Standardization of the Pediatric Urodynamic Study

FROM THE GUEST EDITOR

David B. Joseph, M.D.

The urodynamic study plays a critical role in the management of pediatric neurogenic bladder dysfunction. The study itself often falls under the direct guidance and interpretation of the pediatric urologist. All of us recognize that the accuracy and reproducibility of the pediatric urodynamic study is dependent on the technical aspects of the study, available resources, and multiple subjective variables. The availability of resources will be unique to each institution. But given that some differences will always occur between institutions, there are variables which can be standardized and consistently controlled. Standardization of the urodynamic study allows for accurate internal comparison when reviewing a child’s study at two different points in time. It results in improved communication among colleagues when discussing urodynamic data at international meetings. And equally important, it enhances our ability to participate in multi-institutional studies creating consistent objective results between participating centers.

I recently held a cyber chat with three leading authorities regarding the technical aspects of pediatric urodynamic testing, in an attempt to develop a recommendation for standardization. This follows in the footsteps taken by the ICCS and their effort with standardization of terminology. I would like to thank Stu, Ulla, and John for their time and significant insight. I’ve learned a lot through our electronic discussion and hope that it is also beneficial to you.

FROM THE EDITOR

Anthony A. Caldamone, M.D.

If there is an area of pediatric urology that begs for standardization of both methodology and terminology, it is that of the urodynamic study. We have become increasingly dependent on the urodynamic evaluation in managing the spina bifida patient, the extrophy patient, the child who has posterior urethral valves, and the complicated enuretic. Without such standardization it is difficulty to compare results, evaluate reports, and even discuss individual cases. Dr. Joseph and his contributors demonstrate how much variability there can be in the technical aspects of the urodynamic study. Each contributor had adequate justification for their approach. The format that Dr. Joseph has chosen is indeed a true cyber “Dialogue”. I congratulate the authors and moderator for an informative and clear discussion which we all can learn from.
First, let me ask, do each of you think that a consensus can be achieved regarding the standardization of the urodynamic study in infants with a neurogenic bladder?

STU: Yes

JOHN: Yes

ULLA: Yes

At what age do you obtain the first urodynamic study in a neonate with a neural tube defect?

STU: Preferably before closure of the back but if that is not feasible then 1 – 2 weeks after closure. If a study is performed prior to closure then a repeat study is needed about 3 months postoperatively. If there is any delay in obtaining the initial urodynamic study I think it is imperative to know if the baby completely empties his/her bladder.

JOHN: I believe that the ideal age is prior to back closure. However, that is easier said than done and in practicality there are so many other factors that it is difficult to actually have this performed. Therefore, we feel that the best time is approximately 6 weeks after birth. That is not the time chosen for the spina bifida trial (MOMS trial—Management of Myelomeningocele) simply due to funding constraints.

ULLA: For practical reasons it is not possible to obtain urodynamics before back-closure in Sweden, since the back closure is done during the first 24 hours. Therefore, a practical age is 2-3 weeks, when the first wound-healing phase has passed and the child can be moved freely. Of course, the emptying ability of the bladder must be checked as soon as the indwelling catheter is removed following back closure to avoid urinary retention.

Do you think spinal shock occurs after closure of the back, and if so, is there reason to delay the urodynamic study?

STU: Spinal shock occurs in 3 – 10% of children following spinal canal closure and is exhibited for a variable period of time.

JOHN: There clearly is, in our estimation, a spinal “shock effect” and to get data that is most reliable and reproducible we have chosen to wait 6 weeks.

ULLA: A complete spinal shock is almost never seen. But we and others have noted that there is an increase in bladder and sphincter activity during the first 4 months of life in children with MMC. This indicates an increased level of activity in the nerves to the bladder and sphincter. But if this is due to rehabilitation after a spinal shock or is a phenomenon that is included in the evolution of the neurogenic bladder dysfunction (NBD) during the first months of life, can only be speculated about. [Br J Urol 1996; 78:596-601]

Technical aspects of performing the urodynamic study play a critical role in the reliability and reproducibility of a pediatric study. Beginning with the catheter, what size do you use in the newborn?

