Int Urogynecol J (2012) 23:49–56
DOI 10.1007/s00192-011-1540-y

ORIGINAL ARTICLE

Doppler ureteric jet in urogenital prolapse

Tsia-Shu Lo · Cheng-Yu Long · Yi-Hao Lin · Ho-Hsiung Lin

Received: 31 March 2011 / Accepted: 3 August 2011 / Published online: 17 September 2011

Abstract
Introduction and hypothesis This work was conducted to study the Doppler ureteric jets in the assessment of pelvic organ prolapse (POP) patients.
Methods Forty POP-Q stage ≧III patients and 20 without POP were assessed with color Doppler ultrasonography.
Results Among 40 POP, 28 had bladder outlet obstruction (BOO) and 4 had hydronephrosis. Comparing POP and controls, the difference in mean frequency, mean duration, and mean maximum velocity of ureteric jets was not statistically significant. The ureteric jets of POP with BOO are of longer duration and lower velocity. The frequency of ureteric jets was lower in POP with hydronephrosis. Plateau-type waveforms were much more common among POP associated with voiding and ureteric dysfunction.
Conclusions The longer duration and lower velocity of the ureteric jet are strongly correlated with prolapse-associated BOO. The plateau-type waveform and decrease in frequency of ureteric jets indicate possible hydronephrosis. Further investigation is needed to confirm the consistency of this study.

Keywords Doppler · Prolapse · Ultrasonography · Ureteric jet

Trial Registration: Institutional Review Board of Chang Gung Memorial Hospital 96-1785B

T.-S. Lo · Y.-H. Lin
Division of Urogynecology, Department of Obstetrics and Gynecology, Chang Gung Memorial Hospital,
School of Medicine, Chang Gung University,
Taoyuan, Taiwan

C.-Y. Long
Graduate Institute of Medicine, Center of Excellence for Environmental Medicine, Kaohsiung Medical University,
Kaohsiung, Taiwan

C.-Y. Long
Department of Obstetrics and Gynecology,
Kaohsiung Municipal Hsiao-Kang Hospital,
Kaohsiung, Taiwan

H.-H. Lin
Department of Obstetrics and Gynecology, College of Medicine,
National Taiwan University,
Taipei, Taiwan

H.-H. Lin
National Taiwan University Hospital,
Taipei, Taiwan

T.-S. Lo (✉)
Division of Urogynecology, Department of Obstetrics and Gynecology, Chang Gung Memorial Hospital,
Linkou Medical Center,
5, Fu-Hsin Street, Kwei-shan,
Taoyuan 333, Taiwan
e-mail: 2378@cgmh.com.tw

Introduction

Pelvic organ prolapse (POP) is commonly found in multiparous and elderly female [1, 2]. The reported prevalence is 50% and 64.8%, respectively [1, 2]. The affected women may have concomitant bladder outlet obstruction [3]. The incidence of bladder outlet obstruction is 5% for first-degree prolapse and about 40% for procidentia [3]. Hydroureteronephrosis has been recognized in patients with severe uterovaginal prolapse owing to long-term unrelieved bladder outlet obstruction [4]. Preoperative hydronephrosis was found to be 5% in POP (grade >2) candidates for surgery [4]. It is also a cause of acute renal failure in patients with POP [5]. When hydroureteronephrosis persists leading to irreversible renal dysfunction, chronic renal failure and end-stage renal failure may occur [6, 7].

Urodynamic study is the standard method for diagnosis of bladder outlet obstruction [8]. Moreover, intravenous pyelogram and diuretic dynamic scintigraphy are the most widely adopted methods in the diagnosis of hydronephrosis [9]. However, these methods are either invasive or require exposure of patients to ionizing radiation. Conventional ultrasonography (US) is a good alternative imaging modality for patients with urine retention and hydronephrosis [9]. However, it reveals only anatomical information on the volume of post-void residuals, kinking of urethra caused by POP, and the degree of collecting system dilatation, but provides no functional data [10].

Doppler analysis of ureteric jets has been applied to the evaluation of normal ureteric physiology [11], diagnosis of ureteric calculus [12], assessment of renal function, and vesicoureteric reflux [13]. The ureteric jet is the transient forceful ejection of urine from the vesicoureteric junction (VUJ) into the bladder, indicative of both renal and ureteric functions. The ureteric jets are visualized with conventional US based on the difference in specific gravity between urine in ureters and bladder but much better with color Doppler US due to the enhancement of US with Doppler effect [14]. To our knowledge, there are no studies yet on Doppler ureteric jets in patients with POP, and thus, the role of ureteric jets in POP with bladder outlet obstruction and hydronephrosis remains unknown. The aim of this study was to evaluate the color Doppler visualization of ureteric jets in the assessment of POP patients.

