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What is the Appropriate Use of Renal Ultrasound in an Inner City Population with New Onset Acute Kidney Injury?

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Abstract

Objective—We aimed to determine the prevalence of hydronephrosis (HN) in patients who underwent renal sonography for new onset acute kidney injury (AKI) and to identify clinical factors predictive of HN. In patients with HN, we sought to investigate how routine renal US affects patient management, including performance of interventional procedures.

Methods—A retrospective chart review identified 274 adults with AKI who underwent renal ultrasound (US) at an urban teaching hospital from January 2011 through July 2011. The prevalence of HN was determined. Electronic medical records were reviewed for co-morbidities, including risk factors for HN such as pelvic mass, prior renal or pelvic surgery and neurogenic bladder, and for subsequent interventions and outcomes.

Results—US demonstrated HN in 28 patients (10%); 5 (18%) had subsequent interventions. In a multivariable logistic regression model with the outcome being HN, all considered risk factors, pelvic mass, prior renal or pelvic surgery and neurogenic bladder, were significantly associated with HN (odds ratio 6.4 (95% confidence interval 2.7, 15.4) and $p < 0.001$) when adjusting for age and diabetes mellitus. Diabetes had a negative predictive value for HN. No diabetic patients younger than 85 years and without clinical risk factors had HN.

Conclusions—HN is infrequently seen on sonograms in hospitalized patients with AKI who lack risk factors for urinary tract obstruction. Deferral of the US pending a trial of medical management is safe and will reduce medical costs. Adoption of clinical guidelines to assess patients' risk levels for HN is critical to avoid unnecessary imaging.

Keywords

Acute kidney injury; hydronephrosis; urinary tract obstruction; renal ultrasound

Introduction

Acute Kidney Injury (AKI) is characterized by an abrupt impairment in renal function leading to retention of nitrogenous waste and fluid, electrolyte, and acid-base imbalance [1]. Its prompt recognition and management is crucial because of increased risk of resultant end stage renal disease (ESRD) and overall morbidity, regardless of kidney function prior to the acute episode. Even slight increases in serum creatinine (SCr) are associated with a greater risk of death, longer hospital stay, and higher hospitalization costs [2].

The American College of Radiology “Appropriateness Criteria for Acute and Chronic Renal Failure” rates ultrasound (US) as the most appropriate imaging modality in the work up of renal dysfunction due to its utility in determining the presence of hydronephrosis (HN), evaluating kidney length and echotexture, demonstrating parenchymal perfusion with color Doppler and determining hemodynamically significant renal artery stenosis with color and spectral Doppler [3]. Additionally, US is non-invasive, readily available, portable and relatively inexpensive compared to other imaging modalities.

When HN is found in the renal US during workup of an AKI episode, the diagnosis of urinary tract obstruction leads to treatment that can restore renal function. Although the diagnosis of urinary obstruction is inferred by the presence of HN on US, this assumption is fraught with potential pitfalls. HN may not be apparent in very early obstruction or with concomitant dehydration. HN is an anatomic finding that often indicates mechanical obstruction but can also be seen with chronic reflux disease, papillary necrosis, rapid diuresis, chronic urinary obstruction and pregnancy [4, 5].

Prior studies have demonstrated that the use of renal US in patients with AKI for the purpose of detecting HN is not indicated when urinary obstruction is not clinically suspected [5–8]. AKI is more often secondary to intrinsic kidney disease or pre-renal azotemia, and not obstructive uropathy [5, 8]. In this study, we aimed to determine the incidence of HN in a predominantly hospital based adult population and whether clinical factors can predict which patients would benefit from a renal US. In patients with HN, we also sought to determine how the results of the US study affected patient management.

Materials and Methods

This retrospective study was approved by the Institutional Review Board and was compliant with the Health Insurance Portability and Accountability Act. A review of the radiology patient database was performed in an urban university teaching hospital from January 2011 through July 2011. A total of 890 US exams coded with the indication of “renal failure unspecified” and “unspecified disorder of kidney or ureter” were identified. US reports rendered by board certified radiologists were reviewed for the presence of HN, kidney size and echogenicity and presence of stones. Only the exams ordered to evaluate for AKI were included in the study. Many patients had more than one US during this time period, but only the first US was selected for the study. The patients’ charts were reviewed, and SCr and blood urea nitrogen (BUN) at the time of the exam were recorded for each patient.

