British Journal of Medicine & Medical Research
13(7): 1-9, 2016, Article no.BJMMR.23827
ISSN: 2231-0614, NLM ID: 101570965

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The Renal Ultrasound in Patients with Acute Kidney Injury

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Authors' contributions

This work was carried out in collaboration between all authors. Author MKM designed the study, wrote the protocol and wrote the first draft of the manuscript. Author WMN managed the literature searches and coordinated collection of the data. Author NH helped with the protocol design and the writing of the manuscript. Authors ZIS and WAK collected the data for the study. Authors FA and SHD analyzed the data on SPSS. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJMMR/2016/23827
Editor(s):
(1) Rakesh Garg, Department of Anaesthesiology, Intensive Care, Pain and Palliative Care, Dr BRAIRCH, All India Institute of Medical Sciences, New Delhi, India.
Reviewers:
(1) Mingxin Li, Fudan University, Shanghai, China.
(2) Alexander Berezin, Medical University, Zaporozhye, Ukraine.
Complete Peer review History: http://sciencedomain.org/review-history/13152

Original Research Article

Received 24th December 2015
Accepted 15th January 2016
Published 3rd February 2016

ABSTRACT

Aims: Acute Kidney Injury (AKI) is seen in 15% of hospitalized patients and a renal ultrasound (RUS) is often ordered to exclude an obstructive cause in the initial evaluation of AKI. This study was done to evaluate the usefulness of a RUS in patients with AKI in a developing country.
Methods: This was a retrospective study on all patients who were referred to nephrology with AKI and had a RUS, over a one-year period at a tertiary care teaching hospital of Karachi, Pakistan. The patients' charts were reviewed for clinical characteristics and the RUS findings were documented.

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Results: A significant number of patients did not have documented risk factors for obstruction based on the medical history. Hydronephrosis was found in 22.5% (25 out of 111) of patients, and in 14 of these cases, the etiology of the acute kidney injury was found to be obstructive uropathy. The presence of nephrolithiasis and/or benign prostatic hypertrophy was associated with and increased likelihood of finding hydronephrosis on RUS.
Conclusions: We thus recommend doing a renal ultrasound in all cases of AKI due to the fact that most of the time in a developing country, an accurate history is not available, and the prevalence of stone disease and obstructive uropathy is high.

Keywords: Acute kidney injury; hydronephrosis; obstructive uropathy; renal ultrasound.

1. INTRODUCTION

Acute Renal Failure (ARF), now increasingly referred to as "acute kidney injury" (AKI), is characterized by sudden (i.e., hours to days) impairment of kidney function [1]. AKI is a syndrome of rapid loss of kidney function and oliguria, which is associated with adverse patient outcomes [2-6]. Defined as an abrupt decline in renal function, indicated either by increased serum creatinine (CR) level (>0.3 mg/dL [to convert CR to micromoles per liter, multiply by 88.4] or 50% above baseline) or decreased urine production (<0.5 mL/kg/h over 6 hours), AKI is significantly associated with increased mortality [7]. AKI is estimated to occur in up to15% of hospitalized patients and up to 60% of critically ill patients [3,4,8]. Previous work has suggested that vasculitis, glomerulonephritis, and obstructive uropathy may be more prevalent in AKI acquired in the community [9]. The risk of acute renal failure is high in males, older patients and those with underlying medical conditions, is associated with serious outcomes and significantly increases mortality and morbidity [10]. In the initial evaluation of AKI, a renal (or retroperitoneal) grey-scale ultrasonography (RUS) study if often ordered to exclude an obstructive cause [11].

