Journal of Pediatric Urology (2016) **12**, 214.e1–214.e5

Evaluation of bladder capacity in children with lower urinary tract symptoms: Comparison of 48-hour frequency/volume charts and uroflowmetry measurements

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Keywords
Pediatrics; 48-Hour frequency/volume chart; Uroflowmetry; Bladder capacity; Lower urinary tract symptoms

Received 31 December 2015
Accepted 29 April 2016
Available online 7 May 2016

Summary

Introduction
Objective evaluation of bladder capacity (BC) in children with lower urinary tract symptoms (LUTS) is important for recognizing types of bladder dysfunction. Bladder capacity is evaluated from 48-hour frequency/volume (48-h F/V) charts or by uroflowmetry with ultrasound post-void assessment. There are limited data on the reliability of both methods of assessment in children.

Objective
The aim of the study was to compare two modalities of assessment, (F/V chart and uroflowmetry) in cohorts of children with bladder dysfunctions.

Study design
Maximum bladder capacity (MBC) obtained from 48-h F/V charts was compared with volumes calculated from uroflowmetry in a cohort of 86 children with different bladder dysfunctions. The BC obtained by the two modalities was compared for the three most frequent subtypes of bladder dysfunction: monosymptomatic nocturnal enuresis (MNE), overactive bladder (OAB), and dysfunctional voiding (DV). Considering a 48-h F/V chart as standard, the sensitivity, specificity, negative and positive predictive values of uroflowmetry measurements were calculated for detecting low bladder capacity.

Results
The mean maximal bladder capacity (188 ± 99.42 ml) obtained from home 48-h F/V chart measurement was 17 ml lower than the mean value obtained from uroflowmetry (205 ± 112.11 ml) ($P = 0.58$). The differences between bladder capacities estimated by 48-h F/V chart and uroflowmetry for subjects were not significant (Figure). Concordance between 48-h F/V chart and uroflowmetry categorization of BC was present in 64 (74%) subjects. The sensitivity and specificity of uroflowmetry, in comparison with 48-h F/V chart evaluation, for recognizing low bladder capacity were 75.5% and 73.17%. The sensitivity and specificity for the different types of LUTS achieved 68.42% and 58.83% for OAB, 80% and 83% for MNE, and 50% and 83.3% for DV.

Discussion
According to the International Children's Continence Society, the management of MNE in children can be made without uroflowmetry. History and MBC evaluation by 48-h F/V charts yields sufficient information. Nevertheless, in situations where F/V charts are unreliable or unavailable, uroflowmetry can be used as an alternative method. The highest discrepancy between both methods of BC evaluation was found in DV; this was mainly due to the mean PVR of 31 ml.

Conclusion
For children with MNE, both 48-hour frequency/volume charts and triplicate urine flow measurement with PVR evaluation are reliable methods of maximum bladder capacity evaluation. For children with OAB or DV, both methods may be necessary for accurate evaluation of decreased BC, as F/V chart and uroflow results may not be comparable.

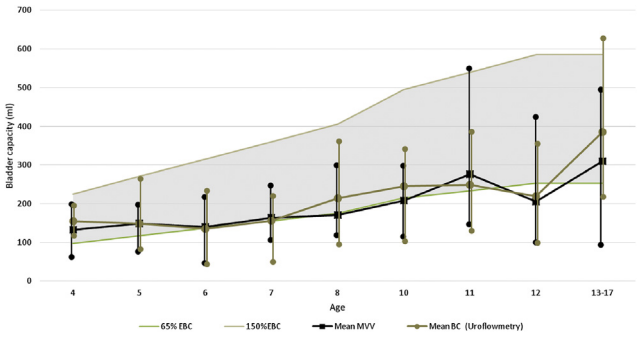

Figure Maximal voiding volume (48-hour frequency/volume chart) and bladder capacity (uroflowmetry) distribution according to age, plotted against reference bladder capacity distribution for children (65–150% estimated bladder capacity).

http://dx.doi.org/10.1016/j.jpurol.2016.04.004

Introduction

The objective evaluation of bladder capacity (BC) in children with lower urinary tract symptoms (LUTS) is of major importance for recognizing the different types of bladder dysfunction. The International Children's Continence Society (ICCS) recommends the use of 48-hour frequency/volume (48-h F/V) charts for this assessment, during which the volume and timing of every void and fluid intake is recorded [1]. The maximal voided volume (MVV) represents the functional capacity of the bladder. This method is non-invasive and is representative of the everyday bladder function of a child. The utility of a 48-h F/V chart assessment has recently been demonstrated in children [2]. Nevertheless, chart evaluation does not recognize post-void residual (PVR), and may underestimate BC when this is significant. Alternatively, BC estimation can be performed during uroflowmetry with PVR measurement [3]. Uroflowmetry repetition increases the reliability of this method in reflecting the child's bladder capacity and function [4]. Uroflowmetry studies yield additional information on PVR, flow-curve shape, and maximal urine flow rate during uroflowmetry (Qmax) values, thus enabling prompt categorization of bladder dysfunction. The disadvantage of this method of BC evaluation in all children presenting with LUTS is its higher cost and personnel involvement. Furthermore, uroflowmetry is not necessary for the diagnosis and management of one of the most frequent types of bladder dysfunction: monosymptomatic enuresis (MNE) [5].

