RELIABILITY OF BLADDER VOLUME DETERMINATION IN CHILDREN BY PORTABLE ULTRASONOGRAPHIC SCANNER IN STANDING POSITION

ABSTRACT

Objective: We aimed to compare pre-voiding bladder and post-voiding residual (BV, PVR) volumes measured by portable ultrasonic scanner (PUS) in standing and supine positions.

Material and Methods: A total of 436 children were included. We composed 2 groups (group-1: PUS vs. volume by catheter, group-2: PUS vs. infused volume during urodynamic study) to evaluate the agreement of PUS measurements with true bladder volume and then third group (group-3) to analyze the correlation between PUS measurements in different positions. In groups 1 and 2, agreement of PUS measurements were evaluated by paired sample T or Wilcoxon signed rank tests. Following the agreement, correlations were analyzed by Pearson's or Spearman's coefficients depending whether variables were distributed normal or not, respectively. Interpretation of coefficients were done as 0.90-1.00 (very high correlation) and 0.70-0.90 (high correlation), respectively.

Results: In group-1, measurements by catheter and PUS were similar (Wilcoxon Signed rank test, p= 0,976) and were highly correlated (r=0.873). In group-2, measurements of bladder volumes infused by urodynamic device and by PUS were similar that revealed the agreement of PUS measurements on different volumes and highly correlated at the 25th and very highly correlated at the 50th, 75th and 100th percentiles of the EBC (estimated bladder capacity related to age). In group-3, BV and PVR measurements by PUS in standing and supine positions were highly correlated that revelaed PUS can be used in both positions.

Conclusion: Measurements of BV before uroflowmetry or PVR volume by PUS in standing position gave similar results with those in supine position.

Keywords: Portable ultrasonic scanner, uroflowmetry, post-void residual urine.

What's already known about this topic?

Bladder catheterisation is the "gold standard" method for accurate measurement of bladder or PVR volume. However; it is invasive and not practical.The only non-invasive tool for measuring urine volume in bladder is USG. It is quick, non-invasive, well-tolerated, may be performed in office setting.

What does this article add?

Waiting for the adequate bladder fullness and then repeating UF may be time-wasting.
The current article showed that bladder volume measurements before and after UF in standing and supine positions are very highly correlated. These results also showed that PUS in standing position can be used to detect pre-voiding and post-voiding volumes during UF procedure in order to prevent time wasting and avoid possible anxiety of the children.

INTRODUCTION

Lower urinary tract dysfunction (LUTD) has a varying prevalence of about 17-22% in pediatric population (1). In majority of cases; evaluation, diagnosis and monitoring the response to treatment can be done by non-invasive methods such as voiding diary, symptom scoring questionnaires, urinalysis, ultrasonography (USG) and uroflowmetry (UF) with post-void residual (PVR) volume measurement. Invasive tools such as urodynamics, cystography and cystoscopy are indicated in a small selected group of cases (2,3).

Bladder catheterisation is the "gold standard" method for accurate measurement of bladder or PVR volume (4). However; because of its invasive nature, it is not practical especially in those undergoing several repeating evaluations (5,6). The only non-invasive tool for measuring urine volume in bladder is USG. Currently, standard suprapubic USG or portable ultrasonic scanner (PUS) is used for this purpose. The use of USG to assess bladder volume was first described in 1967 (7). It is quick, non-invasive, well-tolerated, may be performed in office setting, requires less patient cooperation and necessitates no extra instruments. Reliability of USG and compatibility with PUS has been studied in several studies (8-10).

However; in children, there may be some problems even during a simple procedure such as UF with PVR measurement using USG. Performing UF without sufficient bladder fullness can be time-wasting and child’s occasional resistance for not to being in a supine position for PVR measurement with the fear of having a possibly painful procedure may limit the reliability and the feasibility of the tool. Understanding whether there is enough urine in bladder in standing position before UF and then measuring PVR volume would probably reduce children's anxiety.

In this study, we hypothesized that measurements by PUS in both standing and supine positions are highly correlated and measurement in standing position by PUS can be used for this purpose in children.

