Conforming an Extracorporeal Lithotripter System for Video Urodynamic Studies

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Abstract

Objectives: This study aimed to evaluate the efficiency using existing fluoroscopic unit and lithotripter table of an extracorporeal lithotripter system for video urodynamic studies (VUDS) to determine anatomical abnormalities in patients with neurogenic lower urinary tract dysfunction (NLUTD). **Methods**: The extracorporeal lithotripsy system was adapted to obtain optimum fluoroscopic view according to body shape and observed organs of patients. We reviewed the VUDS data of 25 patients with NLUTD. **Results**: "Christmas tree bladder" (CTB) was found in 5 (20%) patients. Vesicoureteral reflux (VUR) and external detrusor sphincter dyssynergia (DESD) were detected in 3 (12%) and 4 (16%) patients, respectively. Four (16%) patients with normal coordination between detrusor contraction and external sphincter relaxation were proven by VUDS. CTB, VUR, or DESD was not observed in 10 (40%) patients with flaccid bladder. Hematuria, urinary tract infection, or autonomic dysreflexia did not occur in any of the patients. **Conclusions**: VUDS can discern anatomical abnormalities of the urinary tract, and patients in undeveloped areas of the world who have NLUTD can have easier access to VUDS because of the decreasing capital cost of VUDS.

Keywords: Video urodynamics, Neurogenic lower urinary tract dysfunction, Extracorporeal lithotripsy system, Set-up investment, Complications

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Introduction

Urodynamic test has been considered a "starting point" in the diagnosing lower urinary tract dysfunction (LUTD), which can lead to optimal and individual protocols for patients with LUTD (1). However, pivotal anatomical abnormalities of the urinary tract may be overlooked by conventional urodynamic studies (UDS), in which the function of lower urinary tract are evaluated by cystometry and pressure-flow study. Therefore, those radiologic images are used simultaneously during conventional UDS to determine anatomical

abnormalities of the urinary tract according to its function (2). In 1980, video urodynamics studies (VUDS), in which UDS and fluoroscopic cystourethrographies were synchronously documented, were conducted to evaluate the complicated LUTD, including urinary incontinence, complex bladder outlet obstruction, and neurogenic bladder, in approximately 900 consecutive tests by Webster and Older (3). Given that both possible functional pathognomonic traits in cystometry and pressure-flow tests and morphological abnormalities in urinary tract were synchronously detected by VUDS, which can be utilized to prevent complications of neurogenic lower urinary tract dysfunction (NLUTD), including chronic kidney disease (CKD) and refractory urinary tract infections (UTI), it has been considered as the gold standard for NLUTD evaluation (4,5).

Although the combination of radiological C-arm and urological table is mostly used to generate synchronous fluoroscopic images of urinary tract in VUDS, the huge investment for VUDS set-up and facilities for radiation safety has hindered the popularization of VUDS in mainland China, except for a few neuro-urological centers in major metropolises, for example BeiJing, ZhengZhou, and GuangZhou (6,7). However, extensive utilization of extracorporeal lithotripter system (ECLS) is attributed to the high incidence of urolithiasis in China, but whether it is reasonable to use existing C-arm, fluoroscopy table, and radiation safety facilities for ECLS to simultaneously obtain radiological images during UDS for VUDS is unknown? If it is feasible, VUDS will be more easily accessible in undeveloped areas of world and thus decrease the incidence of urological complications of NLUTD. Hence, the objective of this study was to evaluate the efficiency of using existing fluoroscopic unit and lithotripter table of an extracorporeal lithotripter system for VUDS to determine anatomical abnormalities in patients with NLUTD.

Materials and methods

Patients

This study combined an extrocorporal lithotripter system with conventional UDS to perform VUDS in a single hospital from October 2015 to June 2019. The study obtained ethical committee approval (no. 2015014), and all patients included in the study provided informed consent.

Pre-test evaluation

All patients underwent standard pre-test evaluation was performed in including medical history, physical examination, urine culture, serum creatinine assay, and computed tomography of the urinary system. No bacterium was found in the urine culture of any of the patient.

Technique procedures

The HK. ESWL-V extracorporeal lithotripsy system (Wikkon, Shenzhen, China), including the electromagnetic shock wave source, X-ray C-arm localization system, lithotripter table, and controlling unit, was used in this trial, and the table can move three-dimensionally (3D) up to 10 centimeters (cm). The Ellipse urodynamic system (Andromeda, Enschede, Netherlands) could synchronously integrate urodynamic measurement values with images sequences.