Materials and methods

From August 2008 to May 2010, color Doppler US was performed on 40 patients with severe uterovaginal prolapse. The Institutional Review Board of Chang Gung Memorial Hospital approved this study. Informed consent was obtained from patients. Severe uterovaginal prolapse was defined as uterus or vaginal vault prolapse of stages III and IV according to the ICS grading system on maximum Valsalva maneuver [15]. The evaluation of objective and subjective voiding function includes Urogenital Distress Inventory questionnaires [16] and Pelvic Organ Prolapse Distress Inventory 6 [17] and multi-channel urodynamic study. Patients with dysfunctional voiding related to neurological factors, urinary calculus, and pelvic pathological condition related to external compression were excluded. A conventional US on kidney and ureter was scanned for hydronephrosis and ureteric dilatation on all patients.

The multi-channel urodynamic study was recorded at maximum extent of prolapse. Bladder outlet obstruction (BOO) was assessed using bladder outlet obstruction nomogram for women [8]. Patients classified as no or mild BOO were grouped under “no BOO”, while those classified as moderate or severe BOO were grouped under “BOO”.

Color Doppler US examinations were performed on patients when they felt the sense of urgency after being well hydrated with 600 ml of plain water over a 15-min period of time. It was performed by the same person who was blinded against clinical data. The examinations were carried out using color Doppler scanners Voluson 730 expert (General Electric Medical System, Milwaukee, WI, USA) and Aloka ProSound Alpha 5 (Aloka, Tokyo, Japan). Curved array transducers with frequency ranging from 2.5 to 5 MHz were used. The subjects lie supine and the urinary bladder was scanned in the transverse plane. After the color signals were located, both color and simultaneous Doppler waveforms of the jet from the orifice were obtained from each side in turn. The number of peaks, maximum velocity, and duration of the jet were measured. The number of ureteric jets, regardless of duration, was counted over a 5-min period and the frequency of jets for each ureteric orifice was calculated in every patient.

In addition, 20 healthy patients without POP or abnormality were recruited from a group of women undergoing ultrasound examinations for urinary stress incontinence in the area of interest, serving as the control group. Furthermore, among the healthy and study groups, five patients from each group agreed to participate a second color Doppler US examination on the other day under the same setting for the testing of repeatability on the velocity measurement.

The Mann–Whitney test was used for comparison of means, the chi-square test or Fisher’s exact test was used as appropriate for categorical data, and descriptive statistics was used for the presentation of data. Pearson’s correlation was used to performed the correlation analysis. Different statistical tests were used and the difference was considered significant only if the p value was <0.05. All statistical methods were performed using the commercial software SPSS, version 15 (SPSS, Inc, Chicago, IL, USA).

Results

A total of 40 patients were recruited (22 were stage III and 18 were stage IV prolapse). Among them, only four patients were found to have hydronephrosis and all were in the BOO group. Further study on four POP patients with BOO and hydronephrosis revealed that two had marked elevated serum creatinine level. Urinary jets were identified and were satisfactorily recorded in all patients. Among the study group, the mean bladder volume of color Doppler US at scan was 336±42 ml (range, 276–582 ml), the mean frequency of jet on the right and left side was 2.21±0.50

and 2.18±0.46 jets per min, respectively, and the difference between the number of jets from the right and left side ranged from 0 to 0.35 (mean 0.025) jets per min. These differences were not statistically significant (p=0.817). In the control group, the mean bladder volume of color Doppler US at scan was 279±42 ml (range, 213–311 ml), the mean frequency of jet on the right and left side was 2.35±0.44 and 2.29±0.36 jets per min, respectively, and the difference between the number of jets from the right and left side ranged from 0 to 0.40 (mean 0.055) jets per min. These differences were not statistically significant (p= 0.667). In addition, a correlation analysis examining on the intra-examiner agreement for the maximum velocity of ureteric jets measurement on ten patients (five from each group) has shown a good correlation (Pearson's correlation 0.881, $p \leq 0.05$; 0.702). The demographics of the study and control groups were tabulated in Table 1.

