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REVIEW ARTICLE

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ICS educational module: Cystometry in children

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Aims: To introduce the standard procedure of cystometry and interpretation of the results in children.

Methods: The literature on cystometry in children in PubMed for the last 20 years was reviewed. The updated knowledge regarding indication, preparation, technique, and interpretation of cystometry in children were summarized.

Results: Filling cystometry is the core content of a paediatric urodynamic study. In this section, the technique for performing cystometry is introduced in details. Emphasis is placed on correctly setting up the equipment according to ICS and ICCS guidelines, using appropriate terminology, providing indications for its performance with specific considerations for children, and proper interpretation of results.

Conclusions: Cystometry can be used in children including newborn to evaluate lower urinary tract dysfunction.

KEYWORDS
children, cystometry, procedure, urodynamics

1 | INTRODUCTION

The International Continence Society (ICS) and International Children Continence Society (ICCS) define filling cystometry as the urodynamic procedure by which the pressure-volume relationship of the bladder is measured. Filling cystometry is done to provide information on storage function (detrusor activity, sensation, compliance, and cystometric capacity). Filling cystometry in children is usually performed in combination with perineal EMG skin electrodes to add information regarding pelvic floor striated muscle activity.[1–4] On rare occasions needle electrodes are inserted into the pelvic floor musculature to precisely define denervation in patients with neurogenic bladder dysfunction.

The ICS educational module consists of an oral presentation in combination with this manuscript, the latter serving as a scientific background review; the evidence gathered for the ICS PowerPoint presentation is available via http://www.icsoffice.org. The presentation explains when and how to do a filling cystometry and how to analyze the results in children.

Filling cystometry is the core content of a paediatric urodynamic study. In this section, the technique for performing cystometry will be discussed in detail. Emphasis will be placed on correctly setting up the equipment according to ICS and ICCS guidelines,[2–4] using appropriate terminology, providing indications for its performance with specific considerations for children, and proper interpretation of results.[5] Other elements of a urodynamic investigation, for example, pressure flow study or video-urodynamic study will be covered in specific educational modules.

2 | INDICATIONS AND PREPARATION

Filling cystometry is indicated when history and clinical examination raises a suspicion of either anatomic and/or neurologic lower urinary tract dysfunction involving primarily the storage phase, or there is a question that cannot be answered by less invasive testing. Additionally, filling cystometry is relevant when anatomical or functional bladder

outflow obstruction (voiding phase) (eg, valve bladder syndrome, detrusor-sphincter dyssynergia associated with neuropathic bladder), or congenital anomalies of the bladder (exstrophy, ureteroceles, multiple bladder diverticula) may be causing symptoms and signs of dysfunction that may need further delineation.[6] When a urodynamic investigation is ordered the patient and/or his/her parents should fully understand the reason(s) for the test. It is assumed results of the investigation will define pathophysiology and influence treatment strategies. When constipation exists, it should be managed according to set guidelines before cystometry is undertaken. Having an empty rectum before the urodynamic study is advantageous as this allows for accurate monitoring of abdominal pressure and hence detrusor pressure.

Apart from a comprehensive history and complete physical examination, a voiding (or catheterization) diary, uroflowmetry, and post-void residual volume, as measured by ultrasonography, are to be conducted before ordering this invasive urodynamic study. In children, more than one uroflowmetry is strongly suggested to establish with certainty the necessity of an invasive study.[1,2] The child is advised to arrive at the urodynamics suite with a full bladder if possible and the examination starts with a free uroflowmetry. This is best accomplished by adequate but not excessive hydration beforehand and/or appropriate timing of a previous void so the bladder is relatively full at the time the child arrives at the urodynamics facility.

The (parents and) child should be instructed that all lower urinary tract modulating medications be taken either at a set time before the study or stopped at a sufficient interval to minimize their effect. Depending on the reason for the study, it should be however decided individually whether to continue or to stop medication (eg, in follow up evaluation). For children who are anxious or fearful beyond consolation, administration of a sedative (not anesthetics) may be considered but its timing and dose should be documented.

3 | TECHNIQUE

Current guidelines recommend multichannel fluid filled pressure recordings for filling cystometry as the standard in children. This educational module combines ICCS and ICS standards, into practical protocol elements to perform cystometry.

As the documents related to the tip-transducer or air-charged catheter used in pediatric urodynamic studies are limited and the pressures measured using air-charged catheters, microtip catheters are not readily comparable with fluid-filled systems, also in pediatric urodynamic studies fluid—filled systems are considered the ICS standard.

Inserting the catheter and placement of surface EMG electrodes

(1) A transurethral catheter is used to measure the pressure within the bladder. A 6 Fr double-lumen catheter that allows both filling and recording of pressure is recommended. The catheter is inserted after applying lubricating gel. No evidence exists regarding how well this gel acts as an anesthetic in children. In some facilities, a suprapubic double lumen catheter is inserted following administration of a short anesthetic the day before the test.

(2) The transurethral urodynamic catheter can be used to empty the bladder before starting the cystometry; if a relatively large volume is measured ultrasonographically or expected, it may be helpful to empty the residual by aspirating the bladder via the urodynamic catheter.