Determining the cause of acute kidney injury requires a multi-faceted approach and includes the medical history, clinical course, blood and urine tests, including urine microscopy. Renal ultrasound (RUS) is often recommended in the evaluation of AKI to exclude the presence of hydronephrosis and urinary tract obstruction even when the pre-test probability for obstructive uropathy is low [12,13]. RUS has major advantages in terms of diagnostic evaluation of renal diseases. It is readily available, non-invasive and puts less financial load on patients [14]. Renal ultrasonography has become the standard imaging modality in the investigation of the kidneys because it displays excellent anatomic detail, requires no special preparation of the patient and does not expose the patient to radiation or contrast agents. Ultrasonography is used to determine the site and size of the kidney and to detect local lesions like tumors, cysts and renal stones [15]. Furthermore the presence and urodynamic relevance of hydronephrosis can reliably be revealed [15].

Renal stones measuring greater than five millimeter are detected by RUS with 100% sensitivity. For the detection of renal stones in obstructive renal failure, renal ultrasound has a sensitivity of 81% and a specificity of 100% [16]. Post renal causes of AKI have been excluded with the help of ultrasonography, and it has become an established method for most clinical scenarios for the initial diagnosis of AKI. Others have advocated a more restricted use of RUS given that the majority of cases of AKI in hospitalized patients are due to acute tubular necrosis or prerenal etiologies, and thus in most cases RUS results would not be expected to change management [17-20]. In addition, the finding of hydronephrosis on ultrasound does not prove the presence of urinary tract obstruction since it is also seen in high urinary flow states such as with diuretic use, diabetes insipidus, pregnancy, previous obstruction, and congenital megaureter [17]. The purpose of our study was to evaluate the efficacy of renal ultrasound for detection of the causes of acute kidney injury in hospitalized patients. Assessing the clinical utility of RUS to determine the cause of AKI can impact on diagnostic and therapeutic management, as well as the costs of medical care.

2. MATERIALS AND METHODS

The study was conducted at the Clifton Campus of the Ziauddin University Hospital, a one-hundred and eighty bedded tertiary care hospital in the largest metropolis in Pakistan. The

research study employed a retrospective cohort-based design that randomly used medical records from July 2014 and July 2015 on patients with acute kidney injury who were referred to nephrology and had a renal ultrasound (RUS) in the inpatient facility of the hospital. The calculated sample size was 95, which was calculated at an incidence density of 6.9/1000, as documented from neighbouring India [21], given the paucity of data about the incidence of AKI in Pakistan. The confidence level was taken at 95% with a bound of error of 2%. Informed and written consent was obtained from all patients. Patient demographics and relevant clinical characteristics were abstracted from the medical records. Exclusion criteria included age less than 16 years, pregnancy, or prior renal transplant. Flowchart 1 shows the process of selecting patients' charts for review after applying exclusion criteria. The patients were assessed according to whether they had AKI alone, AKI with urosepsis, AKI with hematuria or AKI with lumbar pain. A total of 111 patients' data was obtained after applying exclusion criteria and after deleting those with missing records.

All the patients included in the study had been assessed by a consultant nephrologist at the hospital. AKI was defined as a 50% increase in baseline creatinine, or a urine output of less than 0.5 ml/kg/hr for more than 12 hours. These patients had been referred for a sonogram of the kidneys and urinary bladder. Ultrasound examination was done by a consultant radiologist with the TOSHIBA Xario 200^{TM} ultrasound machine using 3.75 Mhz convex transducer. Renal and urinary bladder ultrasound was done before and after voiding in all the patients. Patient demographics and clinical variables, including risk factors for obstruction such as benign prostatic hypertrophy prior abdominal or pelvic malignancy, nephrolithiasis, and anatomic genitourinary abnormalities were obtained from the medical records. It was also documented if any urological procedures, including bladder catheterization were done and if prompt renal recovery (within 24-48 hours) was seen after relief of the obstruction.

2.1 Statistical Analysis

Demographic and clinical variables among all patients referred to nephrology with AKI and had a RUS were compared on the basis of whether hydronephrosis was present or not, and statistical differences between groups were determined using bivariate logistic regression analysis. A P value of < 0.05 was taken to be significant. All results were analyzed with SPSS version 21.0.