MATERIAL AND METHODS

Our study was approved by local ethical committee (ID: KA180089/10.01.2019). A total of 436 patients under the age of 18 years were included between March 2019 and February 2020. Exclusion criteria were presence of neurogenic bladder, history of bladder surgery, ovarian and/or uterine cystic pathology in girls, vesicoureteral reflux (VUR) detected by previous voiding cystouretrography (VCU) or video-urodynamic study (VUD), abdominal ascites and any surgical incision in the suprapubic region.

In this study, we used a portable ultrasonic bladder scanner (SignosRT Bladder Scanner, Thermo Fisher Scientific Inc., USA) for all measurements. We put the scanner's probe 1-1.5 centimeters above the pubic symphisis on the midline with a slight angle towards the bladder to obtain a good image (Figure-1). The digital output has been obtained from the automated volume measurements at a single 2-dimensional transverse scan. All measurements were performed two times by one pediatric urology fellow (T.C.) and the mean of these two consequtive mesurements were recorded as 'bladder volume' in mililiters (mL).

Patients in group-1 (n=185) were asked not to void shortly before the time of the surgery to ensure a measurable bladder volume. This group was composed of patients who were planned to undergo an endourological intervention such as pyeloplasty, ureteroscopy, percutaneous nephrolithotomy, cystoscopy and hypospadias surgery. After induction of anesthesia, bladder volume was measured in the supine position using the PUS. Then, the child's bladder was catheterized to measure the actual bladder volume using 6 or 8 F nelaton (according to the age) and the amount was recorded. The measurements in this group was used to investigate whether the volumes those were obtained by catheter and PUS are in agreement by excluding the possible movement related artifacts.

The second group (n=35) was used to assess the correlation of PUS with infused fluid during VUD at different fullness degrees and was composed of patients with non-neurogenic lower urinary tract dysfunction. Estimated bladder capacity by age in mililiters (EBC, mL) was calculated using the *(age+2) x 30* formula (11). Then, routine VUD study was performed with the urodynamic device (MMS, Medical Measurement *Systems* B.V., *Enschede, The Netherlands)* and the measurements were performed by PUS at the 25, 50, 75 and 100% of the EBC simultaneously and then recorded in mL. The measurements in this group was used to investigate whether the volumes that were infused by urodynamic device and PUS-detected volumes are in agreement under normal outpatient conditions.

The third group (n=216) was composed of patients with LUTD who underwent UF and PVR measurement in the same session. In patients who underwent UF, bladder volumes were measured at suprapubic area before and after voiding in both standing and supine positions by using PUS and were recorded in mL. The data of this group was used to evaluate the correlations of measurements in different positions.

Statistical analyzes were performed by SPSS package program version 22 (*IBM Statistical Package for the Social Sciences, Version 22, Illinois, USA*) and p value less than 0.05 was considered statistically significant. In groups 1 and 2, agreement of PUS measurements with the reference values that were obtained by catheter or infused volume was evaluated by paired sample T or Wilcoxon signed rank tests. Following the confirmation of the agreement, correlations have been analyzed by Pearson's or Spearman's coefficients depending whether variables were distributed normal or not, respectively. Since there was no reference value in group-3, the correlation of volume measurements in 2 different positions has been performed. Interpretation of coefficients were done regardingly: 0.90-1.00 (very high correlation) and 0.70-0.90 (high correlation) (12).

RESULTS

Of 185 patients in endoscopic intervention group (group-1), 126 were male (68.1%) and 59 were female (31.9%). Mean age was 59±52 (1-204) months. Volumes those were obtained by PUS and catheter were in agreement (Wilcoxon signed rank test, $p= 0.976$) and there was a high correlation ($r=0.873$) between the measurements (Table-1). The correlation coefficients (Spearman's rho) for age groups of 0-59, 60-119 and 120-204 months were as 0.742, 0.848 and 0.901 ($p<0.001$ for each), respectively.

Thirty-five patients, 19 boys (54.3%) and 16 girls (45.7%), were included in the VUD group (group-2). Mean age was 108±40 (30-198) months. During VUD study, the measurements of bladder volumes by the urodynamic device and by PUS were in agreement and highly correlated at the 25th and very highly correlated at the 50th, 75th and 100th percentiles of the EBC (Table-2).