AKI was defined using the Acute Kidney Injury Network (AKIN) criteria of an increase in SCr of >0.3 mg/dl in 48 hours [9]. Patients without baseline SCr but presenting with an elevated SCr ($\text{SCr} > 1.4$) at the time of the exam were also included in the study. Exclusion criteria included age less than 18 years, pregnancy and renal transplant. A total of 274 US exams were included in the study.

Race, age, and gender information was collected. Patients' electronic medical records were reviewed for co-morbidities, including chronic kidney disease (CKD), hypertension, diabetes mellitus (referred to as diabetes for the remainder of the paper), HIV infection, and cancer. The following co-morbidities were considered risk factors for HN: pelvic mass including benign prostatic hyperplasia, prior renal or pelvic surgery and neurogenic bladder. The electronic medical records of the HN positive patients were also reviewed for placement of Foley catheters before or after the US exam. In addition, SCr levels were examined for a trend to determine improvement following the US. All US imaging was performed by RDMS certified ultrasonographers on Philips IU 22, Siemens Sequoia, or GE Logiq E9. Two board certified radiologists (MS and FM) reviewed the images of all sonograms reporting renal pelvic fullness or HN to confirm the presence of HN with disagreements resolved in consensus. HN was defined as dilation of the renal pelvis to at least 1 cm in anterior posterior dimension and/or calyceal dilatation. Patient charts were reviewed to see if an interventional procedure occurred within 30 days following the US. These included placement of nephrostomy tubes, hemodialysis catheters, arteriovenous fistulas or grafts, or urologic surgery.

Statistical analysis

Bivariate associations were assessed with chi-square or Fisher's exact test as appropriate for categorical variables and by Mann-Whitney U test for continuous variables. The association between suspected risk factors and the presence of HN was also assessed with adjusted odds ratios estimated with binomial logistic regression models adjusting for variables with statistically significant bivariate associations with risk factors. Logistic model goodness of fit was assessed with a Hosmer-Lemeshow test. A two-sided alpha of 0.05 was used to denote statistical significance. Statistical analyses were performed with SPSS for Windows (Version 20).

Results

Characteristics of the 274 patients included in this study are presented in Table 1. The majority of the 274 subjects were inpatients either in medical or surgical wards (84%) or in the ICU (11%). A small number of patients presented to the Emergency Department (ED) (3%) or outpatient facilities (1%).

US findings other than HN are included in Table 2. Parenchymal disease characterized by increased renal echogenicity was reported in 159 (58%) patients. Eight patients (3%) had renal stones detected on US exam.

Patients were divided into 2 groups: group 1 (without HN) and group 2 (with HN). There were 28 cases of HN (10%). Of these, 24 (86%) were inpatients, 1 (4%) was an ICU patient

and 3 (11%) were ED patients. Data are presented in Table 3. Race, gender, and patient location were not clinically significant for the prediction of HN. In bivariate analysis, patients with history of cancer ($p<0.001$), pelvic mass ($p<0.001$), prior renal or pelvic surgery or history of neurogenic bladder ($p=0.03$) were significantly more likely to have HN. Conversely patients with diabetes were significantly less likely to have HN ($p=0.01$). Prevalence of hypertension and HIV infection, and documentation of renal stones on renal US, were not significantly different between patients with and without HN (all $p > 0.53$). Median (interquartile range) age was borderline significantly higher ($p=0.04$) among those with HN (72.5 (61,83) years) compared to those without HN (66 (54,77.3). Serum creatinine level and race were not significantly associated with HN ($p=0.58$ and 0.69 respectively).

No patient in our study with diabetes, age < 85 years and without a history of pelvic mass, prior renal or pelvic surgery or neurogenic bladder had HN. In a multivariable logistic regression model with the outcome of presence of HN, any considered risk factor was significantly associated with HN (odds ratio (95% confidence interval) 6.4 (2.7, 15.4) and $p < 0.001$) when adjusting for age and diabetes. There was no significant association between the presence of risk factors for HN and the initiation of hemodialysis (HD). As presented in table 4, six (8%) patients with risk factors for HN went on to HD, and 28 patients (14%) without risk factors also went on to HD ($p=0.21$). However, there was a significant association between the presence of risk factors for HN and a subsequent surgical intervention. Eight patients (11%) with risk factors for HN had a surgical intervention ($p<0.001$) such as nephrostomy placement or transurethral resection of the prostate or bladder neck. No patient without risk factors had a surgical intervention.

