Evaluation of Distal Ureter Peristalsis by Multichannel Impedance Monitoring in Patients with Renal and Ureteral Stones

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Abstract— **Distal ureter peristalsis was evaluated during ureteroscopic examination by means of multichannel impedance ureterography in 30 patients with renal and ureteral stones and in 3 patients with normal ureters. The documented data included the number of ureteric contractility parameters such as peristalsis amplitude, peristalsis rate, ureteral wall tone, duration and velocity of contractions, characteristics of contractile waveforms and their direction (antegrade, cystoid, or retrograde). Peristalsis amplitude tended to decrease while ureteral wall tone had a tendency to increase in patients with stones compared to normal ureters, although both parameters markedly differed in individual patients. As a rule, peristalsis was more disturbed at stone location. More cases of aberrant peristalsis were found in distal (54%) or proximal (45%) ureters with stones compared to the cases with stones in kidney (10%). The retrograde contractile waves were frequently observed in patients with renal (50%), proximal (56%) and distal (25%) ureteral stones. The antegrade peristaltic waves remained in 50% ureters with proximal stones and only in 12% ureters with distal stones. The multichannel impedance ureterography can be employed as a reliable method to study contractile function of a ureter. It may be useful for proper treatment modality choice in patients with urodynamic disorders.**

Keywords— **Ureter, peristalsis, multichannel impedance ureterography.**

I. INTRODUCTION

Contractile phenomenon in ureter is an important feature of urodynamics in the upper urinary tract which contributes to urine transport from renal pelvis to the urinary bladder.

To assess ureteric peristalsis, a variety of different methods are used based on visualization technique or the physiologic measurements. The visualization methods assess general ureteral structure and yield data on peristaltic frequency. The physiological measurements of ureteral function elucidate the intrinsic processes of muscle wall irritation and contraction. They include electromyography, impedance and pressure processing. However, for clinical application, only the intraluminal pressure measurements along ureter were described to measure peristaltic frequency, pressure, and conduction velocity [1, 2]. Paradoxically, the impedance measurements received little attention in clinical trials despite its experimentally demonstrated potency in examination of ureteral function [3, 4].

The uroliths severely disturb urine transport due to obstruction to urine flow. After stone removal, recovery of peristaltic function of distal ureter is critical for urine propelling into a bladder. It is also important for urodynamic restoration and protection of renal parenchyma from the backward pressure impulses and urine refluxes.

The aim of present study was to apply a multichannel impedance monitor as a tool to assess ureteric peristalsis in patients with various stone location in the upper urinary tract.

II. MATERIALS AND METHODS

Patients: Thirty patients with renal (8) and ureteral (22) stones, and three patients who had no calculus in the upper urinary tract were randomly included in this study. Of 8 patients with renal stones 7 patients had unilateral and 1 had bilateral calculi. Of 22 patients with ureteral stones 12 had urolith in proximal ureter, and 10 – in distal ureter (one patient had bilateral stones). They all underwent retrograde ureteroscopy (URS) and endoscopic lithotripsy (LT). Three patients without stones were examined during diagnostic URS, their ureters were considered as normal. Those were the patients under suspicions of roentgen-negative stones in the upper urinary tract.

Study Design: The distal (juxtavesical) ureter peristaltic function was assessed in patients with different stone location in the upper urinary tract. A total of 32 ureters with renal (10), proximal (11) or distal (11) ureteral stones were examined before (24) or after (8) litotrypsy sessions and compared to 3 normal ureters.

Technique: Function of ureter was evaluated by multichannel impedance ureterography (MIUG). This method was carried out using a 8F probe inserted into a distal ueter endoscopically. The signals were fed to an impedance converter "RPKA2-01" ("Medass", Russia). The measuring probe was equipped with 9 consecutively incorporated separate electrodes. The current (2 mA and 32 kHz frequency) was driven to extreme (the 1st and the 9th) electrodes of the probe, while the interim electrodes served for impedance measurements. The potential differences from the consecutive six pairs of

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measuring electrodes (2-3; 3-4; 4-5; 5-6; 6-7; 7-8) permitted to obtain the impedance waveform of the adjacent parts of the ureter during its activity. Original software (MCDP 32) provided simultaneous 6-channel monitoring of the impedance values.