Comparison was made between 40 POP patients and 20 controls. The mean frequency of ureteric jets, mean duration, and mean maximum velocity of ureteric jets of individual subgroups and control group are shown in Tables 2, 3, and 4, respectively. As can be seen, the differences in mean frequency of ureteric jets, mean duration, and mean maximum velocity of ureteric jets were not statistically significant except for the subgroups of POP with BOO and POP with BOO and hydronephrosis. The ureteric jets of POP patients with BOO are of longer duration and lower velocity. In addition to longer duration and lower velocity, the frequency of ureteric jets was also lower in POP patients with BOO and hydronephrosis.

Three types of waveforms could be identified according to the nature of the peaks observed within that particular wave. They were plateau (square and continuous) (Fig. 1), monophasic (Fig. 2), and polyphasic waveforms (Figs. 3 and 4). The distribution of these three types of waveforms among the study population is shown in Table 5. As can be seen, the incidence of plateau waveforms in the POP and POP with BOO groups was 40.0% and 57.1%, respectively. POP patients with BOO and hydronephrosis all showed plateau waveforms, while those without BOO showed no

Table 1 Demographics of the study and control groups

	Control, n=20	POP, n=40	p[a]
Mean age (years)[b]	64.2±12.2 (43.3–79.0)	66.3±12.0 (43.0–89.3)	0.523
Mean parity[b]	2.90±1.29 (1–5)	3.60±1.41 (1–6)	0.068
Mean BMI (kg/m^2)[b]	24.8±2.8 (21.2–3.06)	26.3±3.6 (20.4–35.2)	0.111
Postmenopausal	15 (75.0%)	38 (95.0%)	0.036[c]
Prolapse (ICS staging)			
Anterior wall			
Stage 0	20 (100%)		
Stages I and II			
Stage III		25 (62.5%)	
Stage IV		15 (37.5%)	
Apex			
Stage 0	20 (100%)		
Stages I and II			
Stage III		22 (55%)	
Stage IV		18 (45%)	
Posterior wall			
Stage 0	20 (100%)		
Stages I and II			
Stage III		26 (65%)	
Stage IV		14 (35%)	
Urodynamic			
No BOO	20 (100%)	12 (30.0%)	
BOO	0	28 (70.%)	
USI	20 (100%)	11 (27.5%)	
D.O.	0	4 (10%)	
Mix	0	2 (5%)	
Det.under	0	2 (5%)	
HydroN	0	4 (10.0%)	

BMI body mass index, *BOO* bladder outlet obstruction, *USI* urodynamic stress incontinence, *D.O.* detrusor overactivity, *Mix* mixed type urinary incontinence, *Det.under* detrusor underactivity, *HydroN* hydronephrosis

[a]Mann–Whitney test (p value)

[b]Data listed as mean ± standard deviation (range) with 95% CI in parenthesis

[c]Fisher's exact test

Table 2 Visualization and frequencies of ureteric jets in controls and various groups of patients (jets per minute)

Group	Patients	Jets visible	Mean jet frequency ± SD (per min), range[a]	p[b]
Control	20	40	2.32±0.40 (1.80–3.40)	
POP	40	80	2.20±0.47 (1.00–3.40)	0.332
POP—no BOO	12	24	2.33±0.51 (1.80–3.40)	0.934
POP—with BOO	28	56	2.14±0.45 (1.00–2.80)	0.166
POP—with BOO and HydroN	4	8	1.30±0.26 (1.00–1.60)	<0.01

POP pelvic organ prolapse, *BOO* bladder outlet obstruction, *HydroN* hydronephrosis

[a] Data listed as mean ± standard deviation (range) with 95% CI in parenthesis

[b] Mann–Whitney test (p value)

plateau waveform at all. When compared with the 0% incidence in the control group, the difference was statistically significant for the POP with BOO and POP with BOO and hydronephrosis groups ($p<0.01$, chi-square test; $p<0.01$, Fisher's exact test). Plateau-type waveforms were much more common among POP patients associated with voiding and ureteric dysfunction than in the normal population.

Discussion

The urethra of women with genital prolapse associated with BOO is kinked or compressed externally [3]. With urine retention attributed to severe bladder outlet obstruction, ureteral obstruction may occur secondary to prolapse [3, 4]. There will be a change in the physiology of the ureter in response to the alteration of the bladder function due to the prolapse and BOO. To our knowledge, no one has studied the ureter function in prolapse patients and no comparison has been made between prolapse and non-prolapse patients.