There are limited data on the reliability of both methods of evaluating functional BC in children. The aim of the present study was to compare 48-h F/V chart and uroflowmetry measurements in a cohort of children with well-defined bladder dysfunctions.

Material and methods

All incident, previously untreated subjects referred for LUTS between August 2014 and August 2015 to the Children's Incontinence Clinic of Medical University Gdansk were included in the study (following exclusion of neurological and/or anatomical abnormalities). Bladder dysfunction was categorized according to ICCS terminology on the basis of the medical history, 48-hour daytime F/V chart, 2-week bladder diary, and uroflowmetry. Overactive bladder (OAB) was recognized in subjects with urinary urgency accompanied by frequency with or without incontinence, and a tower-shape curve with increased Qmax on uroflowmetry. Dysfunctional voiding (DV) was diagnosed in patients with a staccato flow pattern on uroflowmetry and a history of recurrent UTI, and, in some cases, significant PVR. Underactive bladder was diagnosed when increased bladder capacity was accompanied by decreased voiding frequency in a subject with straining during voiding and an interrupted flow pattern on uroflowmetry.

A total of 103 children were enrolled: 86 subjects completed the study, 17 were excluded due to non-compliance. The average age of the analyzed cohort, which included 44 girls and 41 boys, was 8 $\pm$ 3.08 years (range 4—17).

Bladder capacity values obtained from the 48-h F/V charts and those calculated from uroflowmetry studies were compared for the total cohort, and for the three most frequent subtypes of bladder dysfunction: monosymptomatic nocturnal enuresis (MNE), overactive bladder (OAB), and dysfunctional voiding (DV). During the initial visit, the parents were instructed by the physician on the performance of void measurements, which were carried out during the weekend when the child was under parental supervision. The maximal BC noted on the 48-h F/V chart, excluding first morning voids, was recorded as maximum voiding volume (MVV). Uroflows were performed, with an Ellipse device (Andromeda Medizinische Systeme GmbH, Germany), as outpatient procedures from the second morning void onward until two further voids were obtained on desire under voluntary water intake; the child was asked to urinate following a normal desire to void. Uroflowmetry measurements were repeated and documented three times on the same visit, and PVR was evaluated by transabdominal ultrasound immediately after voiding [6]. Maximal bladder capacity was recorded from uroflowmetry as the sum of the largest volume of voided urine and its corresponding PVR [7]. The largest bladder capacity was used for further analysis. Low bladder capacity was defined as $<$65% of expected bladder capacity (EBC) and normal bladder capacity as 65—150% EBC [1]. The EBC was calculated according to the Koff formula (30 $\times$ (age in years+1) for children between 4 and 12 years, and 390 ml for older children) [8].

Statistical analysis

Statistical analysis was performed using a commercially available statistics program (STATISTICA 12). The Shapiro—Wilk test was used to evaluate the distribution of variables. Continuous variables were presented as the mean and standard deviation. Probability values of $<$0.05 were considered statistically significant. The Wilcoxon Signed-Rank Test was used to compare pairs of results. Considering the 48-h F/V chart as standard, the sensitivity, specificity, negative and positive predictive values of uroflowmetry BC measurements were calculated for detecting low bladder capacity.

Results

Among the 86 treatment-naïve children who completed the study, 33 (38%) were found to have MNE, 36 (42%) had OAB, and 12 (14%) had DV. Three (4%) subjects demonstrated giggle incontinence, one had an underactive bladder, and one had voiding postponement.

The mean MBC (188 $\pm$ 99.42 ml) obtained from the 48-h F/V chart measurements was 17 ml lower than the mean value obtained from uroflowmetry (205 $\pm$ 112.11 ml) (P = 0.58). The mean MVV obtained by both methods for subjects with OAB, MNE, and DV are presented in Table 1, and their distribution is plotted against age-dependent EBC in Fig. A mean PVR of 30 ml (0—130 ml) was calculated for the DV subgroup.