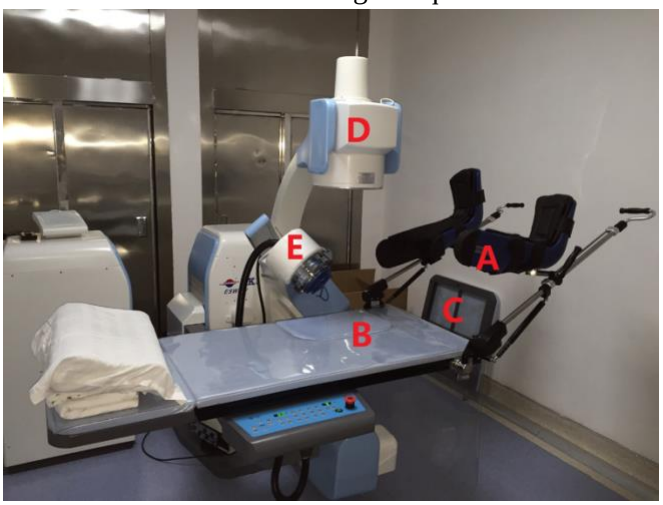

Figure 1. A pair of Power-lift Stirrups (A) was integrated with both sides of lithotripsy table (B) after the detachable tail portion (C) was detached and the optimum fluoroscopic view of X-ray C-arm (D) was achieved by adjusting the shock wave generator (E).

A pair of Power-lift Stirrups (Wikkon) was connected with both sides of the lithotripter table after the detachable tail portion of lithotripter table was detached.

The shock wave generator was adjusted to an angle, with which the optimum fluoroscopic view of radiological C-arm was achieved (Figure 1). The lithotripsy table can move 3D to some extent (up to 10 cm) to achieve optimum fluoroscopic view according to patients' body shape and observed organs (bladder, ureter, and kidney).

VUDS test

All patients were required to be in the lithotomy position. The urinary bladder was infused with diluted contrast agent through an 8-F transurethral catheter. Sphincter electromyography (EMG) used perianal surface electrodes. VUDS was performed by combining cystometry and pressure-flow study with fluoroscopy. Two urologists independently interpreted the results of the VUDS. All methods, definitions, and units conform to the standards recommended by the International Continence Society (8).

Results

A total of 25 patients with neurogenic bladder underwent VUDS. "Christmas tree bladder" (CTB) was found in 5 (20%) patients, in whom poor bladder compliance was observed. The vesicoureteral reflux (VUR) and external detrusor sphincter dyssynergia (DESD) were detected in 3 (12%) and 4 (16%) patients, respectively. However, as shown in Figure 2A and B, both CTB and VUR were observed at a low intravesical pressure of 20 cmH2O in cystometry in a 60-year-old male patient with thoracic spinal cord injury due to a traffic accident 42 years ago and had complained of frequency, nocturia, urgency, and difficulty in micturition in the squatting posture. Figure 3 shows that DESD, which is characterized by involuntary contraction of the striated urethral and periurethral musculature during involuntary detrusor contractions, was observed in a pressure-flow study of VUDS in a 14-year-old girl with Hinman syndrome (non-neurogenic neurogenic bladder). The girl had episodes of nocturnal enuresis, intermittent urination, and strain voiding for more than 10 years. Although DESD was found by VUDS, relaxation of the bladder neck was detected when the patient complained of strong desire to void at a bladder volume of 400 mL.

Normal coordination between detrusor contraction and external sphincter relaxation during voiding phase were also proven by VUDS in 4 (16%) patients.

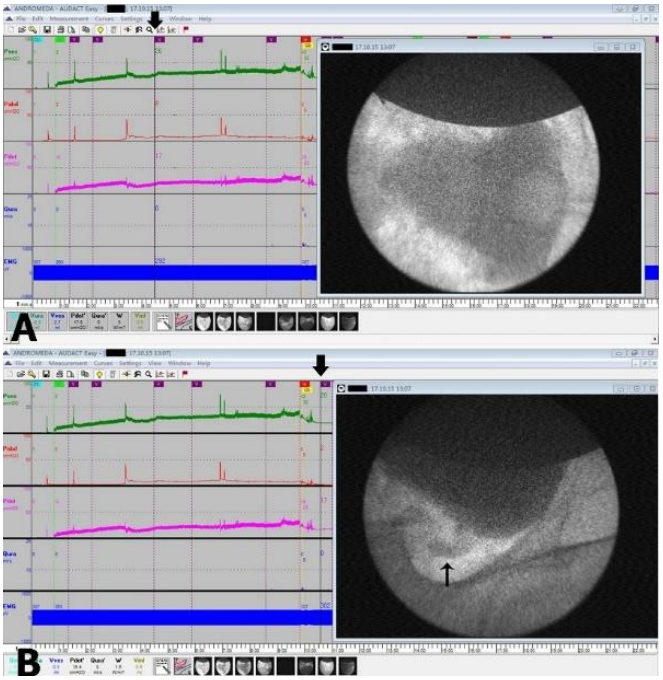

Figure 2. (A) The Christmas tree bladder (CTB) and (B) vesicoureteral reflux (VUR) (thin arrow) were demonstrated at a low intravesical pressure of 20cmH2O (thick arrow) in cystometry in a 60-year-old male patient with thoracic spinal cord injury. The patient who was involved in a traffic accident and sustained the spinal cord injury 42 years ago had complained of frequency, nocturia, urgency and difficulty in micturition in the squatting posture.