The ureteric jet is caused by ejection of urine into the bladder lumen by ureteric peristalsis. The frequency of jets recorded in our study ranged from 1.8 to 3.4 jets per min in non-prolapse female adults. Such finding is similar to the reported data of normal adults [12, 18] with adequate hydration. There was no statistically significant difference in frequency of jets between the right and left sides in both study and control groups.

There are no published data regarding ureteric Doppler jets in POP patients. Kuzmic and his co-authors have demonstrated that either the absence of jets or ureteric jet with reduction of jet frequency or low continuous flow ureteric jets were possible Doppler presentations on patients with obstructive hydronephrosis caused by calculus [19]. Our results demonstrate that in patients with obstructive hydronephrosis secondary to prolapse associated with BOO, ureteric jets were visible in all studied subjects and the jet flow was slow, prolonged, and continuous. A possible explanation would be that in patients with severe obstruction secondary to POP, total obliteration of the ureter is not likely to occur as the obstructed site is at the urethra with the bladder in between serving as a buffer. When the increased pressure in the obstructed collecting system needs to overcome the additional intravesical resistance to flow caused by obstruction, the resulting ureteric jet flow has to be low and prolonged. Therefore, it is obvious that the slow, prolonged, and continuous waveform is correlated with the POP with BOO group and not the group without because extensive prolapse does not necessarily imply obstruction and vice versa.

Table 3 Visualization and mean duration (second) of ureteric jets in controls and various groups of patients

Group	Patients	Jets visible	Mean jet duration ± SD (s), range[a]	p[b]
Control	20	40	2.97±0.58 (2.01–3.75)	
POP	40	80	3.30±0.76 (1.64–5.08)	0.090
POP—no BOO	12	24	2.66±0.77 (1.64–3.80)	0.176
POP—with BOO	28	56	3.57±0.44 (2.51–5.08)	<0.01
POP—with BOO and HydroN	4	8	4.17±0.63 (3.64–5.08)	<0.01

POP pelvic organ prolapse, *BOO* bladder outlet obstruction, *HydroN* hydronephrosis

[a] Data listed as mean ± standard deviation (range) with 95% CI in parenthesis

[b] Mann–Whitney test (p value)

Table 4 Visualization and mean maximum velocity (centimeter per second) of ureteric jets in controls and various groups of patients

Group	Patients	Jets visible	Mean jet max. velocity ± SD (cm/s), range[a]	*p*[b]
Control	20	40	42.3±2.79 (38.67–48.10)	
POP	40	80	38.42±10.39 (12.74–58.07)	0.111
POP—no BOO	12	24	43.6±5.87 (30.10–50.42)	0.381
POP—with BOO	28	56	36.2±11.17 (12.74–58.07)	0.022
POP—with BOO and HydroN	4	8	18.8±4.87 (12.74–24.65)	<0.01

POP pelvic organ prolapse, *BOO* bladder outlet obstruction, *HydroN* hydronephrosis

[a] Data listed as mean ± standard deviation (range) with 95% CI in parenthesis

[b] Mann–Whitney test (*p* value)

On the other hand, the reduction of jet frequency is correlated with the POP with BOO and hydronephrosis groups whose renal function may have been affected. Therefore, one can assume that compared with the duration and velocity of the jet, reduction of jet frequency demonstrates a more severe dysfunctional status on the upper urinary tract.

The ureteric jet waveform has shown to have one to three peaks in adults [20]. This observation is further classified into six patterns by Leung et al. [21]. The biphasic, triphasic, and polyphasic patterns are taken as the physiological steady-state mature mode. The monophasic pattern is predominant in children and indicates immaturity. The square and continuous patterns are taken as the diuretic stress and physiological unsteady-state mode. The physiological steady-state mature mode of ureteric jet waveform is supported with a postulated mechanism [21]. When a bolus of urine enters the terminal portion of the ureter, it builds up the intraureteric pressure. The closed VUJ sphincter is then opened at a certain trigger pressure with a pressure range for the ejection of urine into the bladder as a jet in response to the rise of intraureteric pressure. The VUJ sphincter is closed when the resulting distal intraureteric pressure falls below the trigger pressure. If urine travels and enters the distal portion of the ureter continuously, the sphincter is then relaxed as the increased intraureteric pressure breaks through the trigger pressure level again. This cycle continues until the distal ureter is empty and the jet waveform shows more than one peak.

