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The Reliability of Bladder Volume Determination in Children Using Portable Ultrasonographic Scanner in Standing Position

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What's known on the subject? and What does the study add?

Post-void residual (PVR) volume measurement using ultrasonograpy is an important non-invasive tool used for diagnosis and monitoring the response to treatment in children with lower urinary tract dysfunction. Various portable ultrasonic scanner (PUS) devices are used for this purpose. We hypothesized measuring urinary volume in bladder in standing position first would probably be time-saving in PVR volume measuring process. In our study, measurements by PUS in both standing and supine positions were highly correlated. We concluded that PUS in standing position can be used to detect pre-voiding and post-voiding (PVR) volumes in UF procedure to prevent time-wasting and avoid possible anxiety of the children.

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

Materials and Methods: This study included 436 children. Two groups were composed (group-1: PUS vs. volume by catheter and group-2: PUS vs. infused volume during the urodynamic study) to evaluate the agreement of PUS measurements with true bladder volume. Additionally, the third group (group-3) was created to analyze the correlation between PUS measurements in different positions. In groups 1 and 2, PUS measurement agreements were evaluated using the paired sample T or Wilcoxon signed-rank tests. Following the agreement, correlations were analyzed using Pearson's or Spearman's coefficients depending on whether variables were distributed normally or not, respectively. Coefficients were interpreted as 0.90-1.00 (very high correlation) and 0.70-0.90 (high correlation).

Results: The catheter and PUS measurements were similar in group-1 (Wilcoxon signed-rank test, $p=0.976$) and were highly correlated ($r=0.873$). The measurements of volumes infused by urodynamic device and PUS were similar in group-2 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 estimated bladder capacity related to age. The BV and PVR measurements by PUS in standing and supine positions in group-3 were highly correlated, revealing that 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 the supine position.

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

Introduction

Lower urinary tract dysfunction (LUTD) has a varying prevalence of approximately 17-22% in the pediatric population (1). In the majority of cases, treatment response evaluation, diagnosis, and monitoring 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 catheterization is the "gold standard" method for accurate bladder or PVR volume measurement (4). However,

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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 the bladder is USG. Currently, a standard suprapubic USG or portable ultrasonic scanner (PUS) is used for this purpose. The use of USG to assess the bladder volume was first described in 1967 (7). It is quick, non-invasive, and well-tolerated, which may be performed in-office setting, requires less patient cooperation, and necessitates no extra instruments. USG reliability and compatibility with PUS have been investigated in several studies (8-10).

However, some problems may occur even during a simple procedure, such as UF with PVR measurement using USG, in children. Performing UF without sufficient bladder fullness can be time-wasting and the child's occasional resistance for not 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 sufficient urine in the bladder in a standing position before UF and then measuring the PVR volume would probably reduce children's anxiety.

We hypothesized that measurements using PUS in both standing and supine positions are highly correlated and measurement in a standing position using PUS can be used for this purpose in children.

Materials and Methods

Our study was approved by the local ethical committee (ID: KA180089/10.01.2019). This study included 436 patients under the age of 18 years between March 2019 and February 2020. Exclusion criteria were the presence of neurogenic bladder, bladder surgery history, ovarian, and/or uterine cystic pathology in girls, vesicoureteral reflux (VUR) detected by previous voiding cystourethrography or video-urodynamic study (VUD), abdominal ascites, and any surgical incision in the suprapubic region. The parents of all children included in our study were signed a detailed consent form informing about USG measurement.

This study used a portable ultrasonic bladder scanner (SignosRT Bladder Scanner, Thermo Fisher Scientific Inc., USA) for all measurements. The scanner's probe was placed 1-1.5 cm above the pubic symphysis on the midline with a slight angle toward 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 consecutive mesurements were recorded as "bladder volume" in mililiters (mL).

Group 1 (n=185) was composed of patients who were planned to undergo an endourological intervention, such as pyeloplasty, ureteroscopy, percutaneous nephrolithotomy, and cystoscopy. After the anesthesia induction, the 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. Measurements in this group were used to investigate the agreement of the obtained volumes using a catheter and PUS 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 LUTD. Estimated bladder capacity by age in mililiters (EBC, mL) was calculated using the formula (age+2) x 30 (11). Then, a routine VUD study was performed with the urodynamic device (MMS, Medical Measurement Systems, B.V., Enschede, The Netherlands) and the measurements were performed using PUS at the 25%, 50%, 75%, and 100% of the EBC, simultaneously, and then recorded in mL. The measurements in this group were used to investigate the agreement of the volumes that were infused using an urodynamic device and PUS-detected volumes 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. Bladder volumes were measured at the suprapubic area before and after voiding in both standing and supine positions in patients who underwent UF using PUS and were recorded in mL. The data of this group was used to evaluate the correlations of measurements in different positions.

Figure 1. Measuring bladder volume by portable ultrasonic scanner in standing (a) and supine (b) positions

Statistical Analysis

Statistical analyzes were performed using the Statistical Package for the Social Sciences package program version 22 (IBM Statistical Package for the Social Sciences, Version 22, Illinois, USA), and a p-value of <0.05 was considered statistically significant. In groups 1 and 2, the agreement of PUS measurements with the reference values that were obtained by a catheter or infused volume was evaluated by the paired sample T or Wilcoxon signed-rank tests. Following the agreement confirmation, correlations have been analyzed using the Pearson coefficients for normally distributed variables and the Spearman coefficients not normally distributed variables. There was no reference value in group-3, thus the correlation of volume measurements in two different positions has been performed. The interpretation of coefficients was interpreted as 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 (68.1%) were males and 59 (31.9%) were females. The mean age was 59±52 (1-204) months. Volumes obtained by PUS and catheter were in agreement (Wilcoxon signed-rank test, p=0.976) with 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 0.742, 0.848, and 0.901 (p<0.001 for each), respectively.

