ORIGINAL RESEARCH

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A practical pressure measuring method for the upper urinary tract during ureteroscopy

Abstract

Purpose: The purpose of this study was to develop and test a method for measuring pressure in the upper urinary tract during ureteroscopic operations and to evaluate its efficacy and clinical significance.

Methods: A total of 44 patients, each with a ureteral calculus in the proximal ureteral segment, were enrolled in the study group: 21 patients with an acute and 23 with a chronic obstruction. The ureteroscope was passed forward to the upper segment of the obstructed ureter immediately after the calculus was broken and the intraluminal ureteral pressure was then transmitted along with the irrigant flow (0.9% sodium chloride).

Results: The mean ureteral pressures of the acute obstruction subgroup, the chronic obstruction subgroup and the control group were 74.5 mmHg (22-180 mmHg), 32.5 mmHg (9-53 mmHg) and 10.2 mmHg (8-13 mmHg), respectively. A significant correlation was found between ureteral pressure and the following indexes: the duration of the obstruction ($r=0.985$), the diameter of the ureter above the calculus ($r=0.878$) and the depth of the hydronephrosis of the renal pelvis ($r=0.862$). No associations were observed between the pressure and the serum creatinine level ($r=0.214$) or the urinary leukocyte count ($r=0.047$). The intraluminal pressure correlated with the glomerular flow rate (GFR) of the affected kidney ($r=0.975$, $P=0.001$).

Conclusions: This new method is non-invasive, practical and reproducible. Measuring the intraluminal pressure of the ureter can provide a valuable index to quantify the severity of the obstruction of the upper urinary tract, which is helpful for the prediction of the affected renal function prognosis.

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Ureteral calculi frequently cause ureter obstructions, induce hydronephrosis and damage renal function. It is necessary and important to assess the severity of upper urinary tract obstructions [1,2]. Traditionally, antegrade pressure measurements (APMs) of the renal pelvis and the upper ureter are recorded by percutaneous access to the kidney or by the perfusion pressure-flow test (Whitaker test) [3-5], which risk invasive renal bleeding and urinary tract infection. Other methods, such as radionuclide renogram, Doppler vessel resistance and intravenous urography [6-9], lack sensitivity and specificity. A quantitative, non-invasive and effective method is needed.

Recently, ureteroscopy has become a common minimally invasive examination method in the treatment of ureteral calculi [10]. During ureteroscopy, the ureteroscope presses closely to the ureteral wall, and the intraluminal pressure of the ureter can be transmitted along with the flowing of the irrigation fluid. After the ureteral calculi are fragmented, the ureteroscope passes the calculus, and the pressure of the ureter is measured by connecting the ureteroscope to a sensitive digital pressure monitor. In this study, we aimed to investigate the feasibility and efficacy of this method in patients with varying severities of calculus obstruction.

Materials and Methods

Clinical Data

From July 2010 to July 2011, 44 consecutive patients, including 24 men and 20 women with an average age of 40.2 years (range 18-63 years), were enrolled in the study group.

The inclusion criteria were ureteral obstruction caused by ureteral stones, accompanied by hydronephrosis or pyonephrosis. The exclusion criteria were severe deficiency of blood coagulation function and severe abnormal ureter structure. No contraindications for ureteroscopic lithotripsy were found. The patients had ureteral obstruction histories ranging from 3 hours to 18 months. Those who had a history of over three months were assigned to the chronic subgroup, and those with a history of less than 36 h were assigned to the acute subgroup. The ureteral calculi were diagnosed and evaluated preoperatively through examinations including ultrasonography, kidney-ureter-bladder film (KUB), intravenous urograms (IVUs), computerised tomography (CT) and magnetic resonance imaging (MRI). The mean ureteral calculus diameter was 0.8 cm (range 0.5 to 2.5 cm) and was calculated using ultrasonography, IVU CT and MRI. Each patient had only one ureteral calculus.

An additional 22 patients without obstruction or dilation in the ureters, who underwent ureteroscopy for reasons such as

hematuria, were enrolled as the control group. The average age of the control group was 41.6 years (range 20-65 years).

This study was approved by the institutional clinical research ethics board. Written informed consent was provided by every patient before the operation.

Methods

After epidural anesthesia, the patients were placed in a lithotomy position. Intra-operative monitoring of EKG, pulse, oxygen saturation and body temperature was performed using a patient monitor (EAGLE3000 multi-parameter). A rigid 7 Fr ureteroscope (Olympus Corp) was used. Standard rigid ureteroscopic operating methods were applied.

