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Interpretation of Uroflowmetry and Post-Void Residual Urine in Children: Fundamental Approach to Pediatric Non-neurogenic Voiding Dysfunction

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INTRODUCTION

Before the introduction of the uroflowmeter by von Garrelts in 1957 [1], clinicians needed to watch the patient void to determine voiding function. Uroflowmetry tests have gained wide acceptance as initial screening tests for evaluation of voiding function in children because they are simple, non-inavasive and relatively inexpensive [2]. These tests can give clues to the underlying etiology of voiding dysfunction since the results are summaries of overall performance of bladder contractility and bladder outlet resistance. The post-void residual urine (PVR) is defined as the volume of urine left in the bladder after voiding. It serves as a sign of bladder emptying and is considered a risk factor for developing urinary tract infections (UTI) and recurrences. Today, the PVR is usually measured with suprapubic ultrasound instead of catheterization. However, there is a lack of norograms for the PVR in children. Herein, we introduce the indications and techniques, and how to interpret the results of uroflowmetry tests in children.

UROFLOWMETRY

Indications

Uroflowmetry may be applied to neurologically normal children children after toilet training or in when they are 5 years old if they have lower urinary tract symptoms, i.e. incontinence, urgency, or UTI are suspected of voiding dysfunction, or have signs suggestive of bladder outlet obstruction.

Techniques

The uroflowmeter should be placed in a quiet and private place with a comfortable environment since anxiety may impair the performance of voiding function in children. Before performing uroflowmetry tests, children are asked to drink fluids with amounts equal to the expected bladder capacity (EBC) i.e. (age × 30 + 30) mL one hour before the tests. Children are asked to void when there is a normal desire or urge to void. Boys are asked to void in a standing or sitting position and girls are asked to void in a sitting position. Girls in a sitting position are asked to sit with adequate foot support, a straight back and a tilted pelvis. At least two tests are usually needed since high variability in uroflowmetry tests could lead to a misleading diagnosis [3]. The International Children's Continence Society (ICCS) defines a voided volume of 50 mL or more as relevant for interpretations in children [4]. Uroflowmetry with a voided volume less than 50% of EBC has variable uroflow patterns [5]. Hence, uroflowmetry curves are better interpreted with a voided volume between 50% and 100% EBC for age.

Parameters generated from uroflowmetry

Normal uroflow curves show continuous flow with bell-shaped curves. The horizontal line of the curve is the time in seconds and the vertical line is the flow rate in mL/sec. The maximal flow rate (Qmax) is defined as the peak flow rate (PFR). The area under the curve is the voided volume. The average flow rate is defined as the voided volume divided by the voiding time. If the flow is intermittent, then the flow time is less than the voiding time. Otherwise the flow time is equal to the voiding time.

Interpreting uroflowmetry

1. Before interpreting uroflowmetry, the scale should be adjusted to 1 mL/sec on the vertical axis versus 1 sec/mL on the horizontal axis. Fig. 1A and 1B are the same figures with different scales. Although Fig. 1A is a bell-shaped curve, Fig. 1B may be interpreted as a plateau curve. In addition, if there are sharp peaks in the flow curves (Fig. 2), artifact is considered and the Qmax should be documented only at a peak level with a duration of at least 2 seconds.
2. Among the parameters generated from uroflowmetry tests, voided volume, PFR and uroflow curves are the most important parameters

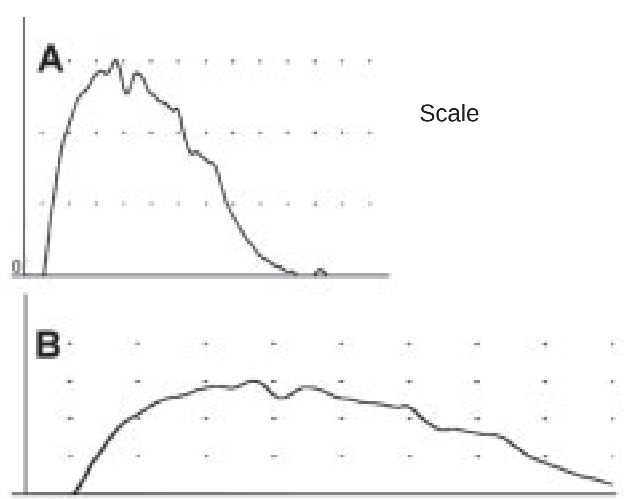

Fig. 1. The same figures using different scales.

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for interpretation. Each parameter will be discussed separately in the following sections.

