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ORIGINAL RESEARCH

EMA

Validation of emergency physician ultrasound in diagnosing hydronephrosis in ureteric colic

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Abstract

Objective: Patients presenting to the ED with obstructive nephropathies benefit from early detection of hydronephrosis. Out of hours radiological imaging is expensive and disruptive to arrange. Emergency physician ultrasound (EPU) could allow rapid diagnosis and disposition. If accurate it might avert the need for formal radiological imaging, exclude an obstruction and improve patient flow through the ED.

Methods: This was a prospective study of a convenience sample of all adult non-pregnant patients with presumed ureteric colic attending the ED with prior ethics committee approval. An emergency physician or registrar performed a focused ultrasound scan and were blinded to the patient's other management. A computerized tomography scan was also performed for all patients while in the ED or within 24 h of the EPU. The accuracy of EPU detection of hydronephrosis was determined; using computerized tomography scans reported by a senior radiologist as the 'gold-standard'.

Results: Sixty-three patients with suspected ureteric colic were enrolled of whom 57 completed both EPU and computerized tomography imaging. Forty-nine had confirmed nephrolithiasis by computerized tomography with 39 having evidence of hydronephrosis. Overall prevalence of hydronephrosis was 68% (95% confidence interval [CI] 56–79%); compared with computerized tomography, EPU had a sensitivity of 80% (95% CI 65–89%); specificity of 83% (95% CI 61–94%); positive predictive value of 91% (95% CI 75–98%) and negative predictive value of 65% (95% CI 43–83%). The overall accuracy was 81% (95% CI 69–89%).

Conclusion: Although the accuracy of detection of hydronephrosis after focused training in EPU is encouraging, further experience and training might improve the accuracy of EPU and allow its use as a screening tool.

Key words: *computerized tomography*, *emergency physician*, *hydronephrosis*, *renal colic*, *ultrasound*.

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Introduction

Patients presenting to the ED with an obstructive nephropathy benefit from early detection and treatment, particularly in the context of associated renal tract infection or renal failure. Complete ureteric obstruction might lead to loss of renal function, with an increased occurrence of irreversible damage after 1–2 weeks.[1] Conventional modalities available for detecting renal tract obstruction include formal ultrasound (US) and computerized tomography (CT). However, both CT and formal US require patient transfer and monitoring in areas remote to the ED, and generally have limited availability out of hours.

The detection of hydronephrosis by bedside US in the ED could allow a more rapid diagnosis and disposition of patients and be used in situations where iodizing radiation or intravenous contrast material are contraindicated and/or formal US is not available. Rapid ED screening for hydronephrosis might exclude obstruction and focus assessment on other potential diagnoses and might allow the selection of patients for further studies to be refined.

An estimated 2–5% of the population will form a symptomatic renal calculus at some point in their lives.[1] Clinical history and microscopic haematuria suggest the diagnosis with a sensitivity of 69–89%.[2–4] CT has proved a more accurate test than US with greater sensitivity for hydronephrosis and calculus detection,[5–10] With intravenous contrast it can give the same information on renal function as IVU[1,2,5,6,8,9,11] but also carries the same risks of radiation exposure, allergy and nephrotoxicity.[7] The advantages of CT have made US a second choice investigation because of its relatively low sensitivity of 19% (specificity of 97%) for detecting calculi compared with sensitivity of 94–97% (specificity of 96–97%) for CT.[6,8] However, patients with ureteric stones have a relatively high prevalence of partial and/or temporary renal tract obstruction, but seldom cause complete obstruction.[1] Because of this high prevalence, this population provides a convenient group in whom to explore options for diagnosing obstruction and these patients will require definitive renal tract imaging as part of their usual management.

The use of emergency physician US (EPU) for traumatic intraperitoneal and pericardial fluid and abdominal aortic aneurysm detection has been increasing in Australasian ED with accreditation processes that follow the Australasian College of Emergency Medicine (ACEM) guidelines.[12–14] Internationally EPU has expanded into areas of ED practice such as intravenous access, lower limb deep venous thrombosis, and fluid localization for either diagnosis or drainage.[12–14] The role of EPU in assessing renal tract obstruction remains somewhat controversial with various studies showing a wide range of accuracy.[2,15–17]

We postulated that EPU might be safe and accurate, and could be used to screen patients for hydronephrosis due to ureteric calculi.

Aim

The aim of the present study was to determine the accuracy of EPU in detection of hydronephrosis compared with radiologist-reported non-contrast CT.