A total of 211 patients, 97 girls (44.9%) and 114 boys (55.1%), were included in the UF group (group-3). Mean age was 116±42 (48-204) months. Before UF, bladder volumes measured by PUS in both standing and supine positions were very highly correlated to each other. Similarly, PVR volumes of the same patients measured by PUS in both standing and supine positions were very highly correlated with each other (Table-3). The correlation coefficients (Spearman's rho) of standing and supine positions for patients younger than 120 months at pre-voiding and post-voiding measurements were 0.986 and 0.953 ($p<0.001$ for each), respectively. The same coefficients for children ≥120 months were 0.933 and 0.982, ($p<0.001$ for both), respectively.

DISCUSSION

In addition to complete medical history and physical/neurological examination, bladder diaries and symptom-scoring questionnaires, UF and PVR measurement are crucial for the evaluation of LUTD in children (13). On the other hand, invasive video-urodynamic (VUD) studies are used to investigate bladder capacity, detrusor pressure, compliance and the presence of VUR.

In children with LUTD, USG is a non-invasive, easily accessible and repeatable tool and plays a major role during evaluation of bladder in terms of residual urine volume assessment, detection of bladder wall pathologies and thickness, visualization of reno-ureteral unit regarding the accompanying abnormalities and presence of rectal distention (14,15). No significant differences were reported in the literature between suprapubic standard USG and bladder catheterization in terms of bladder volume measurement (16). The urine volume in bladder can also be measured by PUS. In recent studies, standard USG and PUS were found to be compatible in terms of bladder and PVR volumes (17-19). Besides, PUS was reported as a reliable tool in bladder volume assessment when compared to catheterization (20-21). On the other hand, PUS does not provide information about the rectal diameter, bladder neck and urethra. The possible deviations from true bladder volumes because of the automated volume calculations at a single 2-dimensional transverse scan should be taken into consideration.

The patient's position during measurement can have an impact on results. Possible anatomical interposition of peritoneal and intestinal structures between bladder and abdominal wall especially in infants may cause deviations in measurements. The effect of position on ultrasonographic measurements has been studied previously in single study (22). They compared PUS and standard USG in 59 children and concluded that standing scanning could be used. However, they emphasized that the accuracy and correlation are lower in post-void measurements in children younger than 10 years. Though, we detected that the correlation was quite high in both age groups. Our study differs from this mentioned study as we used catheter measurements for comparison in a larger number of patients. In the present study, we analyzed the correlation between volumes detected by catheterization and PUS in two ways. First, in the first group under anesthesia, we have been able to evaluate the correlation of these volumes in a child with no physical activity and impact of body movements on PUS. The correlation was high for all age groups, especially for children above 5 years those can perform UF. Second, the group under VUD let us to evaluate the correlation between volumes of the real-time infused fluid and volumes those were detected by PUS in physically active children. The correlation was also very high. These results encouraged us to use PUS in bladder volume detection in supine and standing positions.

UF with PVR measurement is one of the mainstays of evaluation of children with LUTD. However, volunteer voiding control, cooperation of the child, status of the test room environment and bladder fullness degree are very important. Inadequate voided volume is one of the main obstacles to obtain an informative result. There is not solid data on the amount of required voided volume. Although, there is a recent study that reports the interpretation of the UF curve could even be done in small volumes (23). The general consensus is to void during UF at least >50% of EBC (24). A study from Taiwan proposed age-specific lowest acceptable bladder capacity for interpretation of UF as '(age in years×5)+50 mL' (25).

Although we are able to remove the disturbing factors during UF, inadequate bladder volume is the main problem during the test. Waiting for the adequate bladder fullness and then repeating UF may be time-wasting for both parents and healthcare professionals. In these instances, PUS may provide great convenience and comfort. PUS can be used before UF to detect whether the bladder is adequately full or not. Besides, asking the child for a supine position to perform a scan with PUS to evaluate bladder fullness may lead to resistance and may raise the child's concern about the procedure. For this reason, measurement process that can be done in standing position can be advantageous in terms of saving time and decreasing the anxiety. In this study, we aimed to investigate the efficacy of the PUS in measuring bladder and PVR urine volumes in standing position. Following the presence of agreement and very high correlations those were obtained from above mentioned 2 groups, we evaluated the correlation of pre-voiding and post-voiding bladder volumes those were measured by PUS in supine and standing positions. We detected very high correlations confirming our hypothesis that PUS in standing position can be used for detection of bladder volume before and after UF with the aim of preventing time-wasting and possible anxiety of the children. The correlations were also very high for both age groups (<10 and ≥10 years) which was previously mentioned by Zillioux et. al. (22) as an important factor.