Calculation: Evaluation of ureteral function was performed automatically according to the following parameters of impedance ureterogram (Fig. 1):

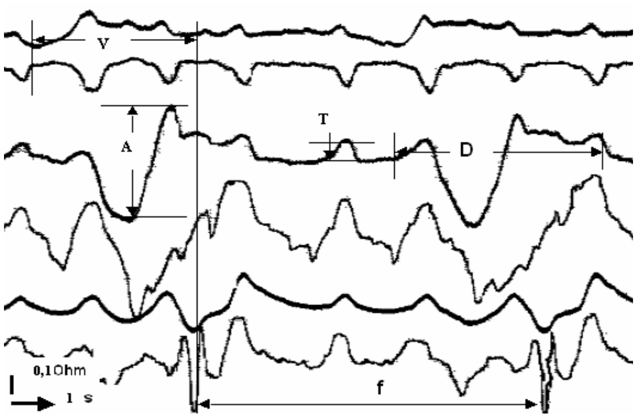

Fig. 1 Calculation of ureteral peristalsis parameters from MIUG traces. A- amplitude of a peristaltic wave was calculated as the maximal deflection of impedance during contraction of ureter; T- ureteral wall tone was an inverse value of impedance deflection taking place immediately to rhythmic breathing activity; D- duration of a contractile wave; f- time period between consecutive contractions; V- velocity of contractile wave was calculated according to the interval between impedance deflections at the 1st and the 6th channel and the distance between these electrodes (75 mm)

In addition to quantitative parameters of ureteric function, multichannel impedance monitoring yielded qualitative characteristics of the upper urinary tract peristalsis. They included the shape of peristaltic wave and the direction of its propagation (antegrade, retrograde, cystoid, chaotic), as well as their rhythmicity.

III. Results

Distal ureter peristalsis in normal ureters: The patients subjected to diagnostic URS that had no stones or urodynamic disorders demonstrated antegrade peristaltic waves ensuring coordinated urine transport into a bladder (Fig. 2a). The peristalsis amplitude ranged from 0.6 to 3.3 Ohm, while the ureteral wall tone varied from 0.8 to 4.7 Ohm^{-1}.

Ureteral peristalsis in stone disease: Average data showed that all the patients with stones in upper urinary tract had a decreased amplitude of ureteric peristalsis by 52-78% and elevated ureteral wall tone (by more than two time) as compared to the normal ureters (Table 1).

Table 1 Characteristics of ureteric peristalsis in patients with various stone location who underwent lithotripsy session (LT) and ureteroscopy (URS)

Parameters	Renal stones before LT	Upper ureter stones before LT	Distal ureter stones before LT	Distal ureter stones after LT	Ureters without stones during URS
Amplitude (Ohm)	1.0±0.1	0.7±0.1	0.7±0.2	0.5±0.05	2.1±0.9
Duration of a contraction (s)	7.1±0.4	7.6±0.2	8.6±0.7	8.1±1.1	9.9±0.8
Frequency of contractions per minute	2.9±0.1	2.8±0.2	3.6±1.5	2.7±0.8	2.0±0.7
Tone of ureteral wall (1/Ohm)	4.2±0.5	4.8±0.3	4.0±1.6	7.2±0.9	2.2±1.4
Velocity of contraction (cm/s)	2.3±0.7	2.9±1.1	-	2.1±1.0	1.3±0.3
Antegrade waves (%)	50	9	-	12	100
Retrograde waves (%)	50	54	-	25	-
Cystoid contractions (%)	50	63	-	50	-
Aberrant peristalsis (%)	10	45	100	38	-

In the ureters of patients with stone disease, peristalsis rate was greater by 35-81%, the contractile wave duration shorter by 13-28%, and the velocity of contraction larger by 64-125% in comparison with normal ureters. In this study, the propagation velocity of contractile waves was calculated only for antegrade contractions.

In stone patients, there was a wide range of peristaltic patterns. Considerable variations in size and form of instantaneous impedance waveform were observed in ureters of patients with stones or immediately after their removal (Fig. 2). Pronounced contractile waves assumed different directions: side by side with antegrade peristaltic waves that spread down a distal ureter towards the urinary bladder, the retrograde waves (b) running in the opposite direction were also recorded, and simultaneous contraction of the whole distal cystoid (c) were commonly encountered. Aberrant peristalsis was found in 37.5% ureters of patients with stones, where the contractile waves could be hardly distinguished, and the weak chaotic waves on impedance ureterogram looked like breathing and cardiovascular waves (e).

Distal ureter peristalsis in patients with renal stones. The most typical mode of peristalsis in ureters of patients with the stones located in renal pelvis consisted of retrograde (Fig. 2b) and deformed cystoid contractile waves (Fig. 2c) or their combination with antegrade waves (Fig. 2d). In these patients, peristaltic arrhythmia was typical.