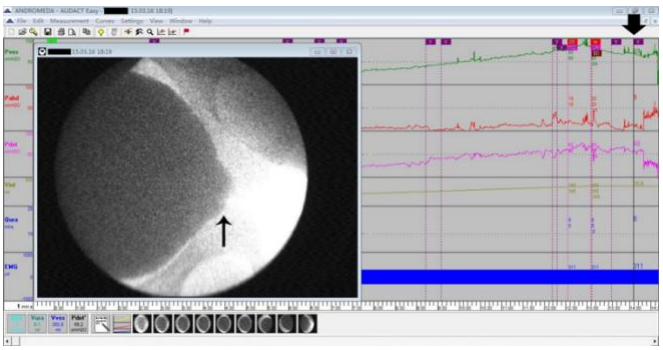

Figure 3. Detrusor–external sphincter dyssynergia (DESD) was represented in a 16-year-old girl with Hinman syndrome who had episodes of nocturnal enuresis, intermittent urination, and strain voiding for more than 10 years. Relaxation of bladder neck (thin arrow) in pressure-flow study was detected when the patient complained of strong desire to void at a bladder volume of 400ml (thick arrow).

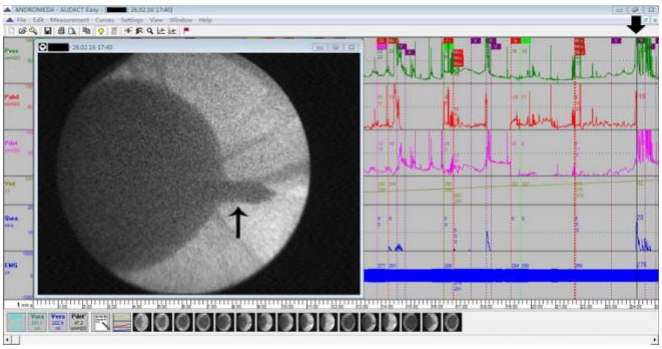

Figure 4. A normal coordination between detrusor contraction and urethral external sphincter relaxation (thin arrow) was demonstrated during pressure-flow study of VUDS in a 65-year-old male patient with incomplete sacral spinal cord injury and urinary incontinence. The patient had a voluntary voiding when he complained of strong desire to void at a bladder volume of 430ml (thick arrow).

Figure 4 shows normal coordination between detrusor contraction and urethral external sphincter relaxation in a pressure-flow study in a 65-year-old male patient with incomplete sacral spinal cord injury who complained of urinary incontinence. The patient had a voluntary voiding when he felt strong desire to void at a bladder volume of 430 ml. CTB, VUR, or DESD was not observed in 10 (40%) patients with flaccid bladder, and indwelling urethral catheter or clean intermittent catheterization was needed in 3 and 7 patients with chronic urinary retention due to underactive bladder, respectively. Hematuria, urinary tract infection, or autonomic dysreflexia did not occur in any of the patients who underwent VUDS.

Although the running cost of each VUDS test is approximately $200 and costs more than conventional UDS ($170) due to the use of contrast agent, the capital cost of VUDS in the trial is the same as that of conventional UDS ($116,000), because of utilization of an extracorporeal lithotripter system. If C-arm, fluoroscopy table, and radiation safety facilities are used to perform VUDS as current neuro-urological centers in developed areas, the total capital cost of VUDS is no less than $700,000.

Discussion

Serious complications of neurogenic bladder, including renal insufficiency and septicemia, are not uncommon and highlights the importance of regular VUDS to detect detrimental changes of NLUTD (5). Key pathognomonic traits in NLUTD, including DESD, which may indicate discoordination between detrusor contraction and urethral sphincter relaxation during the voiding phase, and VUR, which may signify poor bladder compliance and high intravesical pressure, are more easily evaluated with VUDS than with UDS (2).