Table 1 Comparison between mean maximum voiding volume obtained from 48-hour frequency/volume charts and calculated bladder capacity from uroflowmetry study in children with different types of lower urinary tract symptoms.

Type of bladder dysfunction	Number of patients	Mean maximum voiding volume from 48-hour frequency/volume chart	SD	Bladder capacity from uroflowmetry	SD	Difference	*P*-value
Overactive bladder	36	183	105.51	191	113.23	8 ml	0.47
Monosymptomatic nocturnal enuresis	33	169	57.69	186	73.73	17 ml	0.28
Dysfunctional voiding	12	223	132.56	258	141.56	35 ml	0.48
Total	86	188	99.42	205	112.11	17 ml	0.58

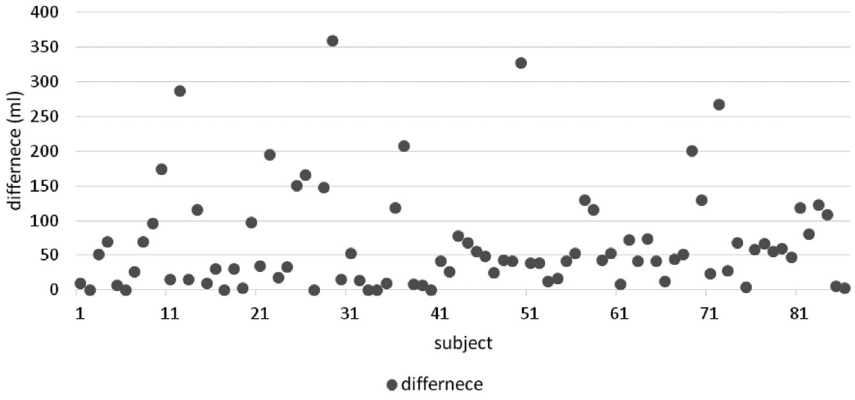

Figure 1 The differences between bladder capacities estimated by 48-h frequency/volume chart and uroflowmetry.

The differences between bladder capacities estimated by the 48-h F/V chart and uroflowmetry for individual patients are presented for the total cohort in Fig. 1. The differences between measurements obtained in subjects with different bladder dysfunctions: OAB (8 ml), MNE (17 ml), and DV (35 ml) were not significant.

Concordance between 48-h F/V chart and uroflowmetry categorization of bladder capacity was present in 64 (74%) subjects. Of these, 34 (53%) had normal BC and 30 (46%) had decreased BC. Discrepancies between both methods were observed in 22 (26%) subjects, and included 13/36 children with an OAB, 4/12 with DV, and 5/33 with MNE. Using a 48-h F/V chart with BC as standard, uroflowmetry failed to recognize low BC in 11 children (6 OAB, 3 DV, 2 MNE) and overdiagnosed low BC in a further 11 subjects (7 OAB, 3 MNE, 1 DV). The sensitivity and specificity of uroflowmetry, in comparison with 48-h F/V chart evaluation, for recognizing low BC were 75.5% and 73.17%. The sensitivity and specificity for the different types of LUTS achieved 68.42% and 58.83% for children with OAB, 80% and 83% for MNE, and 50% and 83.3% for DV (Tables 2—4). There was no age or gender variation in the analyzed subgroups (Tables 5 and 6) from uroflowmetry study in children with different types of LUTS.

Discussion

The evaluation of BC is paramount for the diagnosis and monitoring of treatment of specific subtypes of LUTS [9]. The ICCS recommends the use of F/V charts for this

Table 2 Comparison of uroflowmetry and 48-hour frequency/volume chart modalities for recognizing low bladder capacity in children with overactive bladder.

Overactive bladder			
Decreased bladder capacity			
	48-hour frequency/volume chart		Total
Uroflow	Yes	No	
Yes	13 (68.42%)	7 (41.17%)	20
No	6 (31.35%)	10 (58.83%)	16
Total	19	17	**36**

Table 3 Comparison of uroflowmetry and 48-hour frequency/volume chart modalities for recognizing low bladder capacity in children with monosymptomatic nocturnal enuresis.

Monosymptomatic nocturnal enuresis			
Decreased bladder capacity			
	48-hour frequency/volume chart		Total
Uroflow	Yes	No	
Yes	12 (80%)	3 (16.67%)	15
No	3 (20%)	15 (83.33%)	18
Total	15	18	**33**

Table 4 Comparison of uroflowmetry and 48-hour frequency/volume chart modalities for recognizing low bladder capacity in children with dysfunctional voiding.