During the operations, the ureteroscope was passed forward to the upper segment of the obstructed ureter immediately after the ureter stone was fragmented. When the on-off switch in the tail of the ureteroscope was released, the intraluminal pressure of the ureter was transmuted along with the irrigant flow and could be measured by a sensitive electric pressure signal transducer (TRANSPAC®IV Monitoring kit/42584, Abbott Laboratories) and displayed on a monitor (Figure 1).

The glomerular filtration rate (GFR), an index of the quantity of glomerular filtrate formed each minute in the nephrons of the kidney, was measured by radionuclide renograms obtained with Tc-99 m-DTPA.

Correlation Assessment

The correlation among the intraluminal pressure of the ureter and other clinical factors, including the obstruction duration, glomerular filtration rate (GFR), diameter of the ureter segment above the stone, depth of the hydronephrosis of the renal pelvis, serum creatinine level and urinary leukocyte count, were analysed.

Statistical Analysis

SPSS (Statistical Package for the Social Sciences) version 14.0 was used for all statistical analyses. The data were analyzed with the Student's t-test and $P < 0.05$ was considered as statistically significant. Pearson's correlation analysis was performed to determine the relevance among the ureteral pressure and the clinical factors.

FIGURE 1. An illustration of a retrograde measurement of pressure in the upper urinary tract during the ureteroscopic operations.

Results

Operation data

All of the operations were performed successfully. The mean operating time of the 44 patients in the study group was 33.5 min (range 15-55 min). The mean lithotripsy time was 28.6 min (range 20-42 min). The post-operative hospital stay ranged from 3 to 5 days. No complications, such as bleeding, ureteral perforation or septic shock, occurred. The pressure measuring time was 2.5 min (range 1-6 min) in the study group and 2.3 min (range 1-5 min) in the control group. No significant differences were found between these two groups.

Ureteral pressure

The average intraluminal pressures of the acute subgroup, the chronic subgroup and the control group were 74.5 mmHg (range 22-180 mmHg), 32.5 mmHg (range 9-53 mmHg) and 10.2 mmHg (range 8-13 mmHg), respectively. Significant differences were identified between any two of the three groups ($P < 0.05$).

Correlation analysis

The data of the three groups are shown in Table 1. Correlations were found between intraluminal pressure and the following factors: the duration of the obstruction ($r=0.985$), the diameter of the ureter above the calculus ($r=0.878$) and the depth of hydronephrosis in the renal pelvis ($r=0.862$). No associations were observed between the pressure and the serum creatinine level ($r=0.214$) or the urinary leukocyte count ($r=0.047$). In the chronic subgroup, the mean intraluminal ureter pressure was 32.5 mmHg (range 9-53 mmHg), and the mean GFR of the affected kidney was 23.6 ml/min (range 11.3-45.2 ml/min). There was a significant correlation between the pressure value and the GFR ($r=0.975$).

Discussion

Morphological and structural changes due to obstruction of the ureter include dilation of the upper segments of the ureter

and the renal pelvis. The proper treatment is dependent upon the type of obstruction [1,2]; however, the severity of the obstruction cannot be accurately assessed from the morphology on radiological films or by the depth of hydronephrosis in the kidney [3,4].

The intraluminal pressure of the urinary tract has been reported to correlate with the severity of the renal obstruction and the prognosis [ref]. Different extents of obstruction result in various pressures in the urinary tract and thus to diverse injuries, such as decreased blood flow to the affected kidney, electrolyte disturbance and renal function failure. Significant histological changes have also been observed [11, 12], such as epithelial edema, renal tubule cystic dilation, basal membrane degeneration, renal glomerulus reduction and capillary ischemia and dilation. Glomeruli replacement with fibrous connective tissue has also been observed.

The urinary tract pressure measuring methods currently in use include percutaneous puncture of the kidney and pelvic pressure assessment such as the perfusion pressure-flow test (Whitaker test) [3-5]. The Whitaker test was first described by Whitaker in 1973 and was designed to determine whether urinary tract dilatation is caused by an obstruction by measuring and comparing the pressures in the renal pelvis and bladder. This method is based on invasive and complicated procedures and cannot be easily used in all patients. Additionally, it may result in damage, hemorrhage and infection of the kidney and adjacent organs [ref].

During ureteroscopy [10], the ureteroscope presses closely to the ureteral wall, providing the feasibility of liquid pressure transmission and thus to measurement of intraluminal pressure. In this study, we have shown that measurement of intraluminal ureter pressure by ureteroscopy is non-invasive, convenient, practical and reproducible. It has its specific characteristics as compared with the other methods [13-15].

In this study, the individual intraluminal pressure of the ureters differed in each patient. These pressure values have been previously shown to depend on the severity and duration of the obstruction [16-17]. A significant correlation between the pressure and the GFR was found in this study. Some of the chronic cases, whose pre-operative examinations showed a

TABLE 1. The measuring index values in the patients.