STU: We use a 6 Fr triple lumen catheter.

JOHN: We also use a 6 French catheter.

ULLA: We use a 6 French double lumen for the standard cystometric investigation.

Do you think the catheter can cause iatrogenic bladder outlet or urethral obstruction and falsely elevate voiding/leak point pressure?

STU: We have not noted that the catheter causes any significant form of bladder outlet obstruction. Most children ‘void’ with pressures that vary according to the degree of innervation, or presence of synergy or dysynergy. A child with a complete lower motor neuron lesion tends to leak or ‘void’ with pressures below 20 cm H2O. Children with dysynergy ‘void’ or leak with pressures above 80 cm H2O and synergic children void with pressures around 40 cm H2O.

JOHN: There is no question in my estimation that the catheter can create iatrogenic obstruction and falsely elevate voiding pressures or leak point pressures.

ULLA: In male neonates and small infants there is of course a risk. A difference between a urethral and a suprapubic (SP) catheter has been shown, by Scholtmeijer, in boys with obstruction in the urethra, but it has not conclusively been shown in male babies with normal urethral anatomy [Scholtmeijer RJ and Griffiths DJ: J Ped Surg 25: 669,1990]. We have an ongoing study in which we assess detrusor pressure both with a suprapubic tube and with a urethral catheter at the same investigation. So far we have included 10 infant boys and preliminary results show that there is no significant difference.

Do you think the catheter can cause a guarding reflex that mimics detrusor sphincter dyssynergie (DSD)?

STU: It is possible that sphincter spasm can occur but with a well placed needle electrode that monitors the electrical activity of the external urethral sphincter, muscle artifacts will be obviated. A child with a synergic sphincter tends to relax the sphincter activity just before voiding. If the catheter irritates the child during voiding there might be an increase in activity during micturition or with crying during voiding, which suggests dysynergy. However, that should be clearly detectable. On the other hand, in a child with dysynergy there is no initial quieting of the sphincter before voiding or leaking; in fact, the activity remains the same or actually increases when a rise in bladder pressure occurs, even before ‘voiding’ or leaking takes place.

JOHN: I think it can potentially cause sphincter spasm. I believe this is best dealt with by doing multiple runs before completing the study.

ULLA: In my opinion it can, but I’m not certain if there are studies confirming this theory. In the study in male infants I mentioned earlier, an increase in pelvic floor activity during voiding was quite common. When it was registered, it was seen both when a SP catheter was used and when a urethral catheter was used for the filling and voiding cycle in the same child. The explanation in this case is, of course, that small male infants often have a physiological discoordination at voiding. Therefore, in order to detect if urethral catheter is more often combined with increased pelvic floor activity than SP tube a comparison has to be done in slightly older children in whom discoordination cannot be expected to be a normal phenomenon.

Ulla brought up the use of the suprapubic catheter. Do you think there is a need to use a suprapubic catheter?

STU: I would not use a suprapubic catheter for evaluating babies.

JOHN: We do not use a suprapubic tube.

ULLA: In children all ages with NBD we use urethral catheter for standard cystometric investigations. We often use SP tubes in small male infants with non-neurogenic dysfunction and, as mentioned above, in children between 2 and 5 years of age due to refusal of urethral catheterization. When using SP tubes we use two Cystofix 5 French, one for infusion and one for pressure measurement.
What infusion rate are you using?

STU: We think the ideal infusion rate is 2 ml/minute in the newborn.

JOHN: The rate of infusion is 10% of expected bladder volume per minute as calculated by bladder volume formulas.

ULLA: In the newborn period 2-3 ml/min or 1/10 of expected bladder capacity per minute.

Over what period of time would you allow filling?

