Received: 26 February 2018 | Accepted: 14 May 2018
DOI: 10.1002/nau.23730

REVIEW ARTICLE

ICS educational module: Pressure flow study in children

Jian G. Wen[1,2] | Jens C. Djurhuus MD[3] | Peter F.W.M. Rosier[4] | Stuart B. Bauer[5]

[1] Pediatric Urodynamic Centre, The First Affiliated Hospital of Zhengzhou University, Zhengzhou, China
[2] Department of Pediatric Surgery, The First Affiliated Hospital of Xinxiang Medical University, Weihui, China
[3] Department of Clinical Medicine, Aarhus University, Aarhus N, Denmark
[4] Department of Urology, University Medical Centre Utrecht, Utrecht, The Netherlands
[5] Department of Urology, Boston Children's Hospital, Boston, Massachusetts

Correspondence
Jian G. Wen, Pediatric Urodynamic Centre, the First Affiliated Hospital of Zhengzhou University, Jianshe East Road No. 1, Zhengzhou, 450052, China.
Email: wenjg@hotmail.com

Aims: To introduce the standard procedure and results interpretation of pressure/flow study (PFS) in children.
Methods: The literature on PFS in children in PubMed for the last 20 years was reviewed. The updated knowledge on PFS in children in children regarding indication, preparation, technique, and interpretation were summarized.
Results: This educational module explains when and how to do a PFS and how to analyze the results. All requirements and instructions for the PFS in children described in this document follow ICS reports on Good Urodynamic Practice and urodynamic equipment performance as well as guidelines from the ICCS. PFS can be obtained subsequent to filling cystometry with no specific additional equipment (apart from a flowmeter) or patient preparation needed. It requires both vesical and intra-abdominal pressures being recorded. Information from clinical history, physical examination, voiding diaries, and free uroflowmetry with or without perineal patch EMG and pertinent imaging results should be available before undertaking urodynamic testing.
Conclusions: Following ICS and ICCS guidelines, PFS is an easy procedure and a useful tool to provide information on voiding function in children.

KEYWORDS
children, pressure/flow study, procedure, urodynamics

1 | INTRODUCTION

Pressure/flow study (PFS) provides information on voiding function (outflow obstruction, flow pattern, detrusor contractility, and its sustainability as well as intravesical pressure). Combined with filling cystometry, it is the gold standard for evaluating voiding function in children with lower urinary tract dysfunction (LUTD)/lower urinary tract symptoms (LUTS), especially when less invasive studies fail to provide an adequate explanation for the symptoms and/or the signs of dysfunction.[1–7]

The aim of pressure/flow studies is to reproduce symptoms, to identify the underlying causes for voiding symptoms, and to quantify related pathophysiological processes. It is used to establish as clearly as possible a baseline, so that changes resulting from treatment and/or growth can be assessed, indicating that the investigation may need to be repeated, and to provide some guidelines for the choice of treatment (although results of urodynamic testing may not necessarily be the deciding factor).

The ICS Urodynamics Committee presents this educational module "Pressure/flow analysis in children" to serve as a standard education module of Good Urodynamic Practice for everyone concerned when prescribing, performing, and analyzing pressure/flow testing in general and especially in children with symptoms and signs of LUTD. The educational module consists of a presentation, in combination with this manuscript. This manuscript serves as a scientific background review; the evidence base, for the ICS PowerPoint presentation; available via http://www.icsoffice.org/. The presentation explains when and how to do a PFS and how to analyze the results. The presentation and this manuscript use expert's opinion where evidence is, especially for the clinical practice aspects, unavailable and is marked with: “eo” (expert's opinion).

Voiding dysfunction is prevalent in pediatric urology practice. The subjective bias by both the child and the clinician and the considerable overlap between symptoms from varying disorders make it difficult to evaluate voiding function without employing some objective parameters. All requirements and instructions for the PFS in children described in this section follow ICS reports on Good Urodynamic Practice[2,3] and urodynamic equipment performance[4] as well as guidelines from the ICCS.[5] Pressure/flow measurements can be obtained subsequent to filling cystometry with no specific additional equipment (apart from a flowmeter) or patient preparation needed. It requires both vesical and intra-abdominal pressures being recorded. Information from clinical history, physical examination, voiding diaries, and free uroflowmetry with or without perineal patch EMG and pertinent imaging results should be available before undertaking urodynamic testing.

2 | INDICATIONS AND PREPARATION

The indications and preparation for PFS are similar to that for cystometry. Whether the child is able to void voluntarily or not, evaluation of the voiding, measured in a continuous fashion after the filling cystometry is complete, can be regarded as standard practice. The child and caregiver should be informed in advance along with an explanation as to why both phases, storage (filling), and voiding are going to be measured. The child's cooperation is explicitly sought whenever possible.