Of the 28 patients with HN (group 2, table 4), a total of five patients had interventions within 30 days of the US: four had nephrostomies placed, three bilateral and one unilateral, and one had an HD catheter placed. The association between HN and HD was not statistically significant ($p=0.22$), but the association between HN and a surgical intervention was significant ($p=0.01$).

Also in group 2, the SCr level improved in 23 (82%) patients following the US: three following nephrostomies, 1 following HD, 14 with medical management and Foley catheter placement, 2 with medical management and no Foley catheter placement, 2 with medical management and no Foley due to prior cystectomy and 1 following exchange of a chronic indwelling Foley catheter. One of the four patients in this study who had undergone nephrostomy placement did not improve; this patient had end stage metastatic uterine cancer and was discharged to hospice care.

Also in this group, 19 (68%) patients had Foley catheters at the time of the US, 17 had been inserted in the hospital prior to the US and 2 were chronic indwelling (one suprapubic). Fourteen of these 17 patients showed improvement of renal function; 10 with only additional medical management and 4 with interventions. All four patients who had Foley catheters inserted after the US exam showed improvement of renal function; 3 of these had bladder distention at the time of the US exam.

Discussion

Our study showed a 10% prevalence of HN in patients who had a renal US in the evaluation of an AKI episode, which is concordant with results from prior studies in the literature [5–8]. Obstructive uropathy is a potentially correctable cause of AKI. Although relatively few cases of HN are detected in the work-up of AKI, a baseline US will still often be performed to exclude obstructive uropathy. In addition, detection of a single kidney and findings of chronic renal dysfunction such as small hyperechogenic kidneys [4] can be helpful in assessing a patient at first presentation of kidney dysfunction. In contrast, repeatedly performing the US exam during recurrent episodes of AKI in patients at no increased risk for urinary tract obstruction generally adds very little information while increasing cost.

A study by Licurse et al. [8] identified seven risk factors associated with finding HN on renal US in hospitalized patients with AKI and stratified patients into high, medium, or low risk for HN according to the number of risk factors present. The risk factors were: history of HN; frequent urinary tract infections; known benign prostatic hyperplasia, abdominal or pelvic malignancy, neurogenic bladder, single functioning kidney or pelvic surgery; nonblack race; and no history of congestive heart failure, prerenal AKI or nephrotoxic insult. They concluded that renal US in low risk patients should be deferred as the renal US is highly unlikely to detect HN and impact patient management. Another study by Podoll et al. [5] also identified several risk factors associated with HN: age 65 or older, history of abdominal neoplasm, or any of several disease processes affecting the urinary tract such as known neurogenic bladder or renal or pelvic surgery. Podoll suggests that the additional information provided by US does not impact treatment of the acute episode and delaying the US exam will contain costs by reducing the number of US exams in a given patient. Similarly, we found independent variables associated with HN: history of cancer, pelvic mass, prior renal or pelvic surgery or history of neurogenic bladder. Patients with these risk factors had a higher odds ratio for the presence of HN. In light of recent literature data and our results, it is safe to advise clinicians to defer renal US in populations with low risk for HN until initial measures to improve the AKI episode have failed. However, delaying the US in an outpatient with first presentation of AKI may not be appropriate as the incidence of HN in this population is slightly higher [10]

Other authors [10] postulate that the US results may guide medical management, such as insertion of a Foley catheter or removal of nephrotoxic medications. In addition, inadvertently missing a case of HN can be linked to potential increased treatment costs and irreversible loss of kidney function adversely affecting the individual's quality of life, morbidity and mortality. The personal and societal costs of HD for a person who had a potentially treatable cause of AKI may outweigh the costs of screening the low risk population with a non-invasive test.

Our cohort, comprised mostly of inpatients, showed that having risk factors such as history of cancer, pelvic mass, prior renal or pelvic surgery or history of neurogenic bladder conferred a higher odds ratio for the presence of HN; paralleling the study by Podoll [5]. Diabetes is a major risk factor for the development of hospital acquired AKI, and Thakar et al. showed that diabetic patients who experience an episode of hospital acquired AKI are at

increased risk for developing advanced CKD [11] In our study, no diabetic patient younger than age 85, without any risk factors, had HN. We postulate that this inverse relationship between diabetes and the presence of HN in patients with AKI in our study may be related to a combination of progression of diabetic nephropathy and or a pre-renal or renal insult.