The VUD group (group 2) included 35 patients, wherein 19 (54.3%) were males and 16 (45.7%) were females. The mean age was 108±40 (30-198) months. During the VUD study, the measurements of the 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 (44.9%) females and 114 (55.1%) females were included in the UF group (group 3). The mean age was 116±42 (48-204) months. Before UF, the measured bladder volumes using PUS in both standing and supine positions were very highly correlated to each other. Similarly, PVR volumes of the same patients that were 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 aged ≥120 months were 0.933 and 0.982 (p<0.001 for both), respectively.

Discussion

UF and PVR measurement are crucial for LUTD evaluation in children in addition to complete medical history and physical/neurological examination, bladder diaries, and symptom scoring questionnaires (13). Contrarily, invasive VUD studies are used to

Table 1. The comparison of the measurements using PUS and catheter under anesthesia

Measurement method	n	Mean (mL)	SD (mL)	Median (mL)	Min-max (mL)	Wilcoxon signed-rank 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			

SD: Standard, Min: Minimum, Max: Maximum, PUS: Portable ultrasonic scanner

Table 2. The comparison of the measurements by PUS and infused fluid by VUD device at different EBC percentiles

Bladder fullness	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 who 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, SD: Standard deviation, Min: Minimum, Max: Maximum, PUS: Portable ultrasonic scanner

Table 3. Correlations of pre-voiding and post-voiding volume measurements by PUS in supine and standing positions

Measurement position	n	Mean (mL)	SD (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		

PUS: Portable ultrasonic scanner, SD: Standard deviation, Min: Minimum, Max: Maximum

investigate the bladder capacity, detrusor pressure, compliance, and the presence of VUR.

USG is a non-invasive, easily accessible, and repeatable tool and plays a major role during bladder evaluation 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 distension in children with LUTD (14,15). No significant differences were reported in the literature between the suprapubic standard USG and bladder catheterization in terms of bladder volume measurement (16). The urine volume in the bladder can also be measured using PUS. Recent studies revealed that standard USG and PUS were compatible in terms of bladder and PVR volumes (17-19). Additionally, PUS was reported as a reliable tool in bladder volume assessment compared to catheterization (20,21). Contrarily, 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 considered.

The patient's position during the measurement can impact the results. Possible anatomical interposition of peritoneal and intestinal structures between the bladder and the abdominal wall, especially in infants may cause deviations in measurements. The effect of position on USG measurements has been previously studied in a 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. We detected that the correlation was quite high in both age groups; however, our study differs from this mentioned study as we used catheter measurements for comparison in a larger number of patients. The present study analyzed the correlation between detected volumes using catheterization and PUS in two ways. First, in the first group under anesthesia, we evaluated the correlation of these volumes in a child without physical activity and the impact of body movements on PUS. The correlation was high for all age groups, especially for children above 5 years, who can perform UF. Second, the correlation between volumes of the real-time infused fluid in the group under VUD was evaluated and volumes were detected using 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 evaluating children with LUTD. However, voluntary voiding control, child cooperation, test room environment status, and bladder fullness degree are very important. Inadequate voided volume is one of the main obstacles in obtaining an informative result. Solid data on the amount of required voided volume is unavailable. A recent study revealed that the interpretation of the UF curve could even be done in small volumes (23); however, the consensus is to void during UF at least >50% of the EBC (24). A study from Taiwan proposed the age-specific lowest acceptable bladder capacity for UF interpretation as "(age in years×5)+50 mL" (25).

We can remove the disturbing factors during UF; however, inadequate bladder volume is the main problem during the test. Waiting for adequate bladder fullness and then repeating UF may be time-wasting for both parents and healthcare professionals. Therefore, PUS may provide great convenience and comfort. PUS can be used before UF to detect whether the bladder is adequately full or not. Additionally, 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. Thus, a measurement process that can be done in a standing position can be advantageous in terms of saving time and decreasing anxiety. This study aimed to investigate the efficacy of PUS in measuring bladder and PVR urine volumes in standing positions. Following the presence of agreement and very high correlations in the above-mentioned groups, we evaluated the correlation of pre-voiding and post-voiding bladder volumes measured by PUS in supine and standing positions. Very high correlations were detected that confirm our hypothesis that PUS in a standing position can be used for detecting bladder volume before and after UF to prevent time-wasting and possible anxiety in 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.

Study Limitations

Our study is not without limitations. Since our urodynamics unit (VUD, UF, and PUS instruments) and abdominal USG device are settled in different buildings, it was impossible to make a simultaneous comparison between standard USG and PUS. However, this shortcoming has been overcome by obtaining the 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, and our daily practice that is reserving VUD only for patients who did not respond to medical treatment are the possible causes of a 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 UF. However, the evaluation in infants using PUS is rarely indicated in daily practice regarding the need for uroflowmetric studies. The comparison of measurements in the 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 revealed that bladder volume measurements before and after UF in standing and supine positions are very highly correlated. These results showed that PUS in a standing position can be used to detect pre-voiding and post-voiding volumes during the UF procedure to prevent time-wasting and avoid possible anxiety in children.

Ethics

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

Informed Consent: The parents of all children included in our study were signed a detailed consent form informing about USG measurement.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: T.C., H.S.D., S.T., Concept: T.C., H.S.D., B.Ç., Design: T.C., H.S.D., S.T., Data Collection or Processing: T.C., K.G., A.C.B., Analysis or Interpretation: T.C., H.S.D., K.G., A.C.B., Literature Search: T.C., B.Ç., V.T., Writing: T.C., H.S.D.

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