Although neurological evaluation has been proven to play an important role and urological techniques have been deemed as a research tool in characterizing NLUTD, the pendulum is swinging to the actual DESD disregard of the site and degree of neurogenic damage through urodynamics test (9,10). It is highly likely that DESD can be detected by fluoroscopic findings combined with EMG tracing during VUDS than with EMG tracing alone in conventional UDS because current EMG methods rarely play a decision-making role in LUTD on account of confounded signal due to lack of adhesion to the skin between the perianal muscle and the electrode (11). A previous study published a report that defined DESD as a dilated posterior urethra obstructed by the external sphincter on fluoroscopy with concomitant elevated intravesical pressure due to detrusor contraction detected by pressure-flow studies (12).

The VUDS in this trial showed fluoroscopic images of DESD (Figure 3) similar to those in previous reports. In this trial, DESD was determined in 4 (16%) of 25 patients with NLUTD. All 4 patients with DESD had a high intravesical pressure in involuntary detrusor contraction. As sacral neuromodulation seems to constitute a serious therapeutic option for patients with NLUTD and improvement in DESD has been reported, other causes of bladder outlet obstruction, for example, urethral stenosis, should be differentiated from DESD by VUDS.

Both VUR and CTB can show long-term obstruction of the bladder outlet, which must not be overlooked in order to prevent complications in patients with NLUTD (11,13). VUR in neurogenic bladder has been considered as a secondary type of reflux, which is due to elevated intravesical pressure, chronic infection, and anatomic disruptions occurring near the ureteral orifices

and might lead to pyelonephritis and renal scarring (14). VUR may occur at lower bladder pressure (<20 cmH2O) than that known as the critical detrusor pressure (>40 cmH2O) required for development of VUR and results in kidney function impairment (15). In line with the results from the research by Lee et al. (15), VUR was detected in 3 (12%) of 25 patients with NLUTD in this trial, in which the intravesical pressure when detection of VUR is low (20 cmH2O) in one patient and is >40 cmH2O in others. Since the occurrence of VUR at low intravesical pressure (<40 cmH2O) indicates a lower safe bladder volume than that without VUR, VUDS used in this trial also has a more powerful capacity than conventional UDS in the evaluation of safe bladder volume in patients with NLUTD.

CTB, which has an elongated appearance with a dome like the top of a Christmas tree, indicates poor bladder compliance in patients with NLUTD and is typical of spastic neurogenic bladder (2). Only bladder compliance is assessed by conventional UDS alone, but the shape and contour of the bladder could be discerned by VUDS, and an irregular and thick detrusor indicates fibrosis, and patients with CTB might be not eligible for sacral neuromodulation but can be candidates for augmentation of the bladder. CTB was observed in 5 (20%) of 25 patients, and CTB combined with VUR was observed in a 60-year-old female patient with thoracic spinal cord injury. Pathognomonic traits in the urinary tract might be discovered by conforming an extracorporeal lithotripter system to perform VUDS, which can provide more accurate evaluation of patients with NTULD that conventional UDS.

A high incidence of urolithiasis leads to a high rate of extracorporeal shock wave lithotripsy in hospitals in undeveloped areas of China, thus providing us the opportunity to utilize the fluoroscopic unit (C-arm) and lithotripter table of the extracorporeal lithotripter system in order to obtain simultaneous fluoroscopic images of VUDS in this trial. The trial showed that the combined use of fluoroscopic unit, lithotripter table, and facilities for radiation safety of the extracorporeal lithotripter system can be sufficiently utilized to perform VUDS. Hence, the capital cost of VUDS may be markedly reduced from no less than $700,000 to $116,000, and VUDS would be more accessible to patients with NLUTD in some undeveloped areas.

However, this trial has some limitations. First, the number of subjects was too small to determine all the traits of NLUTD showed by VUDS, for example, relaxed urethral sphincter (16). Second, patients had to be in lithotomy position and did not void in standing position on account of the shape of the lithotripsy table; therefore, non-neurological patients are not suitable for this trial (17). Finally, the low image definition obtained by the fluoroscopic unit in this trial impaired insight on urinary tract abnormalities. In the future, more patients should be recruited to prove the efficiency of this trial in the evaluation of NLUTD, and the extracorporeal lithotripter system should have a more versatile table that allows supine, semisupine, lithotomy, and sitting positions, aside from 3D movement, during VUDS. Additionally, higher image definition should be provided by the extracorporeal lithotripter system.

Conclusions

In this study, the fluoroscopic unit, lithotripter table, and facilities for radiation safety of the extracorporeal lithotripter system were utilized to obtain simultaneous fluoroscopic images in VUDS to determine the presence of DESD, VUR, and CTB in patients with NLUTD. The set-up investment of VUDS can be reduced, making it VUDS more easily accessible to patients with NLUTD in undeveloped areas in China and the rest of the world.

Declaration of interests

The authors declare no conflict of interest.

Author contributions

XN led in conceptualization and writing the original draft. All other authors contributed to reviewing and editing the manuscript.

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