Our study failed to find an association between race and the presence of HN. Licurse et al. found that nonblack race was an independent variable conferring an increased risk for obstruction [8]. This may be due to a selection bias in our study. In our inner city low income population the vast majority of individuals was black or other race, and white race comprised only of 13% of individuals.

In our study, 14 patients with HN demonstrated improved renal function with bladder drainage and clinical management. We noted HN in 17 patients who had a newly placed Foley catheter prior to the US exam, suggesting chronic unsuspected urinary retention. In light of these findings, we believe that renal sonography in a patient with AKI must include images of the urinary bladder.

Our study has several limitations. The first limitation, not restricted to our study, is in defining episodes of AKI by elevation of SCr, which is not an exact biomarker for kidney function [12]. In elderly patients, the diagnosis of AKI may be underestimated due to reduced muscle mass resulting in a lower rise in SCr [10]. In addition, in patients with AKI superimposed on CKD, creatinine clearance may not be at equilibrium, causing SCr to fluctuate, rendering determination of AKI difficult. Second, our study, conducted from January 2011 through July 2011, only includes short-term follow up of an AKI episode. Long term assessment of patient outcomes related to the AKI episode was not performed. Third, patient selection bias is introduced by inclusion of only patients who underwent a renal US during AKI work up, and thus the actual incidence of HN in AKI cannot be definitively determined [10]. Fourth, there is a lack of established protocol for HN risk assessment by clinicians. Finally, clinical preferences of physicians specific to our institution and our inner city urban patient population may also have skewed results.

In conclusion, our study corroborates the low yield of US in identifying urinary obstruction in a low risk inpatient population presenting with AKI. Deferral of US exam in hospitalized patients pending a trial of medical management is safe and may contain medical costs. If the patient's renal function does not quickly improve with medical management, an US should be performed and images of the bladder should be included as unsuspected urinary retention may play a role, especially in the elderly. Most importantly, adoption of clinical guidelines to assess patients' risk level for HN is critical to avoid unnecessary imaging.

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References

1. Prasad N, Krishna A. Acute kidney injury: definition controversies and epidemiology. *Clinical Queries Nephrology*. 2011; 1:1–5.
2. Chertow GM, Burdick E, Honour M, Bonventre JV, Bates DW. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients. *J Am Soc Nephrol*. 2005; 16:3365–3370. [PubMed: 16177006]
3. American College of Radiology website. American College of Radiology; ACR Appropriateness Criteria® acute kidney injury (AKI), unspecified. <http://www.acr.org/~media/ACR/Documents/AppCriteria/Diagnostic/RenalFailure.pdf> [Accessed April 28, 2013]
4. O'Neill CW. Sonographic evaluation of renal failure. *American Journal of Kidney Diseases*. 2000; 35:1021–1038. [PubMed: 10845813]
5. Podoll A, Walther C, Finkel K. Clinical utility of gray scale renal ultrasound in acute kidney injury. *BMC Nephrology*. 2013; 14:188. [PubMed: 24011084]
6. Stuck KJ, White GM, Granke DS, Ellis JH, Weissfeld JL. Urinary obstruction in azotemic patients: detection by sonography. *Am J Roentgenol*. 1987; 149:1191–1193. [PubMed: 3318342]
7. Keyserling HF, Fielding JR, Mittelstaedt CA. Renal Sonography in the Intensive Care Unit. *Journal of Ultrasound Medicine*. 2002; 21:517–520.
8. Licurse A, Kim MC, Dziura J, et al. Renal ultrasonography in the evaluation of acute kidney injury: developing a risk stratification framework. *Arch Intern Med*. 2010; 170:1900–1907. [PubMed: 21098348]
9. Mehta RL, Kellum JA, Shah SV, et al. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. *Crit Care*. 2007; 11:R31. [PubMed: 17331245]
10. Liu KD, Chertow GM. Curbing the Use of Ultrasonography in the Diagnosis of Acute Kidney Injury: Penny Wise or Pound Foolish? Comment on “Renal Ultrasonography in the Evaluation of Acute Kidney Injury”. *Arch Intern Med*. 2010; 170:1907–1908. [PubMed: 21098349]
11. Thakar CV, Christianson A, Himmelfarb J, Leonard AC. Acute Kidney Injury Episodes and Chronic Kidney Disease Risk in Diabetes Mellitus. *CJASN*. 2011; 6:2567–2572. [PubMed: 21903988]
12. Waikar SS, Liu KD, Chertow GM. Diagnosis, Epidemiology and Outcomes of Acute Kidney Injury. *CJASN*. 2008; 3:844–861. [PubMed: 18337550]

