Urol Res (2012) 40:345–348
DOI 10.1007/s00240-011-0414-6

ORIGINAL PAPER

The incidence and clinical features of acute kidney injury secondary to ureteral calculi

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Received: 15 October 2010 / Accepted: 30 July 2011 / Published online: 19 August 2011

Abstract The aim of this study is to evaluate the incidence and clinical features of acute kidney injury (AKI) secondary to ureteral calculi. Between February 2002 and December 2009, the prevalence of AKI was 0.72% in our series of 2,073 cases of ureteral stones. The AKI patients received ureteroscopy or percutaneous nephrostomy as the primary treatment. The most popular symptom was significant decrease in urine output (75%, 12/16). Five cases (33.3%) were caused by bilateral ureteral stones, and 76.19% of the stones were located in the upper ureter, the mean size of single stone was 1.35 ± 0.38 cm. The serum creatinine before treatment was 514.34 ± 267.04 μmol/L and the blood urea nitrogen before treatment was 21.31 ± 10.24 mmol/L. 46.67% of the patients had a functional or anatomical solitary kidney unit. Our study suggests that risk factors for developing AKI in ureteral stone patients are bigger sized stones, ureteral stones in patients with only one functioning kidney or pre-existing kidney disease, and bilateral ureteral stones. Early effective drainage in these cases could decrease the risk developing AKI secondary to ureteral calculi.

Keywords Acute kidney injury · Epidemiology · Ureteral calculi

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Introduction

Ureteral calculi is one of the most popular reasons among the surgical causes of acute kidney injury (AKI) [1]. Once the diagnosis of AKI secondary to ureteral stone is made, it will need an emergency treatment to decompress the kidney by stenting or nephrostomy, and the definitive treatment to fragment the stone may be performed once the renal function recovered to normal. Furthermore, 15% of AKI patients secondary to urolithiasis need to receive dialysis first [1]. There is an increased cost, more traumatic treatment, and longer hospitalization time than usual.

Thus, features and risk factors of this disease should be identified to decrease the occurrence of AKI secondary to ureteral calculi. Nevertheless, to our knowledge, there is currently no published study regarding the incidence and clinical features of AKI secondary to ureteral calculi. Therefore, we performed the first study to review all AKI patients secondary to ureteral calculi in the Department of urology in our hospital. In this study, we identified the incidence of AKI caused by ureteral stone as a proportion of all ureteral calculi patients hospitalized over the past 8 years. We also examined the clinical features and laboratory examination associated with the condition to identify the risk factors for the disease progression, and defined the role of ureteroscopy (URS) or percutaneous nephrostomy (PCN) in the management.

Materials and methods

Patients

We performed a retrospective study of all ureteral calculi patients with the complication of AKI found by reviewing ureteral stone patients hospitalized from February 2002 to December 2009. All ureteral calculi patients underwent radiologic examination (plain X-ray and ultrasonography or unenhanced spiral computed tomography, if necessary) to determine location and size of the stone. Because most AKI patients secondary to urolithiasis came to hospital without a baseline of serum creatinine before the obstruction, AKI was diagnosed meeting the following criteria according to the definition made by AKI network with a little modification [2]: (1) patient without a history of chronic kidney disease (CKD) had a serum creatinine level higher than 176 μmol/L (2 mg/dL), (2) or patient had a raised serum creatinine higher than the baseline of the serum creatinine about >26.4 μmol/L (0.3 mg/dL) within 48 h, or a percentage increase in serum creatinine of more than or equal to 50%, (3) and/or patient with history of urine output <0.5 ml/kg/h for longer than 6 h.

Methods

On admission, demographic data of the patients were collected (gender and age). Presenting clinical, laboratory features and clinical outcome related to URS or PCN as the primary treatment was evaluated. This protocol has been approved by the committee of provincial hospital affiliated to Shandong University.

Statistical methods

Quantitative variables are presented as means ± standard deviation and qualitative variables as percentage. Data from AKI patients were compared with the no-AKI patients. *t* test was used to analyze the age and the stone size, Fisher exact test or Logistic regression was used for categorial variables groups. A $p < 0.05$ was taken as significance. The statistical analysis was done using the SPSS 17.0 for windows.

Results

Fifteen cases of ureteral calculi patients with the complication of AKI were identified over the 8-year period, constituting 0.72% (15/2,073) in the ureteral stone in hospital patients. One patient was hospitalized twice due to AKI. Nine AKI patients had a history of urolithiasis. The basic characteristics of the study population are shown in Table 1. The presenting symptoms of the AKI patients included oliguria (31.25%, 5/16), anuria (43.75%, 7/16), loin pain (64.71%, 11/16), nausea (37.50%, 6/16), vomiting (31.25%, 5/16) and abdominal pain (1/16, 6.25%). The mean age was 39.33 ± 13.03 years; 11 (73.33%) were male. Eight cases (53.33%) were caused by unilateral ureteral stones, five (33.33%) were caused by bilateral ureteral stones, two (13.33%) were caused by unilateral ureteral stones and contralateral renal pelvis stone which obstructed the ureteropelvic junction. The characteristics of ureteral stones with AKI are shown in Table 2. The mean size of single ureteral stone with AKI was 1.35 ± 0.38 cm. The serum creatinine before treatment was 514.34 ± 267.04 μmol/L and the blood urea nitrogen (BUN) before treatment was 21.31 ± 10.24 mmol/L.

