderate hydronephrosis present by any user	85 (78–90)	76 (68–82)

The value of a test depends on the test characteristics, pretest probability of disease (or prevalence), and threshold for further testing or treatment.[21] This value then needs to be weighed against the "cost" of the test (in this case, clinician time to conduct the ultrasonography, investment in training, equipment, etc). Although ultrasonography alone (particularly if determined by a nonfellowship-trained clinician) may not represent a definitive test, it is possible that it can be combined with other elements of the history, examination, or point-of-care testing. For example, when a kidney stone is suspected, a point-of-care (or laboratory) urinalysis is often performed. Microscopic hematuria is reasonably sensitive (in our population, about 88%, similar to that of previous studies) for ureteral stone, but poorly specific (about 40% in our study), yielding a positive likelihood ratio of about 1.5 and a negative likelihood ratio of about 0.3. Hematuria alone thus does not yield any better results than ultrasonography alone by a nonfellowship-trained clinician; however, a patient starting with a prevalence of stone of 50% with both hematuria and hydronephrosis on ultrasonography has an 80% likelihood of stone, whereas one without either hydronephrosis or hematuria has a probability of stone of about 10%, assuming the tests are independent. Future work will focus on whether or how it is worthwhile to incorporate point-of-care renal ultrasonography along with other factors from the patient's history, physical examination, and point-of-care urine testing to potentially help arrive at a threshold at which further testing that involves more cost and potential harm (such as CT) may be avoided.

In summary, detection of hydronephrosis with bedside ultrasonography performed by clinicians of varied experience displays moderate diagnostic value in predicting hydronephrosis identified by CT, which correlates with ureteral stone. However, presence or absence of hydronephrosis as determined by emergency physicians with fellowship training in ultrasonography yielded more definitive test results.

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