Methods

Study design and setting

This was a prospective study of a convenience sample of patients with presumed ureteric colic, undertaken in the ED of a tertiary teaching hospital with an annual census of 46 000. The study had Area Ethics committee approval.

Study population and protocol

All non-pregnant patients over 18 years old who attended the ED with a clinical diagnosis of ureteric colic as determined by the treating ED medical officer were eligible for enrolment. Written informed consent was obtained from all patients. Foreign language interpreters were utilized when required.

Emergency registrars and emergency physicians (EP) who had attended an ACEM-accredited US workshop and undertaken a further 1 h of training in basic renal US by a senior radiologist were able to enrol patients in the study. Recruited patients underwent EPU by the enrolling doctor during their ED stay. The doctor performing the EPU was not involved in the treatment of the patient and was blinded to the CT scan result. A non-contrast CT scan of the renal tract also was performed on each patient, either while they were in the ED or organized externally at a single designated private radiology suite within 24 h of EPU. One senior radiologist blinded to the EPU result reported the CT scans.

Measurements

Using a Toshiba US machine Model: SSA-550A (Tochigi-Ken, Japan) and a 3.5–5 MHz curved array

probe on abdominal preset, investigators obtained and recorded images and measurements of both kidneys (diameters of each renal pelvis and of each kidney's longitudinal and transverse sections). Images were saved digitally and printed. Investigators completed a reporting form that included demographic data, the location of symptoms, the presence or absence of hydronephrosis for each kidney and the severity of hydronephrosis (mild, moderate or severe) if present. An US diagnosis of hydronephrosis was made based on the features listed in Table 1. Bladder size was estimated and documented (as empty, half or full).

CT images were performed on a four-slice Toshiba Aquilion (TSX-101A) scanner or a 16-slice Toshiba Aquilion scanner. Information recorded by the radiologist included the presence or absence of hydronephrosis and its severity, the presence of calculus and incidental findings.

Data analysis

The accuracy of the EPU was determined by calculating the sensitivity, specificity, positive (PPV) and negative predictive values (NPV) with 95% confidence intervals (CI), using the CT scan report as the reference standard. Assuming a rate of hydronephrosis of 75% in patients with renal colic,[19] we estimated approximately 50 patients would be required to detect a sensitivity of 90% with 95% CI of ±10%.

Microsoft Excel 2004 for Mac, version 11.2 and Vassarstats Statistical Computation website (http://faculty.vassar.edu/lowry/VassarStats.html) were used for analysis.

Results

Sixty-three patients were enrolled in the study. Six patients did not complete the study because CT scans were not performed or were not available for analysis. Of the remaining 57, there were 48 men (84%) and 9 women (16%). In the present study 34 (54%) patients presented with left-sided symptoms and 29 (46%) presented with right-sided symptoms. The mean age was 43.7 years (range 18–67). Two patients presented more than once during the study period and each presentation was recorded separately.

Of the 57 patients, 48 had CT-confirmed diagnosis of nephrolithiasis and 39 had CT-confirmed hydronephrosis. Nine patients had negative CT scans for nephrolithiasis and hydronephrosis. The prevalence of hydronephrosis in the study population was 39/57 or 68% (CI 56–79%).

Thirty-one of 39 patients with CT-proved hydronephrosis had positive EPU scans. The main results are summarized in Table 2. EPU demonstrated sensitivity of 80% (CI 65–89%) and specificity of 83% (CI 61–94%), a PPV of 91% (CI 75–98%) and an NPV of 65% (CI 43–83%). Overall accuracy of EPU for the detection of hydronephrosis was 81% (CI 69–89%).

The study authors performed 60% of the scans, 12 other EP or trainees (registrars) performed the remainder.

Discussion

The present study found that with minimal training, EP and trainees were able to achieve a sensitivity of 80% and a specificity of 83% for the diagnosis of hydronephrosis using bedside US in the setting of suspected acute renal colic.

Emergency physician US has potential advantages in the diagnosis of hydronephrosis. It can be performed at the bedside using a portable machine, is immediately available and repeatable 24 h a day, 7 days a week. Patients do not leave the department to go to potentially less monitored areas, which obviates the need for portable monitoring and/or nurse escort. EP have been

Table 2. Comparison of emergency physician US (EPU) and CT in detection of hydronephrosis

	CT – positive	CT – negative
EPU – positive	31	3
EPU – negative	8	15

Table 1. Grades of hydronephrosis

Grade I	Grade II – mild	Grade III – moderate	Grade IV – severe
Slight blunting of calyceal fornices	Obvious blunting of calyceal fornices and enlargement of calices, but intruding shadows of papillae are easily seen	Rounding of calices with obliteration of papillae	Extreme calyceal ballooning

Adapted from the study by Grainger and Allison.[18]

using bedside US in the ED over recent years and in Australia have training and accreditation procedures for its use in other conditions.[12–14]

In the present study we investigated the ability of EP, with 1 h of focused training in renal US in addition to an ACEM-accredited US workshop, to detect the presence of hydronephrosis. Previous studies have compared EPU with IVP[2,15–17] or compared radiologist-performed US with CT.[5,9] This is the first study that directly compares EPU detection of hydronephrosis with the current 'gold-standard' of radiologist-reported CT scan.