(3) A completely fluid filled open 8-Fr. feeding tube or a small air-free fluid filled balloon catheter is inserted into the rectum to record abdominal pressure.

(4) Both transurethral and rectal catheters should be secured with tape adjacent to their respective skin openings. After insertion, the catheters are attached, via connecting tubes, to the external pressure transducers and leveled to the height of the pubic symphysis.

(5) After cleaning the skin two surface EMG electrodes are positioned symmetrically, left, and right from the external anal sphincter, to record reactivity of pelvic floor muscles. No specific evidence regarding skin preparation to reduce impedance or electrode placement is available.[2] A third reference electrode should be placed at an electrically neutral position; preferably over a bony prominence and not an abdominal or leg muscle.

Position and zeroing the pressure

(6) Filling cystometry is preferably best performed in a seated position; however, lying supine or an infant held in mother's arm is also acceptable.

(7) Before filling the bladder, the bladder pressure channel must be zeroed to atmospheric pressure with the transducer situated at the level of the symphysis pubis, irrespective of the position of the child.

(8) Testing the catheter and sensor: Initial resting pressure should roughly represent the weight of the abdominal contents (below the diaphragm, in centimeter "water"-column) above the pelvic floor, for example, 15-25 cm H_2O. The fluid filled transurethral catheter requires some fluid in the bladder to allow for a degree of "unfolding" in order to obtain an accurate initial resting pressure. Furthermore, when using gel to insert the catheter, it should be flushed away from the pressure measuring side holes. When the child is upright the initial substracted detrusor pressure should be close to zero. To further test catheter and sensor function in

infants the lower abdomen is gently pressed (Credéd) whereas older children are encouraged to cough. The abdominal pressure rise should have a response peak similar to bladder pressure so detrusor pressure remains about zero.

(9) Even though children usually move and/or talk during the investigation, causing pressure variations that may serve as a quality control measure during the test, regular cough "tests," or Credé maneuvers in infants, should be promoted throughout filling to continuously check the catheters' ability to accurately record pressures.

(10) In children old enough (and neurologically able) to respond: the sensation of filling should be ascertained according to the ICS standard sequence, as defined by: "first sensation of filling" and subsequently and respectively, "normal desire" and "strong desire to void." These landmarks should be indicated on the urodynamic tracing.

Filling cystometry

(11) Based on bladder diary notations or estimating capacity based on age (age [yrs] + 1 × 30 = capacity [mL]) bladder filling should occur at a rate approximating 5-10% of estimated capacity per minute, using saline, as recommended by the ICCS. Apart from the bladder diary, age related and expected capacities should be kept in mind.[7,8]

(12) During filling, intravesical and abdominal pressures are recorded and subtracted simultaneously to obtain true detrusor pressure. During the recording, the flowmeter is kept in position so leakage or incontinence will be shown in the uroflow tracing curve.

(13) When voiding or leakage occurs, or a strong desire to void is expressed (movement in newborns or infants or curling of toes in older children) these observations may be interpreted as a sign of a full bladder. The filling is stopped and this event marked as the end of filling. It also represents the end of the filling cystometry. Storage function is evaluated until this point.

(14) Subsequently, as an older child is encouraged to urinate, voiding pressures, and uroflow measurements are recorded simultaneously, thus obtaining a pressure flow study. The pressure flow study will not be discussed further here.

(15) Directly after voiding an evaluation of the technical quality as well as the clinical representativeness of the study should be undertaken to determine whether a second filling cystometry (and pressure flow study) is necessary. Depending on the specific question being asked or the local protocol, performing a second filling cystometry may be initiated. Often at this time the child is relaxed enough so that a more accurate tracing of the filling phase is obtained.

End of test

(16) When the filling cystometry (and pressure flow study) is conclusive, all catheters and the EMG electrodes are removed.

(17) Children are instructed to carry out their normal activities but advised to drink an additional water after the test to "void away" any urethral irritation as well as to reduce chances of developing a urinary tract infection.

(18) A clinical evaluation report is completed immediately after the test to be optimally able to integrate urodynamic observations and features with clinical observations during the measurement, while still fresh in the mind of the observer.

Notes:

1. For EMG kinesiologic recording, surface electrodes are widely used in children to study pelvic floor activity. Electrophysiologic standards require that the skin should be degreased and desquamated tissue removed before applying a conductive gel and the electrodes. Hooked needle electrodes can be used for kinesiologic EMG recording when it is important to determine denervation in neurologically compromised individuals; however, the invasiveness of obtaining this measurement should be weighed against the expected gain from the information. Concentric needle electrodes are useful for motor unit potential analysis during urodynamic testing when it is necessary to know if new onset or progressive sacral spinal cord denervation is present.

2. For retrograde filling, 0.9% saline is recommended. In young children, temperature of the filling solution as well as the medium itself may influence bladder capacity and detrusor activity. It has been established that filling rate and fluid medium have an impact on bladder function.[9] It is important to use an appropriate rate of filling (5-10% of estimated bladder capacity per minute) in infants.[1,5]

3. A double lumen catheter has the advantage that it can stay in place (especially during voiding if adequately secured) for a second filling cystometry, if deemed necessary.