Table 1 Basic characteristics of the study patients

Characteristic	AKI ($n = 15$)	No-AKI ($n = 2,058$)	p value
Age (years)	39.33 ± 13.03	44.32 ± 14.53	NS
Sex			
Male	73.33% (11/15)	71.38% (1,469/2,058)	NS
Female	26.67% (4/15)	28.62% (589/2,058)	NS
Bilateral stone	33.33% (5/15)	2.43% (50/2,058)	<0.001
Stone location			
Upper	76.19% (16/21[a])	35.48% (748/2,108[b])	<0.05
Middle	4.76% (1/21)	12.86% (271/2,108)	–
Lower	14.29% (3/21)	51.04% (1,076/2,108)	<0.05
Upper + low[c]	4.76% (1/21)	0.14% (3/2,108)	–
Upper + middle[d]	–	0.47% (10/2,108)	–
Stone size			
Upper	1.05 ± 0.34	0.82 ± 0.40	<0.05
Middle	1	0.65 ± 0.29[f]	–
Lower	0.72 ± 0.10[e]	0.62 ± 0.29[g,h]	<0.05
One functional kidney	46.67% (7/15)	0.29% (6/2,058)	<0.001
CKD	6.67% (1/15)	0.38% (8/2,058)	<0.001

NS not significant

[a] For the 15 AKI patients, 8 with unilateral ureteral stones, 2 with unilateral ureteral stones and contralateral kidney stones, 5 with bilateral ureteral stones, 1 patient with unilateral ureteral stones was hospitalized twice, so a total of 21 ureters with calculi

[b] 2,058 ureteral calculi patients without AKI, 2008 with unilateral ureteral calculi, 50 with bilateral ureteral stones, for a total of 2,108 ureters with calculi

[c] Multiple calculi located in the upper and low ureter of the same ureter

[d] Multiple calculi located in the upper and middle ureter of the same ureter

[e] Compared with the upper group of AKI, $p < 0.05$

[f] Compared with the upper group of no-AKI, $p < 0.05$

[g] Compared with the upper group of no-AKI, $p < 0.05$

[h] Compared with the middle group of no-AKI, $p > 0.05$

Table 2 The characteristics of the ureteral stones with AKI

Location	Single stone in the ureter		Multiple stones in the ureter	
	Number	Size	Number	Size
Upper	11	1.35 (0.7–2.0)	5	0.85 (0.7–1.0)
Middle	1	1.0 (1.0)		
Low	1	1.0 (1.0)	2	0.7 (0.7)
Upper + low			1	1.0 (1.4, 0.6[a])
N	13		8	

[a] One patient with two stones in the same ureter, one stone with the size of 1.4 cm in the upper ureter and the other of 0.6 in the lower ureter

Of the eight patients caused by unilateral ureteral stones, seven patients had a nonfunctioning contralateral kidney, one patient had a history of CKD secondary to systemic lupus erythematosus (SLE).We included the patient with CKD into this study because the renal function of this patient had an acute loss due to ureteral calculi. Among the seven patients with a nonfunctioning contralateral kidney, five patients had an atrophic kidney contralateral to the ureteral stones, one patient had a history of nephrectomy, and one case shown by emission computed tomography (ECT) had no function of the contralateral kidney.

The female patient with the ECT study showing no function of the contralateral kidney was hospitalized twice due to AKI, and she had multiple kidney stones and ureteral stones on the same side. She received URS for the treatment of ureteral calculi during her first hospitalization and received extracorporeal shock wave lithotripsy (SWL) for the treatment of the kidney stones 78 days after the first URS without the stent removed. One day after SWL, she complained of anuria and was hospitalized again due to AKI. During the course of the second URS, we found multiple stones in the upper ureter and the stent was encrusted by the stones.

There were 14 patients received URS as the emergency (within 12 h of admission to the emergency room) treatment of AKI, and there was another patient received elective URS operation in our hospital after the renal function restored to normal by emergency dialysis and PCN in other hospital. The preoperative patient management is the same as the other preoperative management of emergency or elective URS.

Among these AKI patients, 14 patients without a history of CKD had a complete renal function recovery after 2–10 days, only one patient who had chronic renal dysfunction secondary to SLE had a partial recovery of renal function (pre-operation serum creatinine 442 μmol/L, BUN 32 mmol/L, post-operation serum creatinine 155 μmol/L, BUN 12.2 mmol/L at day 9). All patients survived at the 90-day follow-up.

Discussion

Acute renal failure (ARF), characterized by a sudden impairment of kidney function, has many terms, such as AKI, renal impairment, renal insufficiency, is now increasingly referred to as AKI because it comprise a broader range of extent. However, absence of a universally accepted nomenclature for this condition makes the comparison among studies extremely difficult [3], we used the term AKI in our study.