3. RESULTS

3.1 Study Participants

Table 1 shows that of the 111 patients referred to nephrology who met inclusion criteria, the majority (n=100) of the referrals were for AKI alone. 7 patients had AKI with lumbar pain, 3 had AKI with urosepsis and 1 had AKI with hematuria.

Table 1. Reason for referral to nephrology

AKI alone n (n%)	100 (90.1%)
AKI and Lumbar Pain n (n%)	7 (6.3%)
AKI and Urosepsis n (n%)	3 (2.7%)
AKI and Hematuria n (n%)	1 (0.9%)

AKI: Acute Kidney Injury

Table 2 shows the demographic data for the patients who had been referred to nephrology and underwent RUS. The mean age was 63.5 years and there was a slight male preponderance (55.9%). The majority of patients did not have a significant medical history. 15 patients had underlying CKD, 13 had a prior clinical diagnosis of cystitis and 7 had pre-existing BPH. Of the 111 patients, 2 had a history of abdominal malignancy and 1 had a history of renal stones.

Table 2. Patients' characteristics

Patient characteristics	All patients (n=111)
Demographic Data:	
Age (years)	63.5 +/- 17.6
Male gender	62 (55.9%)
Medical History:	
No significant medical history	65 (58.6%)
CKD	15 (13.5%)
Cystitis	13 (11.7%)
BPH	7 (6.3%)
Abdominal malignancy	2 (1.8%)
Renal stones	1 (0.9%)
Others	8 (0.2%)

Data are presented as mean +/- SD, n (%), Abbreviations: CKD chronic kidney disease, BPH benign prostatic hypertrophy, Others includes neurogenic bladder, congenital renal or urinary tract abnormality, prior pelvic or renal surgery for reason other than cancer, and abdominal trauma

3.2 Ultrasound Findings

Table 3 summarizes the RUS results for all 111 patients. The majority (n=56) of patients had a normal RUS. Unilateral hydronephrosis was found in 15 patients and bilateral hydronephrosis in 10 patients. Overall, 22.5% had hydronephrosis. Nephrolithiasis was found in 5 patients, and increased parenchymal echogenicity in 19 patients. Of the 25 patients who had hydronephrosis, 14 (56%) underwent a urological procedure for relief of obstruction, and thus the AKI was attributable to the obstructive nephropathy in those patients. Table 4 shows that in patients who had AKI, 10 were found to have BPH, 5 were found to have renal/urinary tract stones and 1 patient had an abdominal mass. None of the risk factors found during ultrasound were statistically significant.

Table 3. Renal ultrasound results for all patients

	n= 111
No abnormalities	56 (62.6%)
Hydronephrosis	
Unilateral	15 (16.6%)
Bilateral	10 (11.1%)
Renal/urinary tract stones	5 (4.5%)
Increased renal parenchymal echogenicity	19 (17.1%)
Abdominal mass	1 (0.01%)
Renal enlargement	8 (7.2%)
Absent/shrunken kidney	4 (3.6%)

3.3 Hydronephrosis

Table 5 summarizes the number of participants who had hydronephrosis and bladder abnormalities according to whether they had AKI alone or a corresponding symptom/diagnosis with the AKI. 19 patients with AKI had hydronephrosis and 14 had bladder wall abnormalities. The P values reached statistical significance for all subgroups.

Table 4. Patients with AKI and risk factors for obstruction (n=111)

	Patients with AKI	P value
Stones n (n%)	5 (4.5%)	0.440
BPH n (n%)	10 (9.0%)	0.272
Abdominal Mass n (n%)	1 (0.9%)	0.739

AKI: Acute Kidney Injury

Table 5. Hydronephrosis and bladder abnormalities in all patients (n=111)

	Patients with AKI (n=111)	P value
Hydronephrosis		0.004
Bilateral	10 (9%)	
Unilateral	15 (13.5%)	
Trabeculated wall of bladder	8 (7%)	< 0.001
Thick/nodular wall of bladder	9 (8%)	< 0.001