In our study, the ureteric jet pattern of POP patients with BOO and hydronephrosis secondary to prolapse revealed a more unsteady-state mode. The definition of BOO is

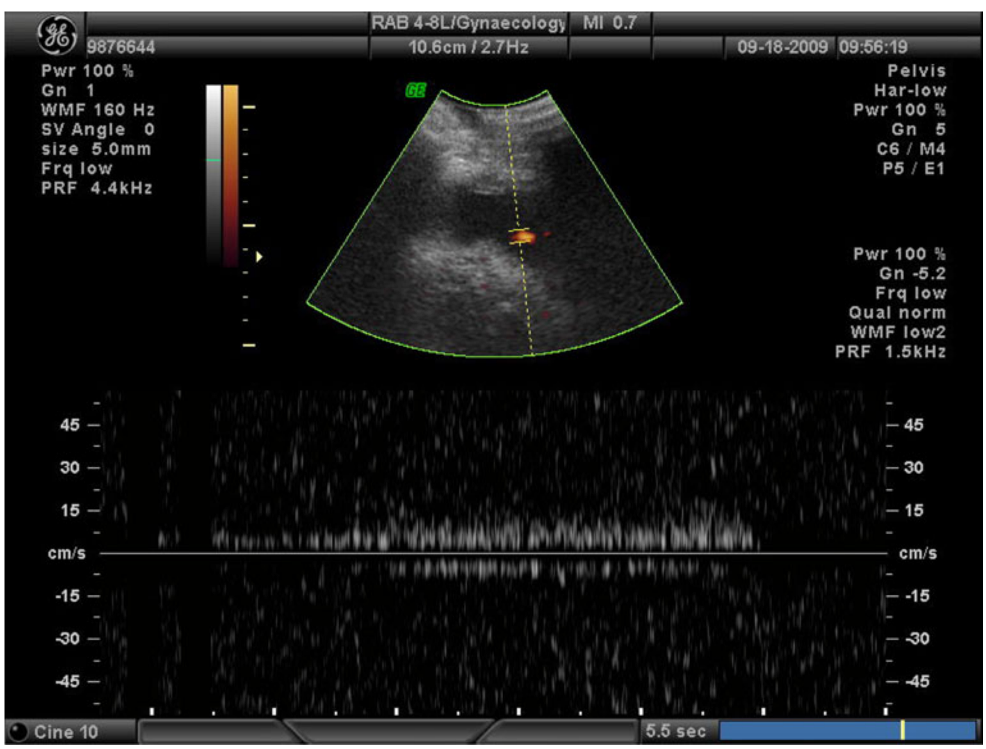

Fig. 1 Patterns of the ureteric jet: plateau (continuous)