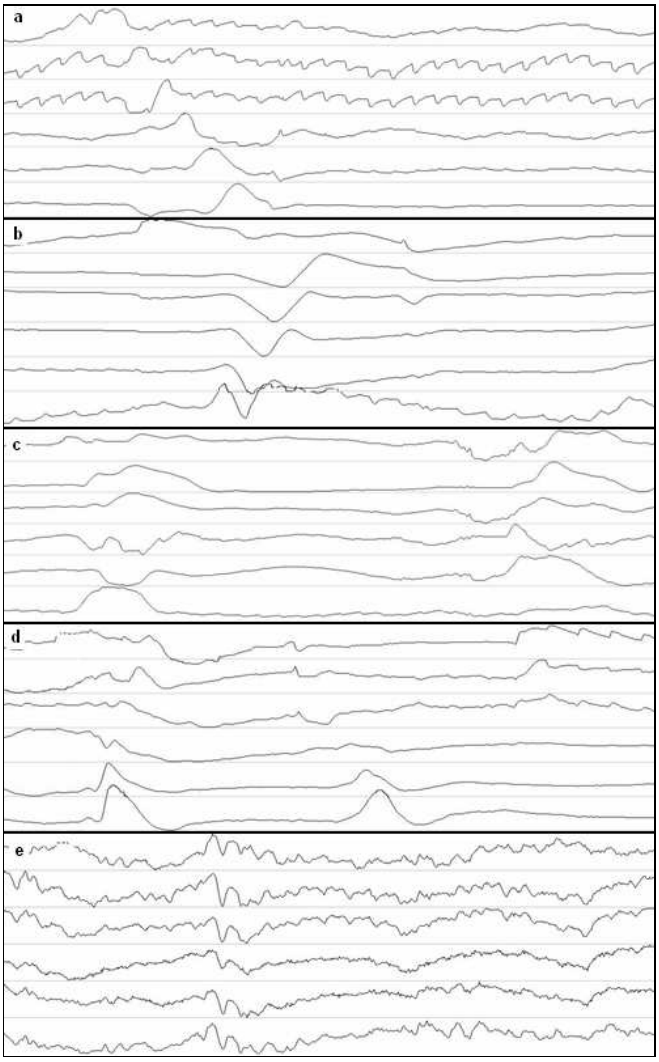

Fig. 2 Examples of MIUG in patients (a) with normal ureter; (b,c) with stones in renal pelvis (b) demonstrating retrograde peristalsis; (c) peristalsis arrhythmia, retrograde, antegrade and short cystoid contractile waves; (d) with stone in uretero-pelvic segment demonstrating aberrant peristalsis. The recording period was 24 s

Such evident peristaltic activity was observed in the most (78%) examined ureters. Here, the peristalsis amplitude ranged from 0.6 to 2.4 Ohm while ureteral wall tone ranged from 1.4 –to 5.0 Ohm^{-1}. The ureter of only one patient demonstrated extremely weak peristalsis (0.1 Ohm) accompanied by elevated tone of ureteral wall (10.7 Ohm^{-1}) referred to aberrant peristaltic mode. It was one of three ureters that were stented for 1.0-1.5 months before the lithotripsy procedures. Two others demonstrated the moderately high peristalsis amplitude (1.0 and 1.9 Ohm), with antegrade, retrograde and cystoid contractile waves.

Ureteic peristalsis in patients with stones in the upper third of ureter: As assessed by quantitative and qualitative parameters, ureteric peristalsis in these patients differed from that with renal stones. The peristalsis amplitude was lower (range 0.2-1.6 Ohm), while the ureteral wall tone was higher (range 1.4-7.2 Ohm^{-1}) in comparison with those with renal stones. Cystoid and retrograde contractions prevailed, and the antegrade contractions were rare. Propagation velocity of the contractile wave in the ureter was the greatest among all examined ureters. In these patients far more ureters demonstrated weak irregular contractions (4 of 11, 36%), than in patients with renal stones. This mode of ureteral contractile function was referred to an aberrant peristalsis (Fig. 5).

Ureteric peristalsis in patients with stones in distal ureter. Aberrant peristalsis was recorded in 100% patients examined before stone destruction and in 38% patients observed immediately after stone removal. Among them two patients were subjected to dilation of a uretero-vesical orifice during URS. Despite this mechanical procedure, they demonstrated quite regular peristalsis with well-defined cystoid contractions in the distal ureter. One of these patients had diminished peristalsis amplitude (0.2 Ohm), the other's value was 0.6 Ohm, and both patients had elevated ureteral wall tone (5.4 and 9.8 Ohm^{-1}, respectively).