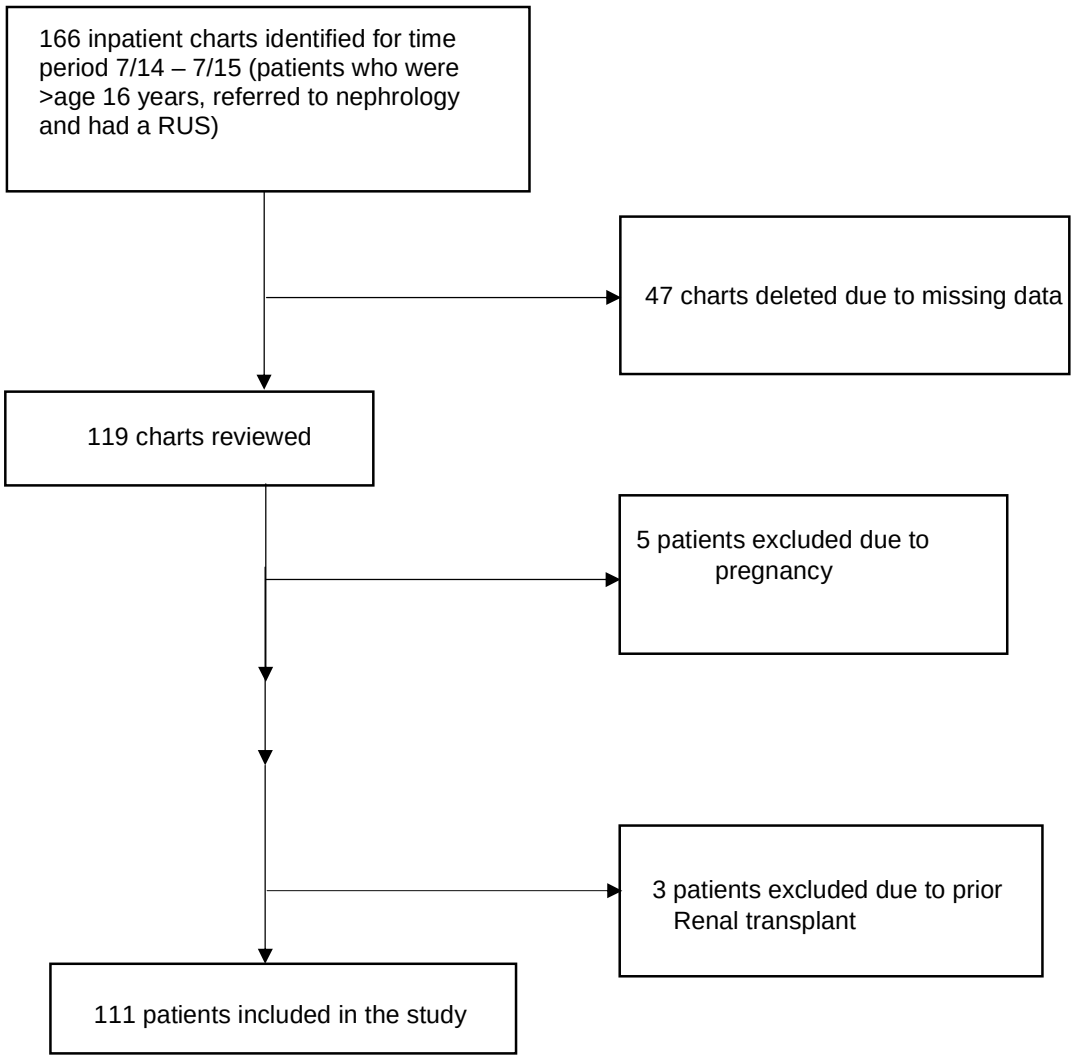
Table 6 records the demographic and clinical characteristics for the patients according to the presence and absence of hydronephrosis. Male gender and age > 65 years was not significantly associated with hydronephrosis. However, the presence of benign prostatic hypertrophy and nephrolithiasis was significantly associated with the presence of hydronephrosis.