	Duration of obstruction (days)	The diameter of the ureter above the calculi (mm)	The depth of hydronephrosis (mm)	Serum creatinine ($\mu\text{mol/L}$)	Urine WBC count (/ μL)
Research group	45.2	14.1(12-16)	37.2(21-46)	103.4(35.3-742.5)	578.5(80-1180)
Control group	0.0	4.5(3-8)	9.3(6-15)	45.4(15.3-142.5)	56.3(20-180)

similar depth of renal pelvis hydronephrosis, had different ureteral pressures. This suggests that the technique may reflect the actual renal function. In the acute subgroup, the higher pressure patients recovered sooner than those with lower ureteral pressure. These results suggest that the ureteral pressure measured by this method may reflect the severity of hydronephrosis and the prognosis of the function of the affected kidney.

It should be noted that the patient number was limited in this study. Further studies with a larger number of patients are needed to evaluate the efficacy of this method.

In summary, measuring the intraluminal pressure of the ureter can provide a valuable index for quantifying the severity of the obstruction of the upper urinary tract. It may prove to be a helpful predictor of the renal function prognosis.

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References

1. Matlaga BR, American Board of Urology. Contemporary surgical management of upper urinary tract calculi. *J Urol*. 2009;181(5):2152-6.
2. Delvecchio FC, Preminger GM. Medical management of stone disease. *Curr Opin Urol*, 2003,13(3):229-233.
3. Whitaker RH. Methods of assessing obstruction in dilated ureters. *Br J Urol*. 1973;45(1):15-22.
4. Whitaker RH. The Whitaker test. *Urol Clin North Am*,1979,6(3):529-539.
5. Tchetgen MB, Bloom DA, Robert H. Whitaker and the APR: a pressure-flow study of the upper urinary tract. *Urology*. 2003;61(1):253-256.
6. Thoeny HC, Binser T, Roth B, et al. Noninvasive assessment of acute ureteral obstruction with diffusion-weighted MR imaging: a prospective study. *Radiology*. 2009;252(3):721-8.
7. Djurhuus JC, Sorensen SS, Jorgensen TM, et al. Predictive value of pressure flow studies for the functional outcome of reconstructive surgery for hydronephrosis. *Br J Urol*. 1985;57(1):6-9.
8. Whitaker RH, Buxton-Thomas MS. A comparison of pressure flow studies and renography in equivocal upper urinary tract obstruction. *J Urol*. 1984;131:446.
9. Dacher J, Pfister C, Thoumas D, Véra P, Liard-Zmuda A, Chomant J, Mitrofanoff P, Dosseur P. Shortcomings of diuresis scintigraphy in evaluating urinary obstruction: comparison with pressure flow studies. *Pediatr Radiol*. 1999;29(10):742-747.
10. Wu CF, Shee JJ, Lin WY, Lin CL, Chen CS. Comparison between extracorporeal shock wave lithotripsy and semirigid ureterorenoscope with holmium:YAG laser lithotripsy for treating large proximal ureteral stones. *J Urol*. 2004;172(5 Pt 1):1899-902.
11. Seseke F, Thelen P, Heuser M, Zöller G, Ringert RH. Impaired nephrogenesis in rats with congenital obstructive uropathy. *J Urol*. 2001;165(6 Pt 2):2289-92.
12. Seseke F, Thelen P, Hemmerlein B, Kliese D, Zöller G, Ringert RH. Histologic and molecular evidence of obstructive uropathy in rats with hereditary congenital hydronephrosis. *Urol Res*. 2000;28(2):104-9.
13. Shafik A. Ureteric profilometry: a study of the ureteric pressure profile in the normal and pathologic ureter. *Scand J Urol Nephrol*. 1998; 32(1): 14-9.
14. Mortensen J, Frokiaer J, Tofft HP, Djurhuus JC. The influence of pyeloureteral peristalsis on pelvic pressure during increase in flow rate. *Urol Res*.1988; 16(4): 295-301.
15. Roshani H, Dabhoiwala NF, Dijkhuis T, Lamers WH. Intraluminal pressure changes in vivo in the middle and distal pig ureter during propagation of a peristaltic wave. *Urology*. 2002; 59(2): 298-302.
16. Itoh K, Nonomura K, Matsuno T, Furudate M, Koyanagi T. Radionuclide constant pressure perfusion study on measurement of exit urine flow: experimental and preliminary clinical investigations. *J Urol*. 1993;150(2 Pt 1):420-6.
17. Veenboer PW, de Jong TP. Antegrade pressure measurement as a diagnostic tool in modern pediatric urology. *World J Urol*. 2011; 29(6):737-41.