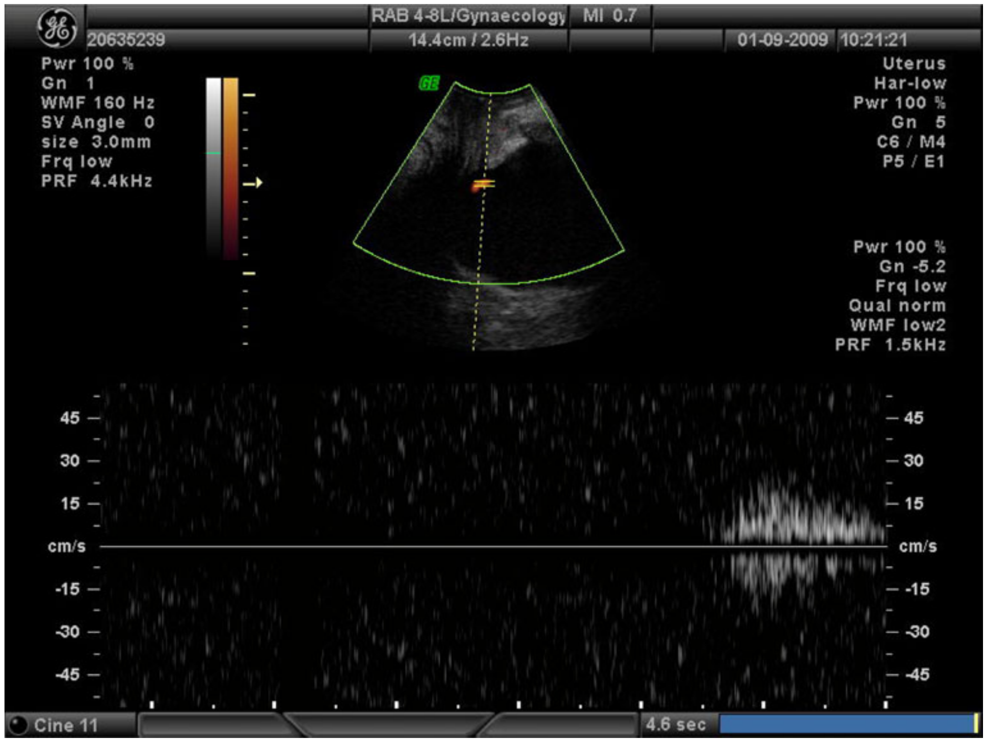

Fig. 2 Patterns of the ureteric jet: monophasic

defined urodynamically with an increase of detrusor pressure at maximum flow (DetPmax) in association with the decrease of urinary flow [8]. The detrusor pressure at maximum flow is relatively high in POP patients associated with BOO as compared with the normal study group. It is therefore understood that the trigger pressure for the VUJ sphincter to open is set to be high on POP patients, which brings the intraureteric trigger pressure closer to the intravesical pressure. With low pressure gradient, the ejection would be lower and the slope would also be less steep. The peak of the ureteric jet waveform is demolished and the waveform seems to be flattened. It would also

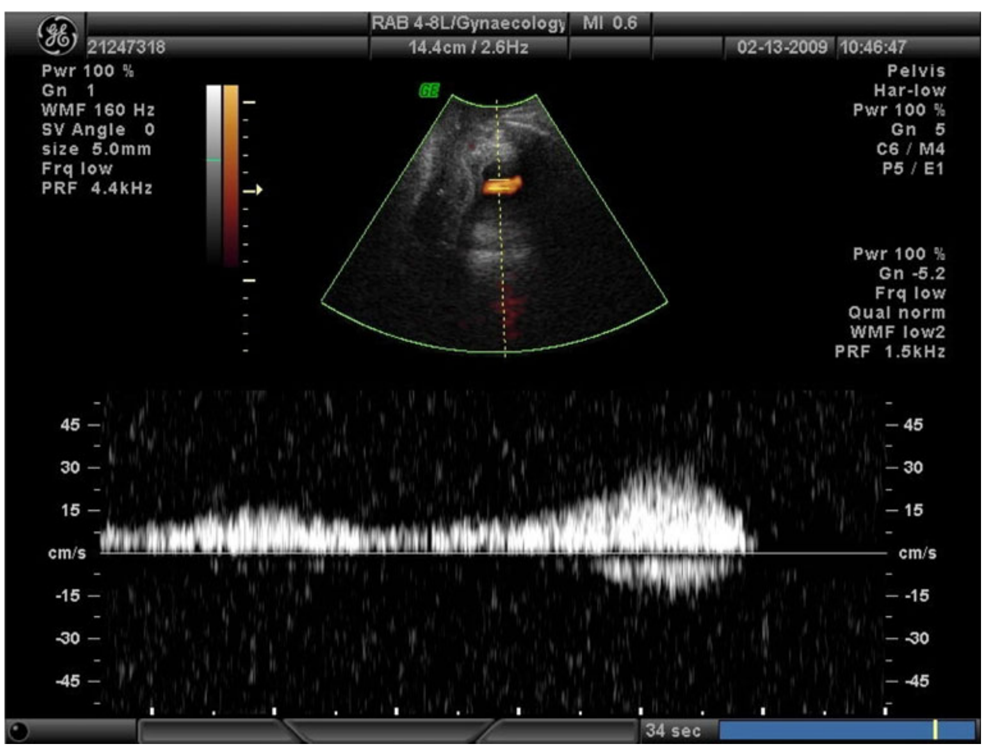

Fig. 3 Patterns of the ureteric jet: polyphasic (biphasic)

