Voiding patterns after Urethral reconstructive surgery

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*By*

*Ahmed Abdel Naeem Ali El Mogy*

*MB.B.CH.*

Faculty of Medicine

Benha University

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INTRODUCTION

The objectives of urethral reconstructive surgery are to maintain function and to produce an aesthetically satisfactory penis. Urethroplasty is the gold standard treatment to manage urethral stricture disease with greater than 90% success for most repair types. (Wong et al., 2010)

The methods to evaluate the reconstructed urethra include direct observation of the urinary stream, voiding cystourethrography and uroflowmetry (Hussein et al., 2013)

Uroflowmetry tests are simple and non-invasive, and they have been adopted by urologists as preliminary screening tools for voiding dysfunction in men with lower urinary tract symptoms (Juliao et al., 2012).

Due to the increasing popularity of the urethral repair for all types of urethral defects namely, hypospadias and urethral stricture and their potential sequelae include stricture recurrence, critical analysis of the uroflowmetry findings could reflect the elasticity of the neourethra. As described by Poiseuille’s law, the pressure differential created by a tube is directly related to its length and inversely related to the radius. Thus, the neourethra could be stricture-free while its length-to-caliber ratio may be acting as a resistance. In the absence of frank stricture and neomeatal stenosis, elasticity in the neourethra could explain the high incidence of plateau flow curve, increased resistance, and proximal fistula (Braga et al., 2007).
**Uroflowmetry**

**Introduction**

Urodynamics, the study of the lower urinary tract function, is designed to reproduce the lower urinary tract symptoms of the patient experiences under controlled and measurable conditions for the analysis of function and dysfunction to identify the cause of symptoms (Abrams et al., 2006). The procedure provides the clinician with the necessary information to systematically approach the patient’s diagnosis and choose the optimal treatment. UDS have different components which include noninvasive evaluation (uroflowmetry) and invasive evaluation (filling cystometry, pressure–flow studies and/or urethral function measurements). UDS may be complemented by simultaneous electromyography recording and/or X-rays (video-urodynamic study) (Storme et al., 2016).

Measurement of urine flow and residual urine (with ultrasound) as a standalone examination is by far the most common procedure in pediatric urodynamic practice. The results of the flow/residual examination decide whether the child requires further investigation. This may be repeated at the same setting to ensure that a reasonable volume of urine is expelled with each micturition. Flow measurement is a cornerstone of diagnosis in children after toilet training. Maximum flow rate is the most relevant variable when assessing bladder outflow (Neveus et al., 2006).

**Indications**

Prior to invasive UDS, it is important to do non-invasive UFM. Without a catheter, evaluation of flow is more accurate than during the pressure-flow study. Indications for UFM include initial evaluation of patients with benign prostatic hypertrophy, urinary incontinence, urethral strictures, recurrent urinary tract infections and neurogenic bladder dysfunction. In patients with LUTS, UFM may suggest an abnormality of voiding/emptying. UFM has also been very helpful in follow up of patient status post urethroplasty in determining stricture recurrence (Storme et al., 2016).

**Equipment**
### Table (1) Types of uroflowmeters

<table>
<thead>
<tr>
<th>Type of flow metre</th>
<th>Principle</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotating disc</td>
<td>Momentum flux principle: Urine is directed onto spinning disc, at constant speed, controlled by a servomotor. The power required to maintain a constant disc speed is proportional to the flow of urine opposing the rotation of the disc. The volume is calculated by integration</td>
<td>Accurate flow rate measurements, Fast response time</td>
<td>Interpretation of traces: artifacts can arise from “wag effect.” See below</td>
</tr>
<tr>
<td>Weight transducer</td>
<td>Gravimetric principle: Weight of urine collected indicates the volume and, by differentiation, the flow rate</td>
<td>Accurate volume measurements, Relatively simple</td>
<td>Relatively slow response time, “Wag effect,” Density of urine affects results, Density must be set, More prone to “knocking” artifacts</td>
</tr>
<tr>
<td>Electrical Capacitance</td>
<td>Bimetallic strip: the electrical capacitance of a dipstick, mounted in the chamber, changes as the height of the column of urine in a container of a standard size alters</td>
<td>Least expensive, No mechanical parts</td>
<td>Density must be set, Prone to “knocking” artifacts</td>
</tr>
</tbody>
</table>

*(Cafferel et al. 2006)*
Fig. (29): Uroflowmeter (right), complete voiding equipment with funnel and chair (left) During uroflowmetry patient must void as usually does (Storme et al., 2016).