ULLA: In standard cystometry 10-30 minutes per filling voiding cycle. In natural fill we usually register for two or three voiding cycles, depending on bladder capacity. In some children we register during 12 hours from 6 pm to 6 am, to get an indication of what happens in the bladder during sleep.

Do you use room temperature fluid or warmed fluid to body temperature for filling? How are you warming the fluid if that is used?

STU: We try to use saline warmed to 37°C. The infusate is kept in a warmer until the study is about to begin. The bag is then connected to the tubing that will be infused into the child.

JOHN: We definitely use body temperature fluid for filling and the fluid is warmed in a fluid warmer.

ULLA: We try to have body temperature. The plastic bag with fluid is put into a water bath keeping it at body temperature before the investigation but during the investigation. Thus, temperature on the infused fluid is not kept at an absolute level, and probably a little bit lower than body temperature.

Do you think there is any role for a natural fill study in infants?

STU: Natural fill cystometry in infants is not feasible in our hands because it takes too long to complete partly because it is hard to keep a rectal monitoring catheter in place for that extended period of time. As a result someone would have to monitor the child’s movements to denote artifacts of motion from true detrusor pressure changes.

JOHN: I do not think a natural fill study is practical in neonates or children.

ULLA: I think natural filling can be used, but is not suitable for the yearly follow-up of children with the neurogenic bladder because it is more time consuming and because poor compliance is difficult to estimate and follow. We use natural fill for specific indications especially when interested in what happens during the night. This can be used in many varieties of bladder disturbances including NBD. We have tried more and more to switch to natural fill in the daytime evaluation of non-neurogenic dysfunction and record 2-3 voiding cycles. The disadvantage is the fact that the quality of the registration is much better if the child is not moving, because of the number of artifacts that are produced.

In natural fill we use a novel fiberoptic transducer with a diameter of 0.42 mm, which we introduce into the bladder through an open-tip PVC catheter (6 or 8 F). The PVC catheter is then withdrawn leaving the registration transducer in place. The small dimensions of this new transducer, compared to the conventional microtip catheters, does not induce urethral obstruction. The indication for an SP tube in natural fill and standard cystometry in our department is only in children who refuse urethral catheterization, often ages 2-5 years, or if they have had an earlier unpleasant experience of transurethral manipulations. Standard cystometric investigations of infants boys with non-neurogenic bladder dysfunction are also investigated via SP catheters.

How many times should the bladder be cycled?

STU: We prefer to cycle the bladder twice. On rare occasions the bladder will be filled a third time if we have not fully determined the interrelationship between the detrusor and the sphincter. If the child leaks and we end that study, the bladder is emptied before another cycle of filling is attempted.

JOHN: The bladder is cycled at least twice and we do continue after the initial leak.

ULLA: In the routine case we do 3 filling-voiding cycles. However, in the follow-up cases we often restrict the number of fillings to one or two, especially if the bladder capacity is very high causing repeated fillings to take to long. Also in the NBD we often reduce the number of fillings since these children are followed yearly at our rehabilitation centre.

Do you continue or repeat after the initial leak?

ULLA: It depends on the diagnosis and at what time point of the filling the leak occurs. In the NBD, the filling continues until the leakage equals the filling rate, but only if the pressure level in the bladder is safe. In the incontinent extrophy child, we try to block the outflow to test the maximal volume of the bladder with safe pressure. In the non-neurogenic bladder it depends on whether it occurs in the beginning or in the end of the filling.

I find EMG recording to be the most difficult aspect of the study to perform and interpret. The most common methods for assessment include the surface patch, dual wire electrodes, and the single, concentric needle.

What are you using in your study?

STU: We use a 24 G bipolar needle electrode.

JOHN: We presently use a patch. However, the patch is simply to be able to find non-specific perineal activity which might indicate DSD.

ULLA: In my institution patches are used.