IV. Discussion

It is assumed that transport of urine from kidney into the bladder is performed by gradual contractions of ureter that looks like antegrade peristaltic movements. This antegrade peristalsis serves to protect the renal parenchyma. It can be reliably concluded that peristaltic contraction wave in normal ureter travels from proximal to distal regions, i.e. antegradely. In contrast, distally generated backflow accompanying the retrograde contractile waves can produce backward pressure and urine refluxes that are dangerous for kidney.

In this study, the multichannel impedance method allowed evaluation of ureter peristalsis quantitatively (the peristalsis amplitude, the peristalsis rate, duration and velocity of contractile wave propagation, and ureteral wall tone) and qualitatively, - according to contractile waveform and its direction (antegrade, retrograde, or cystoid). The antegrade distribution of peristaltic waves along the ureter was characteristic of normal ureters.

The retrograde waves were found in patients with stones in kidney (50%) as well as in distal and proximal ureters (25-54%). These waves can indicate urine refluxes, and signify about urine backflow. Cystoid contractions recorded by MIUG represent simultaneous contraction of ureteral region 7.5 cm in length, which is equal to the distance between the 1^{st} and the 6^{th} pair of electrodes.

In clinics, the methods evaluating ureteral peristalsis based on visualization technique are advantageous since they are not invasive, although they permit only quantification of ureteral peristaltic frequency. This urodynamic parameter fails to reflect ureteral function comprehensively. Our study showed that peristalsis rate did not differ significantly in patients with various stone location.

Usage of the ureteric pressure transducer catheter in an attempt to compare the human ureteric response to drugs showed that they had no effect on contraction frequency [2]. The authors recorded the mean number of contractions 0–4.1/min, and the conduction velocity (1.5 to 2.6 cm/s). In pigs, the propagation velocity of peristaltic wave through the ureter was approximately 2 cm/s [5].

In this study, peristalsis velocity recorded by MIUG was 1.3 cm/s in normal ureters, and a little bit higher (2.1-2.9 cm/s) in the ureters of patients with stones in the upper urinary tract. Such results may reflect the specificity of ureter peristalsis in patients with urinary stones. Probably, stone-caused irritations induced rapid and simultaneous contractions in distal ureter despite presence of a stone. Such cystoid contractile activity of distal ureter was often observed in cases of kidney (50) or ureteral (63%) stones.

Moreover, multichannel impedance measurements showed that the ureters with stones demonstrated decreased peristaltic amplitude and increased ureteral wall tone compared to normal ureters. The amplitude was smaller if impedance was measured near to calculus. The lowest peristalsis amplitude and the highest tone were recorded in the ureters with distally situated stones especially after instrumentation during lithotripsy session.

The decreased contractile activity due to procedure of stone destruction can be responsible for its modulation via a direct mechanical effect. However we observed overt contractions of distal ureter after instrumentally dilated ureterovesical orifice or stent indwelling. In contrast, the aberrant peristalsis without apparent contractions of a ureter was documented in some patients with various stone location. Thus, MIUG can shed light on the individual intrinsic features of ureter.

The data in this study are in collaboration with the recently reported results on the usage of a ureteral pressure transducer catheter, which records peristaltic frequency, conduction velocity, and intraureteral pressure in patients who had undergone ureteroscopy with or without stone removal who suggested that the instrumented human ureter displayed a variable response [1].

Since ureteral peristalsis have evolved as important factors in routine clinical urology, MIUG method can be useful for deciphering the role of ureteric peristalsis in urinary transport.

V. CONCLUSIONS

The method of multichannel impedance ureterography is an efficient diagnostic tool to examine ureteric function. This method allows evaluation of ureteric peristalsis quantitatively in terms of peristalsis amplitude, peristalsis rate, duration and propagation velocity of the contractile wave, ureteral wall tone. It also provides qualitative assessment of contractile wave shape and direction (antegrade, retrograde, cystoid). The mode of peristalsis varied greatly in ureters of individual patients. However peculiar features were found in the ureters of patients with stone disease, which differed in patients with various stone location. The weak irregular contractile function and high ureteral wall tone were often characteristic of distal ureteral stones. Apparent contractile waves of antegrade and retrograde direction traveled equally with cystoid contractions in ureters of patients with renal stones. Aberrant peristalsis as well as evident cystoid and retrograde contractions was characteristic of proximal ureteral stones.

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