Urine output is a functional biomarker for the kidney, but the relationship between urine output and renal injury is complex. For AKI, oliguria is an insensitive indicator since the urine output may remain adequate when the patient with nonoliguric AKI. But the decrease of urine output is a clue for post-renal AKI [4]. In our study, seven patients came to the hospital complaining of oliguria, and five patients with anuria. A total of 75% (12/16) patients in our data had oliguria in different degree. It is consistent with the opinion of Nally [4] that the decrease of urine output is a valuable indicator for AKI caused by ureteral obstruction.

The gold standard method of detection of AKI is inulin clearance or nuclear isotope clearance [5], but it is not so convenient to perform this method to predict AKI in clinical practice. And some other biomarkers, such as cystatin C [6], neutrophil gelatinase-associated lipocalin (NGAL) [7], N terminal prohormone of atrial natriuretic peptide [8], have been reported to predict AKI, but they have not been as universally used as the detection of serum creatinine in clinical practice. Serum creatinine changes are usually used to detect the acute kidney dysfunction [9] because it is specific for renal function. Measuring serum creatinine level is a practical approach for discovering short-term alteration in renal function, although the level of serum creatinine may be affected by factors, such as age, sex, race, muscle mass and medications [10, 11]. All the patients with a history of oliguria in this study could be obviously reflected by the change of serum creatinine. In our data, for the patient with the shortest history of anuria (10 h), the serum creatinine pre-operation and post-operation of this patient was 164 μmol/L, 101 μmol/L, respectively.

It is well-known that bilateral ureteral calculi can cause post-renal AKI. In our data, only five cases were caused by bilateral ureteral calculi, and two were caused by unilateral ureteral calculi and contralateral kidney stone, for a total of 46.67% (7/15) were caused by bilateral urinary obstruction, and 53.33% (8/15) were caused by unilateral ureteral calculi. It needs more data to confirm because of the small number of data. Among the eight cases with unilateral ureteral obstruction, one had a solitary kidney unit because of nephrectomy, and six a functional solitary kidney unit, one with a history of CKD secondary to SLE. For a total 46.67% of all the AKI cases had only a solitary kidney unit.

As shown in Table 1, the patients with only one kidney are more prone to AKI secondary to ureteral calculi ($p < 0.001$). For the patient with CKD, even this case had two functional kidney, unilateral ureteral stone with no obstruction in the contralateral urinary tract made a result of AKI because of the loss of renal function storage. It shows that AKI occurrence related with the preexisting kidney impairment ($p < 0.001$).

As shown in Table 1, most (51.04%) of the stone without AKI were located in the lower ureter, the stone in the upper ureter was 35.48%, whereas most (76.19%, 16/21) of the stones with the complication of AKI were located in the upper ureter ($p < 0.05$).The diameter of stone size in the upper ureter are bigger than that in the lower ureter. We thus infer that, the bigger the stone size, the higher the stone location in the ureter. It can also explain why the stone with AKI were usually located in the upper ureter, and the stone without AKI were usually located in the lower ureter because the stone size of AKI were bigger than that without AKI.

The stone size and location with AKI are shown in Table 2. Inserting a double J stent before the stone causing complete obstruction usually is a method to prevent the occurrence of AKI secondary to ureteral calculi. However, in our study, the female case ECT showing no function of the contralateral kidney was hospitalized the second time due to AKI 1 day after SWL with a placed stent. During the second URS, we found that the obstruction was caused by two factors, one is the multiple stones in the upper ureter sliding down from the kidney, the other is the blocked stent because the surface of the stent had been encrusted with stones. So we must be alert about the encrustment of the stent when a patient with a placed double J stent, only effective drainage can prevent the occurrence of AKI secondary to ureteral calculi.

We did not analyze the calculi due to shortage of such facilities in our department, and therefore the data could not be included in the present study. This limitation is also prevalent in clinical practice since the biochemical nature of calculi is unknown before doing lithotripsy, and radiologic appearance is the primary indicator of the stone character.

The incidence of AKI secondary to ureteral stones based on this definition during the study period is 0.72%. In men and women, the incidence of AKI during the 8 year was 0.75 and 0.68%, respectively. But it did not reflect the real occurrence rate of AKI secondary to ureteral calculi. One reason is that our study was based on the ureteral calculi patients admitted to the hospital, another reason is that it is not a uniform definition of AKI. The AKI patient with raised serum creatinine level of <2 mg/dL or even normal serum creatinine levels without the history of oliguria have been overlooked. It is well-known that AKI can be present in patients with normal creatinine levels, mostly middle-aged or elderly patients [12]. But the data drawn out according to this definition could reflect the characters of AKI secondary to ureteral calculi.

Conclusion

Based on our study, we conclude that risk factors for developing AKI in ureteral stone patients are: bigger sized stones; ureteral stones in patients with only one functioning kidney or pre-existing kidney disease; and bilateral ureteral stones. Early effective drainage in these cases could decrease the risk developing AKI secondary to ureteral calculi.

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