Preparation

The preparation of the patient and the room are very important to reproduce a normal void. The patient should know he/she will void into an uroflowmeter (per their usual habit) usually standing up or sitting down. The patient should also be made aware of the importance of the exam to evaluate voiding symptoms. Ideally, the exam would be done with normal desire to void (preferably first desire to void), not under urgency. Bladder over distention could alter normal flow and increase post void residual (PVR) (Storme et al., 2016).

The expected bladder capacity (EBC):

The expected bladder capacity (EBC) for age was defined as (age in years + 1) X 30 ml. This formula is useful up to age 12 years, after this age EBC is level at 390 ml (Neveus et al., 2006).
Uroflowmetry Technique

Paper speed of 0.25 cm/s is the standard, as it allows an accurate and systematic curve construction. Different paper speeds change curve shapes, and thus can alter the interpretation of the test. Urinary flow and PRV depends on bladder urinary volume. For accuracy of testing, voided volume must be over 150 ml and ideally less than 400–500 cc as the detrusor muscle may become overstretched and contractility may decrease, consequently creating a false result *(Storme et al., 2016)*.

Interpretation

*International Continence Society (ICS) Definitions and Their Application*

**Flow rate** is defined as the volume of fluid expelled via the urethra per unit time. It is expressed in milliliters per second.

**Voided volume** is the total volume expelled via the urethra. It is the area under the flow curve and can be estimated. In the example shown *(Fig.30)*, each square represents a volume of 50 mL (5 s × 10 mL/s = 50 mL). There are 10 squares of 50 mL and 5 half complete squares under the flow curve. 10 × 50 mL + 5 × 25 mL = approx. 625 mL. This can be used to estimate whether a flow trace is above 200 mL volume and below the usual voided volume for the patient and therefore can be used in their case.

**Maximum flow rate** *(Q max)* is the maximum measured value of the flow rate after correction for artifacts. The automated printout generated by most machines will not know what is an artifact and may give a wrong *Q max*. Looking at the trace is the best way of working out *Q max*.

**Voiding time** *(T100)* is total duration of micturation, i.e., includes interruptions. When voiding is completed without interruption, voiding time is equal to flow time.

**Flow time** *(TQ)* is the time over which measurable flow actually occurs. Difference between voiding time and flow time means that there is an intermittent flow. It does not tell you what is the nature of the intermittency.
**Average flow rate** \((Q_{ave})\) is voided volume divided by flow time. The average flow should be interpreted with caution if flow is interrupted or there is a terminal dribble. \(Q_{ave}\) can be calculated by timing a void and then measuring the volume voided.

\[
\text{Volume/time} = Q_{ave}
\]

**Time to maximum flow** \((TQ_{max})\) is the elapsed time from onset of flow to maximum flow. As the automated \(Q_{max}\) measurement can be wrong, the time to \(Q_{max}\) must also be ascertained directly from the trace (*Napier et al., 2012*).

![Fig. (30) A normal urine flow rate curve and its derived parameters (*Napier et al., 2012*).](image)

**Maximum flow rate** \((Q_{max})\)

Among the parameters generated from uroflowmetry, \(Q_{max}\) is regarded by the ICCS as the most relevant variable when assessing bladder outflow. For practical use, Yang et al. (2014) suggested a minimally acceptable \(Q_{max}\), i.e., around the 10th percentile of the dual-\(Q_{max}\) nomogram, of > 11.5 ml/second in children aged < 6 years and >15.0 ml/second in children aged > 7 years (*Yang et al., 2014*). In Single-\(Q_{max}\) nomograms, the 5th, 10th, 25th and 50th percentiles of overall single-\(Q_{max}\) were 8.5, 10.7, 13.5 and 17.9 ml/s, respectively (*Yang et al., 2014*). The ICCS considers a \(Q_{max}\)
(ml/s) larger than the square root of the VV (mL) as within normal limits (Neveus et al., 2006). Therefore, Q max plays an important role in monitoring the effectiveness of medical and surgical treatment for voiding dysfunction. Surgeons usually use Q max as a parameter for bladder outlet obstruction in children undergoing hypospadias repair (Andersson et al., 2011).