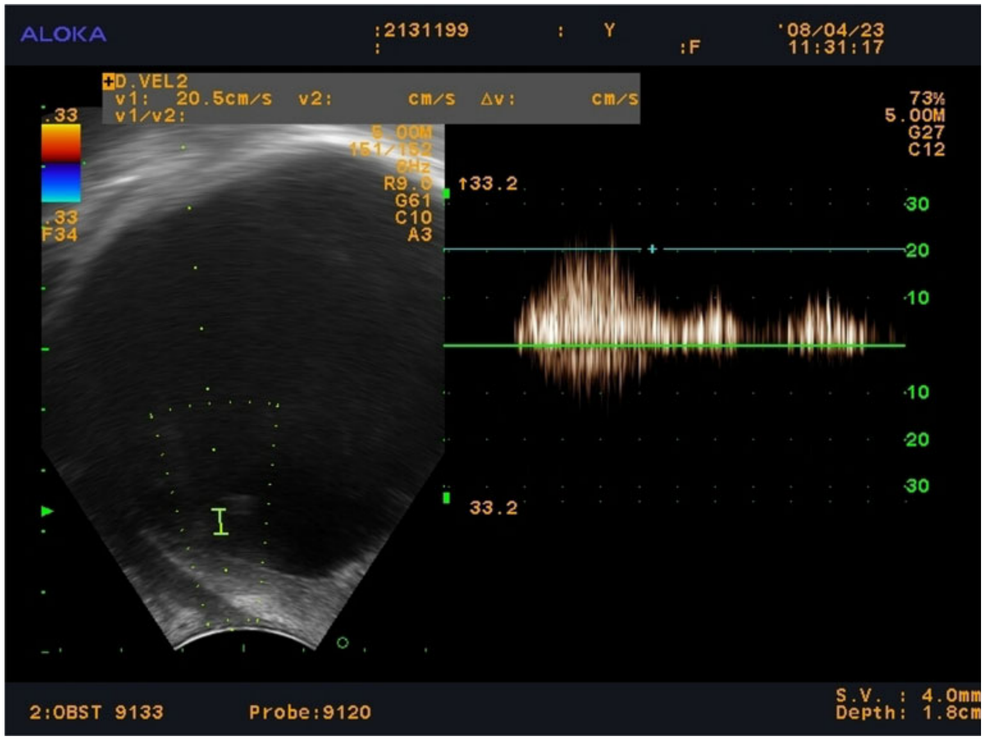

Fig. 4 Patterns of the ureteric jet: polyphasic (triphasic)

prolong the complete expulsion of the urine bolus. This is further reflected by the objective difference in mean jet velocity and mean duration.

Although the evaluation of ureteric jets may add information concerning ureteric function in POP patients, it is important to recognize the limitations of this technique. Doppler diagnosis is very dependent upon the proper examination technique [21]. The frequency of ureteric jet visualized on Doppler varies much with the manner of hydration. With more fluid taken within a short period of time, the ureteric jet is visualized more rapidly. Therefore, standardized management of hydration is needed for all in order to obtain a consistent feature of urinary jets.

Moreover, the ureteric jet waveform can be modified by the intravesical pressure during examination [21]. Our results might have been better with a maximum bladder capacity. However, in our earlier study performed with maximum bladder capacity, patients became uncooperative and restless; hence, we shifted the bladder condition to a comfortable bladder. This seemed to offer a reasonable compromise between good data collection on the one hand and patient cooperation on the other.

In a POP condition, the accuracy of the measurement on BOO relies heavily on the urodynamic study. The procedure is invasive, expensive, and not always available for all units. Furthermore, it is not a diagnostic method for evaluating the upper urinary tract function and additional image study is needed. In this study, the measurement of ureteric jet pattern and morphology is a single procedure, much easier to obtain, and does not require catheterization and micturation. There is no evidence on the literature to suggest that color Doppler US should replace other measuring methods or incorporate into clinical practice on BOO and POP. However, the technique may feasibly be

Table 5 Visualization and waveform of ureteric jets in controls and various groups of patients

Group	Patients	Jets visible	Plateau	Monophasic	Polyphasic
Control	20	40	0	10 (25%)	30 (75%)
POP	40	80	32 (40%)	14 (17.5%)	34 (42.5%)
POP—no BOO	12	24	0	6 (25.0%)	18 (75.0%)
POP—with BOO	28	56	32 (57.1%)	8 (14.3%)	16 (28.6%)
POP—with BOO and HydroN	4	8	8 (100%)	0	0

Patterns of the ureteric jet: plateau = square and continuous; polyphasic = biphasic, triphasic, and polyphasic

POP pelvic organ prolapse, *BOO* bladder outlet obstruction, *HydroN* hydronephrosis implemented in no urodynamic equipped clinical practice for evaluating patients with advanced stage POP.