Table 1

Patient characteristics

Patient characteristics	Patients with risk factors for HN [†] (n=73)	Patients without risk factors for HN (n=201)	Total (n=274)	P value [*]
Age (years) ^{**}	73 (63.5,80)	64 (54,76)		<0.001
Female gender	22 (30%)	110 (55%)	132 (48%)	<0.001
Race	Black	91 (45%)	118 (43%)	0.24
	White	22 (11%)	35 (13%)	
	Other	88 (44%)	121 (44%)	
Patient location	Intensive care unit admission	25 (12%)	30 (11%)	0.14
	Inpatient admission	61 (84%)	229 (84%)	
	Emergency Department patient	5 (7%)	9 (3%)	
	Outpatient	1 (1%)	4 (1%)	
Creatinine at time of Ultrasound (mg/dL)	2.4 (1.7,3.8)	2.2 (1.5,3.4)		0.12
Medical History				
Chronic Kidney Disease	21 (29%)	68 (34%)	89 (32%)	0.43
Hypertension	59 (81%)	159 (79%)	218 (80%)	0.76
Cancer	42 (58%)	39 (19%)	81 (30%)	<0.001
Diabetes mellitus	32 (44%)	108 (54%)	140 (51%)	0.15
HIV infection	0 (0%)	16 (8%)	16 (6%)	0.08
Renal stone found on Ultrasound	0 (0%)	8 (4%)	8 (3%)	0.11

[†] Risk factors: any or several of the following: pelvic mass, prior renal or pelvic surgery or history of neurogenic bladder

^{*} P values by Chi-square or Fisher's exact test as appropriate for categorical variables and by Mann-Whitney U test for continuous variables

^{**} Values are median (interquartile range)

Table 2

Nonspecific and Incidental Renal Ultrasound Findings

Nonspecific and Incidental Renal Ultrasound Findings	Total n=274
Parenchymal disease	58% (159)
Renal stones	3% (8)
Single kidney	8% (23)
Simple cysts	28% (76)
Complex cysts	5% (13)
Perinephric fluid	7% (20)
Ascites	2% (6)
Angiomyolipoma	1% (4)

Table 3

Presence of hydronephrosis according to patient characteristics among patients with acute kidney injury

Patient characteristics	Group 1 (Hydronephrosis absent) (n=246)	Group 2 (Hydronephrosis present) (n=28)	Total (n=274)	P value *
Age **	66 (54,77.3)	72.5 (61, 83)		0.04
Pelvic mass	42 (17%)	15 (54%)	57 (21%)	<0.001
Prior renal or pelvic surgery or history of neurogenic bladder	13 (5%)	5 (18%)	18 (7%)	0.03
Chronic kidney disease	82 (33%)	7 (25%)	89 (32%)	0.37
Cancer	64 (26%)	17 (61%)	81 (30%)	<0.001
Diabetes mellitus	132 (54%)	8 (29%)	140 (51%)	0.01
Hypertension	197 (80%)	21 (75%)	218 (80%)	0.53
HIV infection	15 (6%)	1 (4%)	16 (6%)	>0.99
Renal stone found on Ultrasound	8 (3%)	0 (0%)	8 (3%)	>0.99

* P values by Chi-square or Fisher's exact test as appropriate for categorical variables and by Mann-Whitney U test for continuous variables

** Values are % or median (interquartile range)

Table 4

Interventions within 30 days of Ultrasound

Intervention within 30 days of ultrasound	Risk factors for hydronephrosis (n=73)	No risk factors for hydronephrosis (n=201)	P value *	Group 1 (hydronephrosis absent) (n=246)	Group 2 (hydronephrosis present) (n=28)	P value *
Hemodialysis	6 (8%)	28 (14%)	0.21	33 (13%)	1 (4%)	0.22
Surgical intervention	8 (11%)	0 (0%)	<0.001	4 (2%)	4 (14.3%)	0.01

* P values by Chi-square or Fisher's exact test as appropriate for categorical variables and by Mann-Whitney U test for continuous variables