In studies of normal children and adults a linear correlation has been found between maximum flow and the square root of voided volume (Szabo and Fegyvernski, 1995).

Thus, preliminary evaluation of the results of a flow measurement is possible. If the square of the maximum flow (ml per second) is equal to or exceeds voided volume in ml, the recorded maximum flow is most probably within the normal range (Abrams et al., 2002).

**Flow curve shape**

The shape of the curve may serve as a guide to the existence of a specific condition. The precise shape of the flow curve is determined by detrusor contractility, any abdominal straining and the bladder outlet. In normal voiding the curve is smooth and bell-shaped. Overactive bladder may produce an explosive voiding contraction that appears in the flow measurement as a high amplitude curve of short duration, i.e. a tower-shaped curve. In case of a child with organic outlet tract obstruction, a low amplitude and a plateau-shaped curve is produced. Similarly, this may be the case when there is a tonic sphincter contraction during voiding. However, more commonly sphincter overactivity during voiding is seen as sharp peaks and troughs in the flow curve, that is as an irregular or staccato flow curve. This is considered as a continuous but fluctuating flow curve. To qualify for the staccato label the fluctuations should be larger than the square root of the maximum flow rate (Neveus et al., 2006).

Sharp peaks in the flow curve are usually artifacts, and so maximum flow should be documented only at a peak level with a duration of at least 2 seconds (Schafer et al., 2002).

Finally, in case of an underactive or acontractile detrusor when contraction of the abdominal muscles creates the main force for bladder evacuation, the flow curve usually shows discrete peaks corresponding to each strain, separated by segments with zero flow,
namely an interrupted or fractionated flow curve. To avoid confusion due to a multitude of terms regarding the shape of the flow curve the ICCS suggests that a certain terminology should be adopted, including bell, tower, plateau, staccato and interrupted (Neveus et al., 2006).

**Post Void Residual (PVR)**

Residual urine is assessed by real-time ultrasonography after a uroflow measurement. The lowest acceptable limit of 10% of bladder capacity, as often stated in adults, is not relevant in children. Studies in healthy infants and toddlers have shown that they do not empty the bladder completely every time, but they do so at least once during a 4-hour observation period. However, older children should be expected to habitually empty the bladder completely. The unavoidable delay of a few minutes after finishing voiding until ultrasonography results in bladder refilling with up to 5 ml, which is the upper value of residual urine not associated with urinary tract infection (Jansson et al., 2000).

The ICCS arbitrarily defined the reference range of PVR as follows: a PVR range of 5 to 20 ml may be associated with insufficient emptying, so that the examination should be repeated. More than 20 ml residual urine found on repetitive occasions indicates abnormal or incomplete emptying, provided that 1) there has not been any time delay exceeding 5 minutes from the end of voiding until ultrasonography is performed and 2) the child has not over ambitiously delayed micturition and, thus, achieved a state of bladder fullness more than what is normal for him. The case of a longer time delay can be compensated for by subtracting 1 or 2 ml from measured residual urine for every minute beyond 5 (Neveus et al., 2006).

For children aged < 6 years, a single PVR > 30 mL or >21% BC, or repetitive PVR > 20 mL or > 10% BC can be regarded as elevated. For children aged > 7 years, a single PVR > 20 mL or 15% BC, or repetitive PVR > 10 mL or 6% BC can be defined as elevated (Chang et al., 2013).
Limitations of Urine Flowmetry

Urinary flow rates reflect the interaction between intravesical pressure and urethral calibre, but you can only infer what kind of muscle has caused the increase in urinary flow. Smooth muscle contracts and relaxes slowly and produces the reproducible, skewed, bell-shaped curve shown in Fig.2. Striated muscle contraction with abdominal straining produces more rapid changes in pressure, which are different with each strain. On this basis, the investigator may infer whether bladder emptying is by abdominal strain or detrusor contraction. Uroflowmetry is also subject to artifactual variations (Table 2) (Storme et al., 2016).

**Table 2** Artifacts encountered during uroflowmetry and their influence on intravesical pressure, the flow at the external meatus and the observed flow pattern.