3. Voided volume

The PFR uroflow patterns and PVR are all affected by the voided volume. Therefore, clinicians should check the voided volume before interpretation. In a previous study, we defined bladder overdistention as a voided volume >100% EBC or a bladder capacity >115% of EBC [6]. Bladder overdistention is associated with high rates of incomplete emptying (34.9%) and abnormal flow patterns (36.5%). As such, interpretations of uroflowmetry at an optimal bladder capacity, i.e. a voided volume between 50% and 100% EBC, is more reliable. If the child can not hold urine for uroflowmetry with a voided volume of more than 50 mL, check the voided volume on a bladder diary to confirm the diagnosis of overactive bladder.

4. Peak flow rate

The PFR which is an important parameter in the evaluation of adult voiding function, does not apply well in children. The ICCS defines a Qmax of more than the square root of the voided volume as normal. Generally, the PFR is positively associated with voided volume and age. However, as the volume of urine in the bladder exceeds 150% of EBC, the PFR decreases (Fig. 3) [6].The ICCS suggests that the Qmax is the most relevant variable when assessing bladder outflow. But detrusor contractility in children usually can overcome outlet resistance and the Qmax may not honestly respond to the resistance.

5. Flow patterns

The ICCS recommends that uroflowmetry curves be classified into five types, bell, tower, plateau, staccato and interrupted (fractionated). Only bell-shaped curves are regarded as normal. Tower-shaped curves are defined as high amplitude curves with a short duration (Qmax/flow time >2) (Fig. 4A). Staccato curves are defined as continuous curves with sharp peaks and troughs with fluctuations larger than the square root of the Qmax, and are suggestive of sphincter overactivity (Fig. 4B). Interrupted or fractionated curves are defined as curves separated by a zero flow rate, and are suggestive of detrusor underactivity (Fig. 4C). Plateau curves are defined as even flowmetry curves with low amplitude suggestive of anatomical bladder outlet obstruction (Fig. 4D). In healthy children, the reported rates of a normal bell-shaped uroflow pattern were 97.2% in Swedish children [7], 90% in Spanish children [8], and 63% in Chinese children [9]. Although we found a high rate of a non-bell-shaped flow patterns in ethnic Chinese children similar to that in Bower's report [6], non-bell-shaped curves were more frequently observed in voidings with bladder over overdistention than those without overdistention. In addition, repeated abnormal flow patterns or a repeated elevated PVR >20 mL is rare in healthy children [3]. Since all the above curves can be demonstrated ine normal healthy children, clinical information and repeated tests are required in the assessment of pediatric voiding function [3].

6. Inter-observer agreement

The variability in inter- and intra-observer interpretation of uroflowmetry curves can be great. Therefore, one should be familiar with the definition of each uroflow curve recommended by the ICCS. Our previous study found good inter-observer agreement in interpreting 'no abnormality' of uroflowmetry in children [10]. Venhola et al [11]

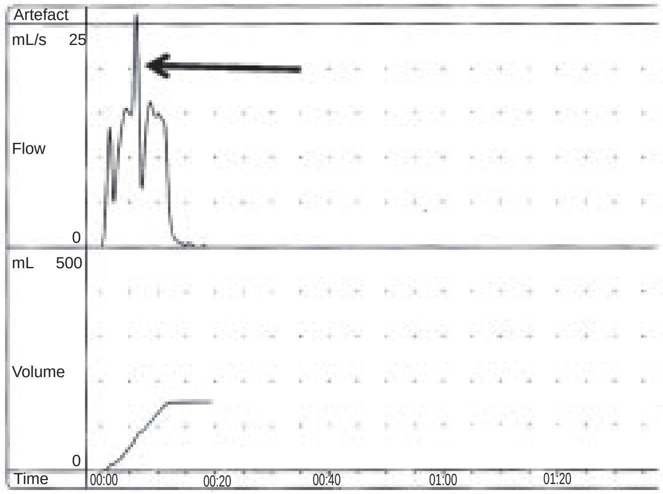

Fig. 2. Artifact in uroflowmetry curves.

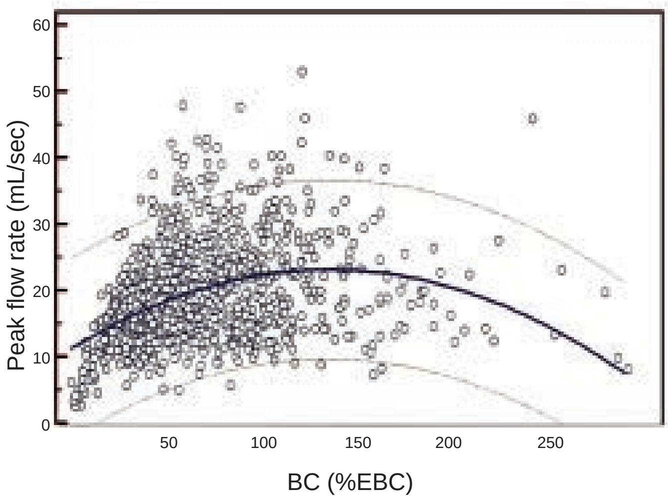

Fig. 3. Maximal flow rate initially increases with the volume of urine in the bladder, then decreases at 150% of expected bladder capacity for age.