Conclusion

The results of our study indicate that longer duration and lower velocity of the ureter jet are strongly correlated with prolapse associated with bladder outlet obstruction. In POP patients, the presence of plateau-type waveform and the decrease in frequency of ureteric jets on color Doppler US on POP patients indicate possible occurrence of hydronephrosis secondary to prolapse and ureteral obstruction. As this is a small pilot study, we have planned further investigations to determine whether examination of the ureteric jet waveform shows reproducible results in assessing ureteric function in prolapse.

Acknowledgment This study was supported by National Science Council Research Grants NSC 97-2314-B-182A-060.

Conflicts of interest None.

References

1. Digesu GA, Chaliha C, Salvatore S, Hutchings A, Khullar V (2005) The relationship of vaginal prolapse severity to symptoms and quality of life. BJOG 112:971–976
2. Gerten KA, Markland AD, Lloyd LK et al (2008) Prolapse and incontinence surgery in older women. J Urol 179:2111–2118
3. Marinkovic SP, Stanton SL (2004) Incontinence and voiding difficulties associated with prolapse. J Urol 171:1021–1028
4. Costantini E, Lazzeri M, Mearini L, Zucchi A, Del Zingaro M, Porena M (2009) Hydronephrosis and pelvic organ prolapse. Urology 73:263–267
5. Yanik FF, Akpolat T, Kocak I (1998) Acute renal failure—an unusual consequence of uterine prolapse. Nephrol Dial Trasplant 13:2648–2650
6. Moore S, Bailey RR, Maling TMJ (1978) Urinary tract obstruction and renal failure due to uterine prolapse. NZ Med J 87:429–431
7. Nassberger L, Larsson R (1982) End-stage chronic renal failure due to total uterine prolapse. Acta Obstet Gynecol Scand 61:495–497
8. Blaivas JG, Groutz A (2000) Bladder outlet obstruction nomogram for women with lower urinary tract symptomatology. Neurourol Urodyn 19:553–564
9. Bueschen AJ, Lockhart ME (2011) Evolution of urological imaging. Int J Urol 18:102–112
10. Dietz HP (2010) Pelvic floor ultrasound: a review. Am J Obstet Gynecol 202:321–334
11. Cox IH, Erickson SJ, Foley WD, Dewire DM (1992) Ureteric jets: evaluation of normal flow dynamics with color Doppler sonography. Am J Roentgenol 158:1051–1055
12. Burge HJ, Middleton WD, McClennan BL, Hildebolt CF (1991) Ureteral jets in healthy subjects and in patients with unilateral ureteral calculi: comparison with color Doppler US. Radiology 180:437–442
13. Blomley MJ, Ramsey CM, Cosgrove DO, Patel N, Lynch M, Glass DM, Peters AM (1997) The ureteric jet index: a novel measure of divided renal function. Clin Radiol 52:771–774
14. Jequier S, Paltiel H, Lafortune M (1990) Ureterovesical jets in infants and children: duplex and color Doppler US studies. Pediatr Radiol 175:349–353
15. Abrams P, Blaivas JG, Stanton SL, Andersen JT (1990) The standardization of terminology of low urinary tract function recommended by the International Continence Society. Int Urogynecol J 1:45–58
16. Shumaker SA, Wyman JF, Uebersax JS, McClish D, Fantl JA (1994) Health-related quality of life measures for women with urinary incontinence: the Incontinence Impact Questionnaire and the Urogenital Distress Inventory. Qual Life Res 45:1201–1218
17. Barber MD, Walters MD, Bump RC (2005) Short forms of two condition-specific quality-of-life questionnaires for women with pelvic floor disorders (PFDI-20 and PFIQ-7). Am J Obstet Gynecol 193:103–113
18. Dubbins PA, Kurtz AB, Darby J, Goldberg BB (1981) Ureteric jet effect: the echographic appearance of urine entering the bladder. Radiology 140:175–177
19. Kuzmic AC, Brkljacic B, Rados M, Galesic K (2001) Doppler visualization of ureteric jets in unilateral hydronephrosis in children and adolescents. Eur J Radiol 39:209–214
20. Wu CC, Yao WJ, Lin F Jr, Hsieh HL, Hwang MH (1995) Spectral analysis of ureteral jets by color Doppler ultrasonography: a preliminary uretero-dynamic study. J Med Ultrasound 3:64–69
21. Leung VY, Chu WC, Yeung CK, Metreweli C (2007) Doppler waveforms of the ureteric jet: an overview and implications for the presence of a functional sphincter at the vesicoureteric junction. Pediatr Radiol 37:417–425