Dysfunctional voiding			
Decreased bladder capacity			
	48-hour frequency/volume chart		Total
Uroflow	Yes	No	
Yes	3 (50%)	1 (16.67%)	4
No	3 (50%)	5 (83.33%)	8
Total	6	6	**12**

assessment, which needs to be performed for at least 48 h in order to reach objective results of the maximal voided volume (MVV) [1]. This is rather time consuming, and involves the whole weekend for both parents and child. Reliable results may be difficult to obtain, especially in less motivated families. Uroflowmetry is an alternative non-invasive method of assessing BC. It has been recognized that uroflowmetry requires repetition to improve its accuracy, reliability, and correct interpretation [10]. It also requires adequate micturition volumes (>50% of EBC for age) for proper evaluation of the curve [11]. Values obtained by both methods have not been extensively compared in children. The present hypothesis was that uroflowmetry may be used interchangeably with 48-h F/V charts when assessing BC in children with different types of urinary tract dysfunction.

The results of the present study showed that both methods of assessing BC are comparable. The difference between the mean values for MVV calculated by chart and BC from uroflowmetry was not significant for the total cohort, or for the three major subgroups (OAB, MNE, and DV). In children with MNE, the reliable evaluation of BC will determine, together with the recognition of nocturnal polyuria, the optimal treatment strategy [12]. According to the ICCS, this can be achieved with a 48-h F/V chart without performing uroflowmetry [13]. Nevertheless, the present study demonstrated that, in situations where diaries are unreliable or unavailable, uroflowmetry could be used as an alternative. The mean difference between both measurements was 17 ml (10%). Furthermore, the sensitivity and specificity of uroflowmetry in recognizing low bladder volumes was high in this subgroup.

In children with OAB, the concordance of both methods was lower. Although the difference in mean MBC was only 8 ml, the sensitivity and specificity of uroflowmetry in detecting low BC was 68.42% and 58.83%. Uluocak et al. reported a larger difference of 95 ml in a group of patients with OAB, but when analyzing age-adjusted values, this difference was not significant [14]. The performance of a single uroflowmetry and lack of exclusion of the first morning void in the evaluation of 48-h F/V charts in the above study may have further influenced the obtained results. A significant difference between uroflowmetry and 48-h F/V chart volumes has been reported in adult women with urinary incontinence but in this study, the first morning voided volume was also used [15].

The highest discrepancy between both methods of BC evaluation was found in subjects with DV. Bladder capacity evaluated by uroflowmetry was increased in children with DV by a mean of 35 ml compared with 48-h F/V chart evaluation. This was mainly due to the mean 31 ml of PVR disclosed by ultrasound. The specificity of uroflowmetry for assessing decreased BC in comparison to 48-h F/V chart was high (83%), but only 50% of subjects with decreased BC according to charts were confirmed on uroflowmetry. In this type of LUTS, uroflowmetry with post-void ultrasound is the more accurate method of MBC evaluation, as it incorporates the characteristic significant PVR observed in DV into the measurement. Therefore, the evaluation of BC in both DV and OAB needs to be conducted with caution, and it may be necessary to use both methods of assessment to achieve the reliable results.

A limitation of this study was the lack of an objective measure of accuracy for home measurements, and the PVR cannot be measured with home 48-h F/V charts and, if

Table 5 Comparison of 48-hour frequency/volume chart and uroflowmetry modalities for recognizing low bladder capacity in younger and older age groups.

Age, years	Number of patients	Maximal voided volume from 48-hour frequency/volume chart	SD	Bladder capacity from uroflowmetry	SD	Difference	*P*-value
4–9	56	153	50.64	161.7	65.88	8.7 ml	0.37
10–17	30	255.4	130.6	288.2	133.5	32.8 ml	0.10
Total	86	188	99.42	205	112.11	17 ml	0.58

Table 6 Comparison of 48-hour frequency/volume chart and uroflowmetry modalities for recognizing low bladder capacity in male and female subjects.

Sex	Number of patients	Maximal voided volume from 48-hour frequency/volume chart	SD	Bladder capacity from uroflowmetry	SD	Difference	*P*-value
Male	42	173.9	75.69	185.2	87.49	11.3 ml	0.075
Female	44	202.8	116.87	225.5	129.34	22.7 ml	0.48

significant, can underestimate BC. A further limitation was the relatively small number of children with DV. The results indicating the value of performing both assessments in this subgroup will need to be verified by studies of larger cohorts.

Conclusion

In children with MNE, both 48-hour frequency/volume charts and triplicate urine flow measurement with PVR evaluation are reliable methods of maximum bladder capacity evaluation. In children with OAB or DV, both methods may be necessary for accurate evaluation of decreased BC, as results obtained by both modalities may not be comparable.

Conflict of interest/funding

None.

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