Table 7 gives the odds ratios for finding hydronephrosis based on demographics, which are not associated with an increased risk for obstruction. However, BPH increased the likelihood of finding hydronephrosis by 3-fold, and nephrolithiasis increased the likelihood 18-fold.

Table 6. Hydronephrosis according to patient characteristics (n=111)

Patient characteristics	Hydronephrosis absent (n= 86)	Hydronephrosis Present (n= 25)	P value
Demographic data:			
Age > 65 years	52	15	0.821
Male gender	46	16	0.368
Medical history:			
BPH	5	5	0.017
Renal/urinary tract stones	1	4	0.002
CKD	14	1	0.113

Abbreviations: CKD chronic kidney disease, BPH benign prostatic hypertrophy



Flowchart 1. Patient selection

Table 7. Odds ratios of hydronephrosis in AKI based on patient characteristics

Patient characteristics	Adjusted odds ratio	P value
Demographics:		
Gender	1.4	0.528
Age > 65 years	0.994	0.709
Medical History:		
BPH	3.255	0.133
Renal/urinary tract stones	18.1	0.015

Odds ratios and P values determined by multivariate logistic regression model, P-value < 0.05 (age > 65, BPH, Renal/urinary tract stones), Abbreviations: BPH: benign prostatic hypertrophy

4. DISCUSSION

Acute kidney injury is a common complication in hospitalized patients, occurring in approximately 10% of hospitalizations [22,23] and the incidence of AKI appears to be on the rise [24,25]. Although the most common cause of hospital-acquired AKI is acute tubular necrosis [26], physicians frequently rule out urinary tract obstruction as the underlying cause of AKI using ultrasonography [27]. However, the indiscriminate use of this procedure increases cost and may expose patients to further unnecessary interventions, and thus restricted use of RUS has been advocated [17-19]. In our study, 22.5% of patients were found to have hydronephrosis, and more than half of them

underwent intervention with relief of obstruction and improvement in AKI. This is a higher number than seen in previous studies. Podoll and colleagues found hydronephrosis in 5% of patients, and less than half of them had AKI attributable to the obstruction [28]. A previous study revealed that 11% of patients with AKI were found to have hydronephrosis on RUS unrelated to their renal failure [29]. Other studies have suggested that the proportion of patients with urinary tract obstruction as a cause of community-acquired AKI is significantly higher than for patients with hospital-acquired AKI [30]. As such, routine ultrasonography in patients with community-acquired AKI would seem justified in the absence of more recent contradictory studies that focus on this patient population [27]. In another study among patients who had AKI in the intensive care unit, only one case in hundred of hydronephrosis was found [31]. However, we did not distinguish patients based on community or hospital-acquired AKI in our study. Another study found hydronephrosis in 15% of non-ICU AKI cases [20].

It is interesting to note that based on history, a significant number of our patients with AKI did not have risk factors for obstruction, like BPH, renal stone disease or an abdominal mass. This is probably due to the fact that many patients are unable to provide a good history as Pakistan has one of the lowest literacy rates in the world (55% according to the United Nations Educational, Scientific and Cultural Organisation (UNESCO)), compounded by the fact that medical-record keeping is hardly available, or inadequate.

It seems that the high incidence of stone disease and chronic obstructive uropathy found in Pakistan has contributed towards the relatively high number of cases of hydronephrosis seen in our study. A previous study from northern Pakistan showed that obstructive uropathy was seen in 10% of all patients [32]. Stones causing obstruction are an important cause of AKI in Pakistan [33]. We found only four cases of stones, but it should be remembered that ultrasound is not the most sensitive imaging modality for stones, especially as it misses ureteric stones. We found that some characteristics like benign prostatic hypertrophy and nephrolithiasis were associated with a higher likelihood of hydronephrosis, however, age greater than 65 years was not associated with a higher risk.