Stu, you use a needle? Do you see a sampling error or the need to move the needle to another position? Also, can you get the needed data from standard equipment or do you need an oscilloscope?

STU: There may be differences from side to side (which can be important) but usually no differences are seen ipsilaterally, once the needle is inserted into the muscle. We use an oscilloscope with audio output that helps to facilitate the accurate placement of the needle electrode into the external urethral sphincter muscle.

There does not appear to be much enthusiasm for paired wires. Do you think that surface pads can provide enough information regarding sphincter activity?

STU: We never use paired wires blindly placed or surface pads, to detect urethral sphincter muscle activity. Surface pads relate nothing more than non-specific activity of the perineum, if that much. You cannot tell the degree of innervation or ongoing denervation with any accuracy.

ULLA: I think that the only conclusion that can be drawn is that there is perineal activity. But in the clinical situation, in terms of treatment, this is often sufficient.
Do you simultaneously perform the urodynamic study under fluoroscopy?

STU: We have not used simultaneous fluoroscopy when a urodynamic study is conducted.

JOHN: We do use simultaneous fluoroscopy.

ULLA: The main indication for fluoroscopy in our institution is high grade reflux and bladder dysfunction when you need to estimate the correct bladder capacity. For example, when you need to know if you have a safe bladder in boys with PUV planned for renal transplantation, or if the refluxing system has to be removed, fluoroscopy is helpful. We do this by estimating the volume in the bladder by taking the sum of voided volume and residual (withdrawn immediately after stopping voiding). If there is no residual, which is easily detected on fluoroscopy, the bladder capacity equals voided volume. Reflux volume is estimated by withdrawing the volume that refills the bladder during 10 minutes after stopping voiding, or less then 10 minutes if the reflux is emptied into the bladder according to fluoroscopy.

Does fluoroscopy help to evaluate the bladder neck?

STU: Fluoroscopy would help to identify bladder neck competency during filling and when it opens just before voiding or leaking.

Do you think fluoroscopy would help to validate detrusor sphincter dyssynergy?

STU: Fluoroscopy may validate the presence of dyssynergy by revealing narrowing in the region of the external urethral sphincter, but if narrowing is seen it may also be due to complete denervation of the sphincter along with subsequent denervation fibrosis. The only way to truly differentiate this is by monitoring external urethral sphincter bioelectric activity during voiding.

JOHN: I believe fluoroscopy helps evaluate the bladder neck and validate DSD.

ULLA: It does. By using simultaneous fluoroscopy and standard cystometry you can beautifully recognize DSD. In the non-neurogenic bladder it is often seen as intermittent opening and closing of the sphincter with contrast all the time, but the distal urethra is empty when the sphincter intermittently is closed. But the problem is that the radiation dose is quite high if the entire voiding cycle is fluoroscopically registered.

Do you think you can use simultaneous fluoroscopy to determine the “pop off” pressure at the time of vesicoureteral reflux?

STU: Knowing when vesicoureteral reflux occurs provides a measure when the “pop off” pressure is critical. Keeping the detrusor pressure below that level should help to minimize the reflux.

JOHN: It is helpful to determine the pressure at which reflux happens, the so called “pop off”.

ULLA: We have done about 400 urodynamic investigations with fluoroscopy in infants and children with VUR, both with and without obstruction in the urethra. I must say that I have never seen a “pop off” effect, meaning that the occurrence of the reflux lowers the pressure in the bladder. But what I have seen in obstructed bladder reflux is that the volume of the reflux might be considerable and even higher than the bladder volume itself. In these cases reflux often appears early during filling without an increase in bladder pressure. In these latter cases end-filling pressure in the bladder might be within normal limits, which only means that the bladder plus the refluxing ureter can safely store the volume infused. The bladder alone can only store the actual bladder volume safely. When including the refluxing volume in the bladder, the storage pressure might be too high, and, of course, this can be referred to as a “pop off” effect.