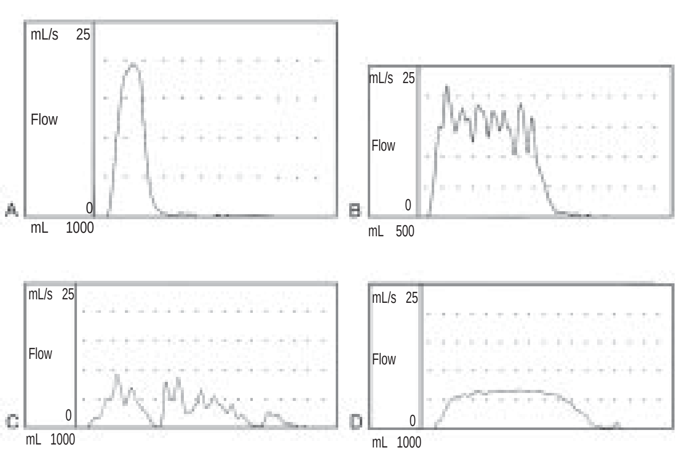

Fig. 4. (A) Tower-shaped curve. (B) Staccato curve. (C) Interrupted curve. (D) Plateau curve.

found identical answers on Qmax and voided volume among four urodynamists, but they reported that the inter-observer agreement was moderate with kappa values ranging from 0.44 to 0.55 for specific types of uroflowmetry curves in children with various types of voiding dysfunction. Gacci et al [12] invited 105 urologists to evaluate 10 selected uroflowmetry curves. They found that there was substantial agreement for the "no abnormality" diagnosis (kappa=0.72), and that flow curves from healthy men or from patients with urethral stricture or benign prostatic obstruction were easily recognizable. Simple classification of normal vs abnormal uroflow patterns is suggested to increase inter-observer agreement and to compare diagnoses and treatments between studies [10].

POST-VOID RESIDUAL URINE

The causes of elevated PVR volume can be obstructive, myogenic and/or neurogenic in nature. Although PVR is a crucial indicator for voiding dysfunction and a significant risk factor for developing UTI [13,14], there are no existing nomograms for PVR. A PVR greater than 10% of bladder capacity is often considered abnormal in adults, but is not relevant in children [2]. Based on the consensus of experts, the ICCS defines a repeated PVR of more than 5 mL and 20 mL as insufficient and incomplete emptying, respectively [2]. According to a longitudinal study done by Jansson et al [15], the median value of the PVR in Swedish children decreased from 5 mL at age 6 months to 2 mL at age 6 years. As such, children are expected to have a lower PVR as they get older. As shown in Fig. 5, we reported that PVR was dependent on the bladder capacity (the volume of urine in the bladder when children start to void). In addition, great variation in the PVR was noted in consecutive voidings (Fig. 6). Two PVR tests are strongly recommended to confirm the status of bladder emptying.

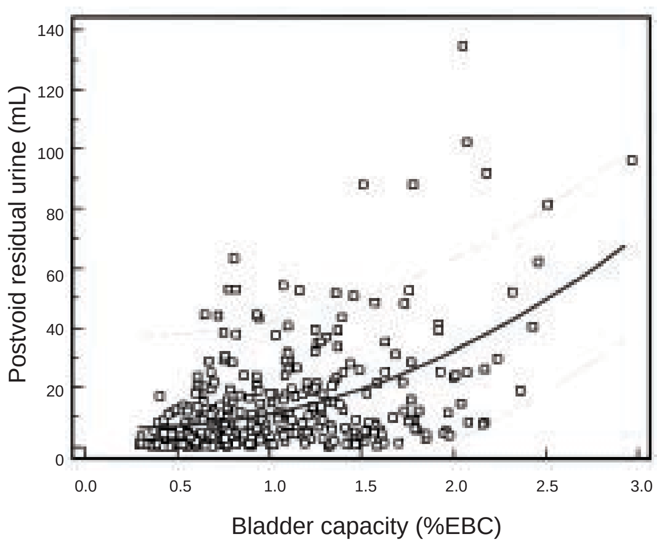

Fig. 5. The post-void residual urine in children is dependent on the bladder capacity (the volume of urine in the bladder when starting to void/ expected bladder capacity for age).