Some have suggested that including RUS in AKI evaluation is important to avoid missing cases of significant urinary tract obstruction. However, not all studies support this, and Podoll and colleagues recommended that obtaining a RUS early in the course of suspected AKI is unlikely to change initial management, and delaying it until the clinical course suggests chronic renal dysfunction might result in fewer unnecessary ultrasounds [28]. On the other hand, there has been a recent increase in patients with obstructive nephropathy, and even in the presence of significant renal dysfunction, the potential for renal recovery is high following relief of the obstruction [34]. This fact should serve as a wake-up call for improved screening to detect obstructive symptoms in patients with prostatic disease and pelvic malignancies [34]. In Asia, the stone-forming belt has been reported to stretch across Sudan, Saudi Arabia, the United Arab Emirates, Iran, Pakistan, India, Myanmar, Thailand, Indonesia and the Philippines [35]. The effect of geography on the incidence of stone formation may be direct, through its effect on temperature; high temperatures increase perspiration, which may result in concentrated urine, which in turn promotes increased urinary crystallization [36]. Pakistan lies in the stone belt with a high reported incidence of urolithiasis, and bladder stones constitute 10-15% of the stone burden in adults [33]. This is consistent with our finding a significant number of bladder stones in our patients. This may also point toward why we are seeing a higher number of patients with hydronephrosis compared with other studies (1-10% of patients) [37-39]. In another study, 35% of patients had hydronephrosis, of which 66% were obstructed, but all the patients with obstruction had a history suggestive of obstruction [17]. The majority of these studies are from western countries where the pattern of stone disease and obstructive uropathy is different from ours.

A strength of this study is that the population seen at our tertiary care hospital is representative of many segments of the population, as people from all walks of life are referred to this tertiary care hospital. It is the first study of its kind to be done in the country. Since the study indicates that a thorough medical history reduces the rates of unnecessary renal sonograms, the results may not apply when this history not available (due to the reasons outlined above). It is true that limiting diagnostic imaging in AKI will conserve some resources, but leaving obstruction unattended (leading to progressive AKI) in a developing country like Pakistan where the burden of stone disease is high, will

compromise care and eventually lead to a greater financial burden. Kidney damage may be more severe and often irreversible if urinary tract obstruction is protracted. The personal costs to a patient with postrenal AKI who fails to recover and requires maintenance dialysis are enormous; the financial costs to society of a preventable case of end-stage renal disease should be factored in the overall costs of screening estimates [27]. Renal ultrasonography is typically the most appropriate and useful radiologic test in the evaluation of patients with AKI [40]. Faubel and colleagues suggest that renal ultrasonography is particularly important in the evaluation of AKI if the diagnosis is unclear or the clinical course is not as expected [41]. It is useful to note that the American College of Radiology (ACR) Appropriateness Criteria rating for the use of ultrasonography in AKI is a 9, the highest rating, indicating that its use in AKI is highly appropriate [40]. The ACR Appropriateness Criteria are a compilation of evidence-based recommendations to aid in the selection of radiologic imaging for a variety of medical conditions. Therefore doing an ultrasound of the kidneys in all cases of AKI in a developing country like Pakistan is highly recommended. This is due to the fact that a thorough history is often not available, and because there is a high prevalence of obstructive uropathy. The results may be applicable to other South Asian countries.

5. STUDY LIMITATIONS

A limitation of the study is the relatively small number of patients, as all patients with AKI are not referred to nephrology, as well as the selection bias of a single hospital setting. There may have been further bias as those cases of obstructive uropathy that are diagnosed by other radiologic methods were excluded. Moreover, the results may not be entirely applicable when a thorough medical history is available.

6. CONCLUSION

We recommend doing a renal ultrasound (to look for obstruction) in all cases of AKI, due to the fact that most of the time in developing countries, an accurate history is not available, and the prevalence of stone disease and obstructive uropathy is high compared to the developed countries.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/13152