3 | TECHNIQUE

PFS is defined as measuring the detrusor pressure and uroflow during the micturition or voiding phase. The detrusor pressure is equal to the bladder pressure minus the abdominal pressure, thus representing the pressure produced by the detrusor. The voiding phase begins when the child and the urodynamicist decide that “permission to void” has been given, or when involuntary voiding begins.[6] This occurs when the maximum cystometric capacity (MCC) has been reached in children with no voiding dysfunction.[7] During this phase the detrusor contracts, producing voiding detrusor pressure as the bladder outlet relaxes. It is not always possible to have very young children follow instructions to void, but in older children it is.

At this phase, the detrusor pressure increases as the pelvic floor relaxes and the urethral pressure decreases resulting in voiding. The pressures are recorded through the same catheter that is used for cystometry. During the recording, a flowmeter connected to the urodynamic equipment, allows flowrate parameters to be juxtaposed against pressure data and correlated with one another. At the completion of voiding the detrusor relaxes and the urethra/bladder outlet “closes.”

During voiding the detrusor may be classified as normal, underactive, or acontractile. Normal voiding is achieved by a voluntarily initiated detrusor contraction; it is sustained and cannot be suppressed easily once it has begun. In the absence of bladder outlet obstruction, a normal contraction will lead to complete emptying.[6] When the child feels voiding is complete, this phase ends and storage phase begins again. During the voiding phase, a flowmeter connected to the urodynamic equipment, allows flowrate parameters to be juxtaposed against pressure data and correlated with one another.

During PFS Q_{max} and voided volume are recorded. Pressure parameters that can be obtained during the voiding phase are: pre-micturition pressure, opening pressure, opening time, maximum detrusor pressure, detrusor pressure at maximum flow, closing pressure, minimum voiding pressure. The maximum detrusor pressure ($P_{det.max}$) is clinically relevant in determining the presence of bladder outlet obstruction (BOO) or contractile detrusor.

After the PFS, the PVR is measured again through the catheter and confirmed by ultrasound.

3.1 | Cooperation

Cooperation is important for successful cystometry and PFS. The following steps might be valuable for achieving this.

- Bowel or rectum preparation; defecation (at home) before the test whenever possible.
- Dedicated and knowledgeable staff able to provide an explanation about the procedure and the aim of urodynamic studies to the patient is paramount: if applicable, engage the child to increase cooperation.
- Administration of sedatives (not anesthetics), and documenting if the child was very fearful is mandatory.
- Prior application of 1% lidocaine jelly or a liquid solution instilled into the urethra as a topical anesthetic may aid in catheter insertion.
- The approach to urodynamic evaluation should be, start with as minimally invasive tests as possible and proceed with invasive investigations, as necessary, to answer the question.
- If the child is still agitated after inserting the catheter in the bladder, having parents present to help calm their child, is advisable.
- Toys, video games, or movies during the examination are very helpful to distract the child and minimize artifact.

- Two cycles of cystometry and PFS to determine the consistency or representativeness of findings is preferable.

4 | INTERPRETATION

The aim is to analyze accurately, and to critically report results after carefully performing the PFS in children.

1. Normal voiding detrusor function- Normal detrusor function is characterized by an initial (voluntary) relaxation of the external urethral sphincter/pelvic floor followed immediately by a continuous detrusor contraction that leads to complete bladder emptying within a normal time span, in the absence of obstruction.
2. Maximum voiding detrusor pressure ($P_{detr \cdot void.max}$) should be reported and related to the flowrate to determine diagnosis. The flowrate should be compared to the free flowrate as one means of evaluating the representativeness of the (pressure/flow) voiding.
3. Detrusor-Sphincter Dyssynergia (DSD): describes a detrusor contraction concurrent with an involuntary contraction of the urethral and/or periurethral striated muscle. Occasionally the flow may be prevented altogether