Is there an advantage to a nuclear study?

STU: The advantages of radionuclide cystography are less radiation and continuous monitoring because it gives you the exact time, bladder volume and pressure that the reflux occurred. The disadvantages include the inability to assess bladder contour and bladder neck and external urethral sphincter appearances during filling and emptying of the bladder.

JOHN: The nuclear medicine study would simply be that of decreased radiation, but in our estimation we gain a lot of information from looking at the bladder neck.

ULLA: I have no experience with this combination.

Do you use sedation during the study and if so, do you have any age limits?

STU: In our hands no sedation is needed and I never use sedation at any age.

JOHN: We do not use sedation at present. We do employ behavior modification techniques, as well as a calm environment and have employed Child Life on occasion for older children.

ULLA: We never use sedation. If there are problems with catheterization we place an SP tube during general anesthesia the day before the investigation.

Once the exam is completed we are left with interpreting the results. How do you define neurogenic detrusor overactivity (hyper-reflexia)?

STU: The definition of neurogenic detrusor overactivity is: (1) a premature contraction that occurs well before the expected bladder capacity is reached during the cystometrogram; (2) a contraction that occurs immediately after a cough or a Credé; (3) a pressure peak rise of at least 10 cm H2O above the immediately prior bladder filling pressure baseline.

JOHN: The classic definition of an uninhibited contraction or neurogenic overactive contraction would be a rise in the detrusor pressure during filling of at least 15cc of water and associated with urge. However, most would now include any magnitude of pressure increase if associated with urge. Obviously in smaller children it becomes much more difficult to quantify, due to the fact they are unable to verbalize whether or not they are having urge. For this reason it is important to do multiple runs during a urodynamic study looking at all the other factors for the child, i.e., movement during the procedure itself. It is also interesting to find that the term hyper-reflexia has been replaced by the term neurogenic detrusor overactivity by the International Continence Society in an effort to standardize the terminology of lower urinary tract function. I think that we in pediatric urology clearly have not continued along this line.

ULLA: All involuntary detrusor contractions during filling should now be referred to as overactivity: in the neurogenic bladder “neurogenic detrusor overactivity,” and in the non-neurogenic bladder “idiopathic detrusor overactivity” [ICS standardization document Abrams et al., 2002 and the new ICCS standardization document].
How do you differentiate neurogenic detrusor overactivity (hyper-reflexia) from a normal contraction in an infant?

STU: If a child voids with that contraction, it is difficult or almost impossible to differentiate between a premature contraction and a normal voiding contraction. If this contraction occurs at a volume that is less than 75% of what is expected for the child’s age, you can probably assume it is a neurogenic overactive contraction.

JOHN: Differentiating a neurogenic overactive contraction from a normal contraction in an infant is difficult and reinforces the necessity of looking at the many different aspects of the urodynamic study and watching the child during the study, including the abdominal activity and the consistency of the contraction at a certain filling volume. This speaks to the importance of an experienced person doing the study.

ULLA: Sometimes neurogenic overactivity is very difficult to differentiate from “premature voiding contractions” seen in 20% of small infants. Often the difference is that the latter are only isolated contractions with leakage of urine, whereas neurogenic overactivity often consists of multiple contractions during filling. To diagnose a neurogenic bladder only on overactivity during filling is difficult, especially if there is a normal voiding contraction at the end of the filling. However, neurogenic dysfunction quite often have overactivity during filling without a proper voiding contraction.

What constitutes poor compliance?