4. It is unnecessary to routinely use a warmed infusion solution for urodynamic studies in children; however, for those younger than 2 years, a warmed solution (37°C) is recommended.[10]

5. The best position for the child during standard cystometry is in a sitting position, watching a video or DVD surrounded by one or both parents, so as to minimize anxiety. Young children (infants) may be held in their mother's (or caregiver's) arms to achieve a meaningful evaluation. It has not been proven in children that patient position during the procedure has a significant and

clinically relevant effect on cystometry. However, this has been proven in adults, patient position during the procedure plays a significant and clinically relevant role.[11]

6. The study should not be performed under general anesthesia; intranasal midazolam may be administered in certain situations, as it does not appear to have a significant effect on outcome.[12]

4 | INTERPRETATION

Parameters during the Filling Phase

1. The filling detrusor pressure ($P_{det.fill}$) means the detrusor pressure during filling. The maximum detrusor filling pressure ($P_{det.fill.max}$) may be reported in the analysis. Detrusor compliance is calculated on the basis of the difference between the initial resting pressure and the detrusor pressure at cystometric capacity. Any phasic pressure increments, interpreted to be caused by detrusor overactivity, should be omitted in the evaluation of the detrusor compliance calculation. It may be advantageous to stop the infusion when reduced compliance is observed to allow the pressure to "equilibrate" for a minute or two in order to uncover artificially reduced compliance, which is sometimes observed as a consequence of too rapid filling rate.
2. Phasic detrusor pressure increments of any amplitude, during the filling cystometry (until end of filling and permission to void is given) are defined as detrusor overactivity. Detrusor overactivity may arise spontaneous or be provoked by a cough or Credé. When history and/or clinical examination have confirmed a relevant neurologic abnormality the term neurogenic detrusor overactivity is used.[1–4,13] Otherwise, idiopathic detrusor overactivity is the preferred term.
3. Detrusor compliance (compliance = $\Delta V/\Delta P$) is an important parameter to note during cystometry. It represents detrusor elasticity or volume adaption. A value of <10 mL/cm H_2O indicates low bladder compliance. Assessing the entire pressure curve during filling in this regard may determine when it is best to measure. The ΔP represents the detrusor pressure difference until just before voiding (or pressure at the end of filling); consequently, compliance will represent the overall bladder compliance, from start to a completely full bladder. It has been suggested that quartiles of compliance measurements during filling be considered. The filled volume does not take into account the amount of actual diuresis occurring during the test. To integrate this volume the cystometric capacity and filling phase compliance should be calculated using voiding volume plus PVR measured immediately after voiding or emptying.
4. Incontinence is defined when any loss of fluid during the filling phase is detected. In children unable to void willingly, fluid loss occurring before the expected bladder capacity is also called incontinence (as opposed to physiologic—normal but uninhibited- voiding when it occurs at "normal for age" capacity).
5. Leak point pressure (LPP) indicates the pressure at which leakage occurs. Detrusor leak point pressure (DLPP) indicates the lowest value of detrusor pressure at which leakage is observed in the absence of increased abdominal pressure or a detrusor contraction. Abdominal leak point pressure (ALPP) refers to measures of the lowest value of intentionally increased intravesical pressure that provokes urinary leakage in the absence of a detrusor contraction. High DLPP (eg, >40 cm H2O) is usually induced by a decrease in bladder compliance and/or detrusor underactivity, is associated with upper urinary tract deterioration.[1,5] Low DLPP indicated urethral incompetence.[1,5] Techniques and evaluation are not further standardized in this document describing filling cystometry.
6. Bladder filling sensation should be reported, on the basis of observations during the test or, when applicable, on the basis of the child's report. ICCS standard terms in this regard apply also for children.[1,2,6]

5 | RECOMMENDATIONS

Based on standards and clinical practice guidelines, the results of complete patient history, comprehensive clinical examination, bladder diary, uroflowmetry, and PVR should be available before considering a filling cystometry (and/or other invasive urodynamic tests).

Filling cystometry is preferably done with a 5-6 Fr double lumen catheter and at a filling rate of ±10% per minute of a diary determined maximum or age—expected bladder capacity.

Filling cystometry should be performed in the sitting position. When relevant medication or sedation is used it should be accounted for while evaluating the filling cystometry and be included in the report. In addition, it is important to note the time of last administration of medication in relation to the start of the cystometrogram, in order to determine the influence of any bladder modulating medication. Immediate evaluation of the test (before removing the catheters) should be done to determine technical quality and clinical relevance, as well as the ability to answer the clinical question that prompted the investigation, initially.

6 | CONCLUSION

To understand the characteristics as well as following good urodynamic practice (GUP), recommendations from the ICS

and ICCS are the basis of successful testing. This educational module provides recommendations for good clinical practice to completing filling cystometry in children using these standards. This narrative manuscript is based on expert consensus about the information contained in the existing literature. We hope that this teaching module will also serves as a challenge to improving (evidence-based) practice.

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