   .. DSD is usually evaluated by a pressure/flow/EMG study or with simultaneous bladder/urethral pressure recordings. High Pdetr.void.max in infants or a staccato detrusor pressure curve during voiding when flowrate reductions are synchronous with detrusor pressure increments indicate the existence of DSD.
4. PVR>20 mL or >15% of bladder capacity (BC) in children age 7-12 years and >30 mL or >21% BC for children 4-6 years on two consecutive uroflows indicates an abnormality.[8] The uroflow is considered normal if the bladder empties at least once during two uroflow measurements. If a low PVR is demonstrated during free flow uroflowmetry then any raised PVR during the urodynamic assessment can be considered as an artifact due to the artificial circumstances of the test and the presence of an in-situ urethral catheter.
5. Detrusor underactivity is defined as a voiding contraction of reduced strength and/or duration, resulting in prolonged bladder emptying and/or a failure to achieve complete bladder emptying within a normal time span.[8] Pressure flow nomograms or calculations are needed to quantify detrusor contractility. Detrusor underactivity may occur with or without an elevated PVR.
6. An acontractile detrusor does not demonstrate any contractile activity during urodynamic assessment. Some children, however, cannot or will not generate a detrusor contraction in a "laboratory" setting. This could be mistaken for a diagnosis. Spending extra time encouraging the child to void, dripping water on the pubic area, or lower extremity and/or having the mother or caregiver encourage the child to void, helps in the process to induce the child to urinate.
7. A high voiding detrusor pressure (usually >74 cmH_2O in boys, 63 cmH_2O in girls[7]) with a low urine flow indicates BOO; low pressure with a low flow indicates underactive detrusor. A pressure flow plot is useful to evaluate the pressure flow relationship in this regard, although clinical calibration is not yet available for children.
8. High voiding detrusor pressures may be induced by significant resistance as is seen in BOO where the detrusor compensates for BOO. Conversely if urethral resistance is low this may be reflected by a low pressure (high velocity) detrusor contraction.
9. A post voiding contraction indicates a detrusor contraction that occurs immediately after micturition is complete. Its clinical relevance is uncertain, but it may be related to detrusor overactivity and/or a sign of CNS dysfunction as well as collapsing mucosa on catheter pressure channel openings.
10. Bladder voiding efficiency(BVE) = (voided volume/total bladder capacity) × 100%.[9]
11. Cystometry volume parameters can be corrected for any diuresis during the test after pressure flow study by immediately recording the PVR and adding it to the voided volume.

The parameters of free flow measurement such as the PVR and maximum flowrate are useful for determining the accuracy of the flowrate and PVR obtained from PFS. If the flowrate and PVR show substantial differences from those obtained during PFS, it indicates an artifact may exist. For example, if the flowrate is lower and the PVR, significantly higher compared to that obtained from free flowmetry (before catheterization), the PFS results may be not representative.

5 | CONCLUSION

PFS is a useful tool for evaluating lower urinary tract function in children. It should be considered as one procedure, along with a "free" voiding uroflowmetry and filling cystometry, but not the only one, to clarify the diagnosis and to make therapeutic decisions as well as to follow up treatment responses to the voiding dysfunction, when less invasive studies are inconclusive. To understand the characteristics in PFS, normal voiding parameters as well as following GUP recommendations from the ICS and ICCS are the basis of successful testing. We present the evidence background for the PowerPoint presentation, to be used for educational the practice of the test, as is available on the ICS website.

ORCID

Jian G. Wen http://orcid.org/0000-0003-0952-118X
Peter F.W.M. Rosier http://orcid.org/0000-0003-0445-4563

REFERENCES

1. Wen JG, Lu YT, Cui LG, et al. Bladder function development and its urodynamic evaluation in neonates and infants less than 2 years old. *Neurourol Urodyn*. 2015;34:554–560.
2. Schafer W, Abrams P, Liao L, et al. Good urodynamic practices: uroflowmetry, filling cystometry, and pressure-flow studies. *Neurourol Urodyn*. 2002;21:261–274.
3. Rosier P, Schaefer W, Lose G, et al. International Continence Society good urodynamic practices and terms 2016: urodynamics, uroflowmetry, cystometry, and pressure-flow study. *Neurourol Urodyn*. 2017;36:1243–1260.
4. Gammie A, Clarkson B, Constantinou C, et al. International Continence Society guidelines on urodynamic equipment performance. *Neurourol Urodyn*. 2014;33:370–379.
5. Bauer SB, Nijman RJ, Drzewiecki BA, et al. International Children's Continence Society standardization report on urodynamic studies of the lower urinary tract in children. *Neurourol Urodyn*. 2015;34:640–647.
6. Christopher RC, Scott AM, Anand P. *Urodynamics Made Easy*. 3rd ed. London: Elsevier Churchill Livngstone; 2009;83–102.
7. Wen JG, Tong EC. Cystometry in infants and children with no apparent voiding symptoms. *Br J Urol*. 1998;81:468–473.
8. Austin PF, Bauer SB, Bower W, et al. The standardization of terminology of lower urinary tract function in children and adolescents: update report from the standardization committee of the International Children's Continence Society. *Neurourol Urodyn*. 2016;35:471–481.
9. Abrams P. Bladder outlet obstruction index, bladder contractility index and bladder voiding efficiency: three simple indices to define bladder voiding function. *BJU Int*. 1999;84:14–15.

How to cite this article: Wen JG, Djurhuus JC, Rosier PF, Bauer SB. ICS educational module: Pressure flow study in children. *Neurourology and Urodynamics*. 2018;37:2311–2314. https://doi.org/10.1002/nau.23730