STU: Compliance is related to the rate of filling of the bladder. As a result I use a very slow fill rate of 10% of expected capacity per minute. I do not actually rely on any specific number but rather see when the detrusor pressure rises above 20 cm H2O. If that occurs at a volume that is less than the expected bladder capacity I would consider that the child has a poorly compliant bladder. I also stop the infusion for a minute or so when the fill pressure exceeds 20 cm H2O to determine if there is a decay in the pressure in order to obtain a more accurate detrusor pressure measurement. I also measure the pressure in the bladder immediately after a catheter has been inserted but before the urine is drained. This pressure is called ‘the pressure at residual volume’ and it is probably the most accurate measure of compliance we have because it reflects detrusor pressure when the bladder is filled naturally from the kidneys. Often, this compares favorably (lower) to the pressure obtained at that volume during the cystometrogram. Unfortunately, you only have one point on the cystometrogram curve that you can make this comparison, but, nonetheless, it provides a degree of accuracy for the pressures obtained during the cystometrogram.

JOHN: Although compliance can be calculated to obtain an actual number (i.e., the change in bladder volume divided by the change in detrusor pressure during that change in volume), I do not do this in my own studies. A general parameter for abnormal compliance is less than 12.5ml/cm of water. We record the detrusor pressure at various volumes of filling, 50, 100, etc. In this way I can see the trend and see at what volume the compliance begins to change or diminish.

ULLA: Calculation of compliance according to the model used in adults cannot be used because the values change according to bladder capacity. For example, a one-year-old with a capacity 60 ml and a six-year-old with BC 200 ml both have an increase in base line pressure of 10 cm of water during filling. Compliance for the one-year-old is 6 ml/cmH2O and the six-year-old 20 ml/cmH2O, despite the fact that the increase in baseline pressure is exactly the same at expected capacity.

If compliance, as a term, should be used it has to be related to bladder capacity (BC). Otherwise we have to use “increase in baseline pressure during filling”, which I prefer, because it is more descriptive and straightforward [Wahl et al, BJU 2004, 94, 1105].

At our institution, an increase in baseline pressure at expected capacity for age of >20 cm H2O is considered as the breaking point between normal and abnormal compliance. However, we use >30 cm H2O as an absolute limit for treatment.

I also think that we must be aware of the fact that the increase in baseline pressure we see during cystometric filling is not a physiological registration of what happens in the bladder, because if we use a filling rate of 10% of bladder capacity, the bladder will be filled in 10 minutes. A natural filling of the bladder to capacity almost never happens during 10 minutes. This does not mean that it is useless. It absolutely reflects a decreased compliance in the bladder, but we have to bear in mind that the numerical values we get are probably not physiological correct, i.e., is not the pressure levels in the bladder after natural filling to the same volume.

As a matter of fact, this is reflected in the natural fill investigations, in which an increase in baseline pressure is almost never seen, even if it has been shown in standard cystometric investigations in the same patient [Webb et al, J Urol, 1992 and Homdahl et al. J Urol, 1997].

How do you interpret pressure when vesicoureteral reflux is present?

STU: It is almost impossible to accurately measure detrusor pressure when high grade reflux is present. When a child has reflux we often perform the cystometrogram with a simultaneous nuclear cystogram to denote at what bladder filling pressure the reflux occurs. This gives some idea regarding compliance before the reflux occurs, as well as a degree of competency of the ureteral orifices.

JOHN: This speaks to the importance of fluoroscopy during urodynamics in that it is imperative to view the timing of vesicoureteral reflux and determine the pressures at which it happens and the effect of pressure on the pop off mechanism of reflux.

ULLA: As the pressure for the combined volume of the bladder and the ureter as explained in my comment regarding the “pop off effect.”

The concluding table (on the back page) reflects the consensus of our authorities regarding technique and interpretation. The minimal accepted standard provides the basis for the study and should be attainable at any institution. The appropriate alternative is felt to enhance the available information without sacrificing the consistency or reproducibility of results. Whether these recommendations are the final say in standardizing the pediatric urodynamic study is not as important as the intent to work toward a common goal.

I would like to thank Tony Caldamone for his outstanding editorial stewardship with the Dialogues in Pediatric Urology and also for the opportunity to contribute.

David B. Joseph, M.D.
### Infant Urodynmic Study

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<th>Alternative</th>
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