Our study is not without limitations. Since our urodynamics unit (VUD, UF, PUS instruments) and abdominal USG device are settled in different buildings, it was not possible to make a comparison between standard USG and PUS simultaneously. However, this shortcoming has been overcome by obtaining exact volume by catheterization or knowing the infused volume in VUD. The absence of blinding during PUS measurements in all study groups can be criticized as a methodological shortcoming. Another limitation can be the relatively small number of patients in the second group. The invasive nature of VUD, excluding the cases with VUR and neurogenic bladder patients and moreover our daily practice that is reserving VUD only for patients who did not respond to medical treatment are the possible causes of small number in this group within the study period. The absence of infant age group patients in group-3 can be considered as a limitation. All patients in this group were old enough with voluntary voiding control to perform uroflowmetry. However, we believe that evaluation in infants by PUS is rarely indicated in daily practice regarding the need for uroflowmetric studies. Comparison of measurements in younger age group, evaluation of the time loss and patient anxiety in older children will be the objectives of our future studies.

CONCLUSION

Our study showed that bladder volume measurements before and after UF in standing and supine positions are very highly correlated. These results showed that PUS in standing position can be used to detect pre-voiding and post-voiding volumes during UF procedure in order to prevent time wasting and avoid possible anxiety of the children.

Ethical Approval: Our study was approved by local ethical committee (ID: KA180089/10.01.2019).

Conflict of interest status: None of the authors had financial support or conflict of interest.

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Table 1 : Comparison of the measurements by PUS and catheter under anesthesia.

Measurement method	n	Mean (mL)	S.D. (mL)	Median (mL)	Min-max (mL)	Wilcoxon signed rankt test	Spearman's correlation coefficient	p
PUS	185	41	52	30	0-350	**0.976**	**0.873**	<0.001
Catheter	185	43	64	23	0-640			

Table 2: Comparison of volume measurements by PUS and infused fluid by VUD device at different EBC percentiles.

Bladder fullnes	**%25 of EBC**		**%50 of EBC**		**%75 of EBC**		**%100 of EBC**	
Number of patients*	35		34		26		16	
	Infused volume	**Volume by PUS**	**Infused volume**	**Volume by PUS**	**Infused volume**	**Volume by PUS**	**Infused volume**	**Volume by PUS**
Mean±SD (mL)	72±21	77±28	143±42	147±47	203±66	197±68	259±103	270±124
Median (min-max) (mL)	75 (22-100)	75 (27-146)	143 (45-200)	145 (43-245)	202 (67-300)	203 (60-310)	270 (90-400)	263 (85-570)
P values of related sample comparison tests	0.566[a]		0.197[b]		0.438[b]		0.366[b]	
Correlation coefficients	0.839[c]		0.934[d]		0.935[d]		0.938[d]	
p	<0.001		<0.001		<0.001		<0.001	

*: Number of patients those reached the aimed bladder fullness,

EBC: estimated bladder capacity

a: Wilcoxon signed rank test, b: Paired sample T test, c: Spearman correlation coefficient, d: Pearson correlation coefficient

Table 3: Correlations of prevoiding and postvoiding volume measurements by PUS in supine and standing positions.

Measurement position	n	Mean (mL)	S.D. (mL)	Median (mL)	Min-max (mL)	Spearman's correlation coefficient	p
Pre-voiding (standing)	211	243	149	205	45-775	**0.968**	<0.001
Pre-voiding (supine)	211	249	150	212	50-780		
Post-voiding (standing)	211	29	42	16	0-278	**0.967**	<0.001
Post-voiding (supine)	211	29	41	18	0-272		