Previous studies have demonstrated US sensitivity of 85–94% and specificity of 100% in detection of hydronephrosis, when performed by radiologists or sonographers.[1,9,10,20,21] CT has proved a more accurate test with greater sensitivity for hydronephrosis and calculus detection.[5–10]

The accuracy reported in our study is comparable to that previously reported in most other EPU trials. Rosen *et al.* with 5 h training compared EPU diagnosis of hydronephrosis with IVP and CT in 126 patients, finding a sensitivity of 72%, specificity of 73%, PPV of 85%, NPV of 54% and accuracy of 72%.[16] By contrast, Henderson *et al.* found a sensitivity of 97% for 'pathology consistent with nephro-ureterolithiasis when compared to IVP' in 108 patients, but did not specifically report the detection of hydronephrosis as an outcome.[2] Lanoix *et al.* reported an accuracy of 94% and sensitivity of 96% after 4 h tuition based on 45 subjects and 39 EP/trainees.[15] However, the reference standard used in that study is unclear.

In an Australian study with 3 days of US training, Rowland *et al.* reported 68% accuracy for EPU using three grades of hydronephrosis: nil, subtle or obvious.[17] They reported a sensitivity of 93% but only a specificity of 47% (PPV 59%, NPV 89%) and used IVP, formal US within 24 h or radiologist review of the EPU as their 'gold-standard'. Four investigators obtained images from 31 subjects. They reported more false-positives than false-negatives whereas our study reports the opposite. In the above studies the difference between the US and CT grading were in subjects with low-grade hydronephrosis. A comparison of these studies is shown in Table 3.

It is worth noting that the sonographic grading of hydronephrosis into mild, moderate or severe correlates poorly with the clinical severity of disease.[22,23] Hence, for the purposes of data analysis in our study hydronephrosis was reported simply as either present or absent.

To be effective as a screening test, EPU would require a high sensitivity (i.e. few false-negatives). Our finding of a sensitivity of 79% and NPV of 65% suggests that EPU is currently not an acceptable screening test to rule out hydronephrosis. However, although eight cases of CT-confirmed hydronephrosis were not detected by EPU, seven of these false-negative scans were reported as mild hydronephrosis on CT. The eighth patient with false-negative EPU had moderate hydronephrosis demonstrated on CT but this scan was performed more than 24 h after the EPU, hence it is uncertain whether this truly reflects the presence of hydronephrosis at the time of the EPU, but has been incorporated into our results for completeness.

Radiological diagnosis of hydronephrosis on CT is subjective with several studies reporting inter-observer variability between radiologists and between radiologists, trainees and urologists.[23–27] The amount of hydronephrosis shown by US varies dynamically with partial obstruction and with hydration status of the patient,[11,25] as hydronephrosis can be induced in healthy volunteers with forced fluid intake. In serial US following hydration, mild–moderate hydronephrosis was induced in 80% of subjects.[28] Repeating the US in dehydrated patients following hydration might alter previously false-negative results.[11] Studies have demonstrated similar dynamic changes with CT. Perinephric stranding,

Table 3. Comparison of the previous studies of emergency physician US and detection of hydronephrosis

	Sensitivity (%)	NPV (%)	Comment
The present study (2005) ($n = 57$)	80	65	CT only; 1 h + course
Rosen *et al.*[16] (1998) ($n = 126$)	72	54	IVU + CT; 5 h training
Henderson *et al.*[2] (1998) ($n = 108$)	97	92	IVU; unclear diagnostic criteria
Lanoix *et al.*[15] (2000) ($n = 45$)	94	94	Multiple reference standards; 4 h training; 39 investigators
Rowland *et al.*[17] (2001) ($n = 31$)	93	89	Used IVU/US/radiologist; 3 days training; 68% accuracy

NPV, negative predictive value.

ureteral dilatation, perinephric fluid and collecting system dilatation showed statistically significant change over 8 h of study.[29] Therefore correlation discrepancy in our study might be explained by any of these factors. It has also been reported that false-negatives on US are usually followed by uncomplicated spontaneous stone emission.[30,31]