<table>
<thead>
<tr>
<th>Artefact</th>
<th>Effect on intravesical pressure</th>
<th>Effect on flow at the external urinary meatus</th>
<th>Effect on flow record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>Increased</td>
<td>Increased</td>
<td>Short sharp spike of increased flow</td>
</tr>
<tr>
<td>Valsalva/strain</td>
<td>Increased</td>
<td>Increased</td>
<td>Wider increased flow spike</td>
</tr>
<tr>
<td>Wagging/cruising</td>
<td>No increase</td>
<td>No increase</td>
<td>Sharp spike with decreased flow either side. Caused by the urinary stream being directed across the funnel with artefactual variation in the incident flow recorded by the measuring transducer</td>
</tr>
<tr>
<td>Manual urethral occlusion</td>
<td>No increase</td>
<td>Zero flow, then increased</td>
<td>Flow interrupted and goes to zero</td>
</tr>
<tr>
<td>External sphincter closure</td>
<td>Possible small increase</td>
<td>Small increase, then zero flow</td>
<td>Urethra fills with urine with increased flow on release of urethral compression</td>
</tr>
<tr>
<td>Knocking</td>
<td>No increase</td>
<td>No increase</td>
<td>Small increase in flow before it stops</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High spike of flow. Spike so bizarre in appearance it could not have been caused by physiological bladder activity</td>
</tr>
</tbody>
</table>
Nomograms for uroflowmetry:

Much work has been devoted to the construction of flow rate nomograms. Nomograms have been described for boys, girls, men under 55, men over 55 and women. In our unit we use the Siroky nomogram for men under 55 and the Bristol nomogram for men over 55 (Abrams et al., 2006).

Fig. (34): Siroky nomogram for men under 55 years of age (Abrams et al., 2006).

Fig. (35): Bristol nomogram for men over 55 years of age (Abrams et al., 2006).
Nomograms for children:

A flow nomogram recently proposed by Gupta et al. was obtained from one of the largest studies that constructed nomograms from boys aged 5–15 years, and allows an interpretation of the Q max and Q ave at different voided volumes (Al-Adl et al., 2014).

The value of the minimum VV necessary to reach any conclusion is also not well established in children. Some studies consider uroflow with VV of 50 ml, while others consider VV as low as 20 ml for evaluation (Gupta et al., 2013).

Fig.(36): Uroflowmetry nomogram for maximum flow rates in boys 5 to 15 years old (Gupta et al., 2013).
In comparative study of tubularized incised plate versus onlay island flap urethroplasty for penoscrotal hypospadias Braga and his colleagues found that the overall complication rate was similar for both techniques, some differences became evident when the type of complication was analyzed. Fistula rate was significantly higher after TIP vs onlay repair. Furthermore, fistula location was strikingly different between the 2 techniques, with proximal fistulas occurring in 73.3% of patients following TIP and in 25% following onlay repair. This particular finding is intriguing. Despite performing urethroplasty over an 8Fr catheter in both techniques, the preponderance of proximal fistulas suggests that a “long TIP” neourethra may generate increased flow resistance (relative to a short TIP for more distal repairs). As described by Poiseuille’s law, the pressure differential created by a tube is directly related to its length and inversely related to the radius. Thus, although the TIP neourethra is stricture-free, its length-to-caliber

**Fig.(37): Uroflowmetry nomogram for average flow rates in boys 5 to 15 years old**

*(Gupta et al., 2013).*
ratio may be acting as a resistance (relative to the onlay neourethra) just beyond the native meatus, giving rise to a proximal fistula in the vicinity of the original proximal hypospadiac meatus (Braga et al., 2007).

Fig.(38): Schematic representation of possible flow dynamics of neourethra following TIP vs onlay repair for penoscrotal hypospadias. A, penoscrotal TIP neourethra is longer than for coronal TIP repair. B, in absence of neomeatal stenosis (usually responsible for common distal fistulas) Poiseuille’s law predicts high resistance in longer tube, and may explain proximal fistula after TIP repair. C, in more distensible (8Fr or greater during voiding) onlay neourethra made from skin would predict less resistance as well as bell-shaped flow curve (Braga et al., 2007).
References