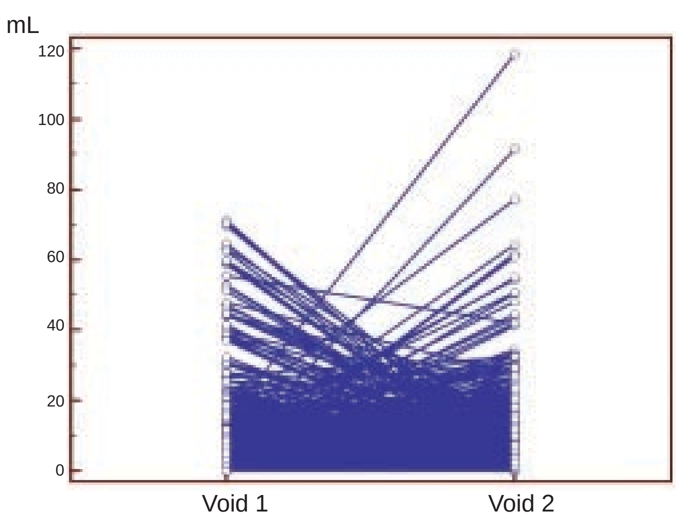

Fig. 6. Great variation in the post-void residual urine in consecutive voidings.

Technique

Today, PVRs are mostly measured with suprapubic ultrasound because it is non-invasive. Erasmie et al's study observed a high correlation (r=0.96) between the real time ultrasound measurement and the catheterized urine volume, but large volumes tended to be underestimated [16]. As the distributions of PVRs were positively skewed and most were below 20 mL, ultrasound could provide a good estimation of PVR in children. Although the PVR may be best assessed by urethral catheterization, its invasiveness makes it unfeasible as a good screening tool for pediatric voiding function.

All PVRs should be assessed within 5 minutes after voiding with 5 MHz suprapubic ultrasound, and estimated by the equation of height × width × depth (of the bladder) × 0.52 mL [16]. A delay in the examination may increase the value of the PVR at a rate of 1 mL per minute [2].

WHEN TO DO INVASIVE URODYNAMIC STUDY AND THE EXPECTED RESULTS

Indications for invasive urodynamic study (UDS)

The routine use of UDS in diagnosis in the non-neurogenic dysfunctional voiding population is open to debate [17,18]. UDS may be indicated in children with persistent lower urinary tract symptoms after empirical treatment for 3 months, or in children with a repeated abnormal uroflow pattern, or an elevated PVR under optimal bladder capacity [19]. The ICCS does not recommend UDS as a regular tool for diagnosis of dysfunctional voiding in children. In 1,000 video-urodynamic studies in children with non-neurogenic bladder sphincter dysfunction (NNBSD), Hoebeke et al [20] found normal bladder-sphincter function in 62 (6.2%), urge syndrome in 582 (58%), dysfunctional voiding in 316 (32%) and 'lazy bladder' in 40 (4%). Although the European Bladder Dysfunction Study prospectively found that the results of UDS did not correlate with treatment outcomes in children with dysfunctional voiding, Kaufman et al reported that up to 63% of children with nonneurogenic dysfunctional voiding had pathological findings if primary treatment failed [21]. Therefore, we suggest that UDS be reserved for children with NNBSD if the primary treatment fails. In addition, repeat UDS can be performed on a schedule to monitor responses to treatment. Other indications for repeat UDS include new onset of symptoms, infections, or new neurological events.

Expected results of urodynamic findings

Through UDS with or without imaging, bladder dysfunction can be grouped as a storage or voiding phase problem. Frequent findings in the storage phase include unstable detrusor contractions, small cystometric capacity and poorly compliant bladder. Voiding phase disorders can be classified into dynamic or anatomical dysfunction. Dysfunctional voiding means intermittent sphincteric contractions or un-relaxed sphincter during detrusor contraction. Possible anatomical obstructions include bladder neck dysfunction, congenital posterior urethral membrane, and posterior urethral valve. Detailed information on the diagnosis and treatment can be found in specialist books.

CONCLUSIONS

Physician dealing with pediatric UTI and lower urinary tract dysfunction should be familiar with non-invasive uroflowmetry and PVR tests which provide valuable assessment of bladder function. Optimal bladder capacity, i.e. a voided volume between 50% and 100% of the EBC, is required in the interpretation of uroflowmetry and PVR.

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