What level of minimum training is required to make EPU an effective screening tool for hydronephrosis? Lanoix *et al.*[15] and Rosen *et al.*[16] trained EP for 4 h and 5 h, respectively, with markedly different results as noted earlier, perhaps because of the very different reference standards used in their studies. Rowland *et al.* demonstrated an overall accuracy of 68% for EPU after 3 days training whereas our study demonstrates an accuracy of 81% after 1 h of focused training in renal scans following completion of an ACEM-accredited workshop.[17]

From our results, it would seem prudent to state that although additional training and experience might improve the accuracy of EPU it will not supplant the use of CT in the foreseeable future. However, despite similar results to ours for EPU accuracy, previous authors have suggested a place for EPU in the detection of hydronephrosis.[2,15,16]

Australasian and American Colleges for Emergency Medicine have published policies on the training and accreditation of EP in focused assessment with sonography for trauma and abdominal aortic aneurysm.[12–14] However, currently there are no guidelines for minimum training and accreditation in renal sonography for EP.

Limitations

As patients were enrolled on a convenience basis due to the presence or absence of an investigator to perform the scans, this might have introduced one or more unknown biases. A trend towards improved investigator performance was noted as scan quality improved with experience; this might have affected the detection rate in the earlier stages of the present study. Some EP performed less than three studies, others more than 10; however, the sample size was too small to afford meaningful subgroup analysis for individual EP. Some of these limitations would be overcome by larger studies.

It is worth noting that several of the EPU sonographers were relatively inexperienced in the use of bedside US and were not yet accredited in other EPU applications such as focused assessment by sonography in trauma (FAST)/abdominal aortic aneurysm (AAA). It is possible that accredited EPU sonographers would be more accurate.

Because of the dynamic nature of renal colic and urinary obstruction, ideally all participants would have had their EPU and CT scan performed within minimal time delay to ensure an accurate assessment of EPU; in one patient CT scanning was performed more than 24 h later. Finally, our study did not include routine evaluation of renal resistive indexes that might improve detection of early obstruction.[28]

Conclusion

Using non-contrast CT as the gold standard, we have found EPU detection of hydronephrosis to have an accuracy of 81%, which is comparable to previous studies. However, on the basis of the present study EPU is probably not accurate enough to rule out hydronephrosis. Further experience and training might improve the accuracy of EPU and allow its use as a screening tool.

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Author contributions

SW contributed to study design, ethics submission, consent and patient information sheets, reporting sheets, data collation and analysis, literature research and manuscript preparation (85%). JB contributed to original concept, study design, ethics submission, investigation, manuscript preparation and supervision (40%). PS contributed to investigator training, study design and CT reporting (25%). AH contributed to research methods, data analysis and manuscript preparation (20%). AG contributed to study design, investigation and manuscript preparation (10%). LC contributed to study design, investigation and data collation (10%).

Competing interests

Justin Bowra is a member of the Ultrasound Committee of the Australasian College for Emergency Medicine. Anna Holdgate holds the position of Section Editor of

Original Research for *Emergency Medicine Australasia*. All other authors declare no competing interests.

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Appendix I. Validation of ED physician US diagnosing hydronephrosis in ureteric colic

Completed forms to be placed in the marked box in the Resuscitation Room.

Date: **Time:**	**ED Physician name:**	
Place patient details sticker here	**Location of symptoms?** (Please circle or comment)	Right
		Left

ULTRASOUND FINDINGS

Hydronephrosis Present?					
Estimate severity	NO	MILD	MODERATE	SEVERE	UNSURE
RIGHT					
LEFT					

Additional comments:

	Empty	**Half**	**Full**
Bladder size?			

Incidental Findings?
(eg. Free fluid/ascites, AAA, effusion etc.)

Study Group Use only:

CT scan Performed	**Liverpool Hospital**	**South West Radiology**	**Elsewhere**
Date & Time of scan			

Appendix II. Validation of ED physician US diagnosing hydronephrosis in ureteric colic

Reporting sheet for dr praneal sharma, radiologist

Date:	**Time:**
Place patient details sticker here	

Diagnosis of Renal / ureteric colic correct?	**YES**	**NO**
Calculus Seen	**YES**	**NO**
	Left	**Right**
Position of Calculus		
Size of Calculus		

CT KUB FINDINGS

Hydronephrosis Present?					
Estimate severity	NO	MILD	MODERATE	SEVERE	UNSURE
RIGHT					
LEFT					

Additional Findings: