Urodynamics in Children: Indications and Technique

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During the past 15 years, urodynamic assessment has become an essential element in the evaluation of children with lower urinary tract dysfunction [11,12,38]. This has become possible with the development of small catheters, refinements in technique and an appreciation of special needs of children undergoing these studies [8]. The result is meaningful and reproducible data, which has permitted the clinician to acquire a greater understanding of the central role the bladder plays in many pathophysiologic processes affecting children. Consequently, most pediatric centers today consider a functional assessment of the lower urinary tract as important as x-ray visualization in defining a particular disease process in order to characterize and treat affected children [48,53]. Herein, the technique of urodynamic evaluation and its applicability in specific disease states in children is described.

Techniques

In an attempt to foster a cooperative child, an explanation of the test in booklet form is sent to the parents so they and the child will know what to expect when arriving at the urodynamics facility. A questionnaire is included which tries to elicit information about the mother's prenatal history, the child's birth and development, his (or her) current bladder and bowel habits and other data that might be pertinent. This information and the specifics of the test are reviewed with the parents and the child prior to the evaluation.

Because the anticipation of pain is an anxiety provoking event that may affect the reproducibility of findings, several procedures for reducing pain have been adopted. For children over age 1 who seem agitated, Meperidine, 1 mg/kg of body weight is given intramuscularly [18]. Xylocaine liquid, 1%, is injected into the urethra just prior to catheterization. Recently, EMLA cream, a topical anesthetic, has been applied to the perineal area if an electromyographic needle is to be placed during the study.

If old enough, the child is instructed to come to the urodynamic suite with a full bladder, in order to obtain an initial representative uroflow. This is performed in a private bathroom equipped with a one-way mirror to unobtrusively observe how the child urinates. In the absence of voluntary voiding, the child is Credéd, if appropriate, or the time of the last diaper change is noted.

A small balloon catheter is inserted into the rectum to monitor intra-abdominal pressure during the study [4,5]. This identifies artifacts of motion and differentiates increases in abdominal pressue from uninhibited detrusor contractions. A triple lumen 7 or 10 Fr. urodynamic catheter with one side hole port 4 to 6 cm from the tip is passed transurethrally into the bladder and the residual urine measured. Sometimes it is necessary to aspirate the catheter to get an accurate volume of residual urine, for the catheter may not drain completely if the bladder is hypotonic.

A urethral pressure profile is performed by withdrawing the catheter using an automated puller at a rate of 2 mm/sec as fluid is instilled through the channel with the side hole port at 2 ml/min [21] (micro-tipped transducer catheters [50] has been advocated by some but they are not readily amenable for children due to their stiffness and fragility). This produces a pressure profile curve of the urethra from the bladder neck to the external sphincter. The pressure profile is recorded first at rest with the bladder empty to determine the static resistance in the posterior urethra and then throughout the micturition cycle after the catheter has been positioned at the point of highest resistance, in order to monitor changes during filling and emptying of the bladder [54].

Next, the bladder is filled via the second channel with saline warmed to 37° C, at a rate equal to 10% of its predicted capacity (wt[kg]x7 for children<2 years [19], and age[years]x30+60 for chilren>2 years [34]) per minute. The third channel continuously measures intravesical pressure to evaluate several parameters: the point of first sensation, an accurate compliance factor of the detrusor wall, the presence of uninhibited contractions and/or a voluntary contraction at capacity, the maximal contractile force and sustainability of the detrusor and the individual's ability to suppress and completely abolish this contraction.

External urethral sphincter electromyography (EMG) is performed using a fine concentric needle electrode inserted perineally in males and paraurethrally in females, and advanced into the muscle under audio and visual control from an oscilloscope of a standard electromyographic amplifier [16]. Individual motor unit action potentials as well as the sphincter's response to various sacral reflexes (bulbocavernosus and anocutaneous reflexes, Credé and Valsalva maneuvers) are analyzed to determine signs of denervation. A continuous recording of the muscular activity is also made during filling and emptying of the bladder to denote intactness of the entire central nervous system [11].

Applications

Urodynamic studies have been most useful in children with neurogenic bladder dysfunction. For children with myelodysplasia very early evaluation after the back has been repaired has [1] helped to identify babies at risk for urinary tract deterioration when high filling pressures and detrusor sphincter dyssynergy are present, [2] allowed for prophylactic treatment to prevent these potential changes from occurring, [3] provided a baseline assessment so subsequent studies may detect signs of denervation and the presence of spinal cord tethering, and [4] aided in counseling parents about future bladder and sexual function [7].

Since initiating serial urodynamic studies in newborns with myelodysplasia beginning in 1978, 72% of children with detrusor sphincter dyssynergy developed reflux and/or hydronephrosis, whereas less than 15% with other lesions did so [7,48]. Once prophylactic therapy with intermittent catheteriza-

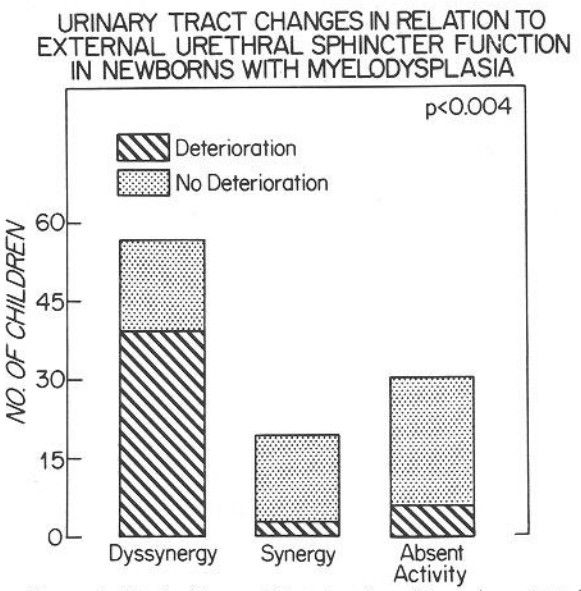

Figure 1. The incidence of deterioration of the urinary tract in three groups of newborns with myelodysplasia divided according to the type of reaction in the external urethral sphincter.

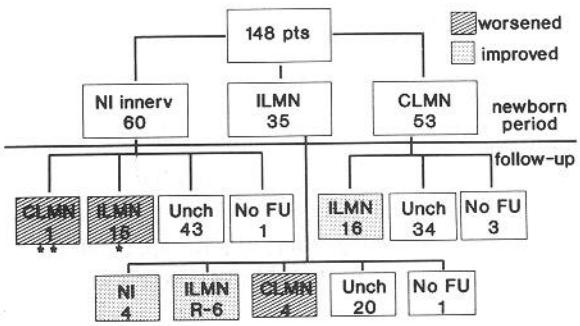

Figure 2. Lower motor neuron changes in newborns with myelodysplasia under surveillance for 5 years. *NI inner*, normal innervation. *ILMN*, partial denervation. *CLMN*, complete denervation. *Unch*, unchanged. *FU*, followup. *NI* normal. **, 1 patient changed from synergy to dyssynergy. *, 4 of 15 patients changed from synergy to dyssynergy.

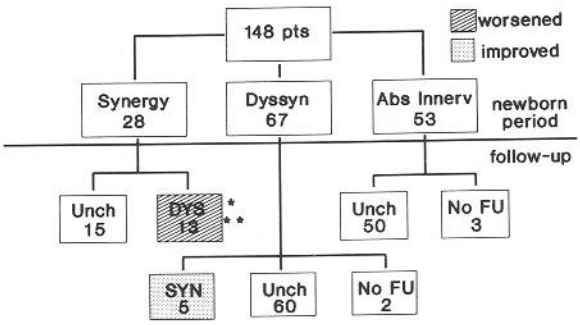

Figure 3. Upper motor neuron changes in newborns with myelodysplasia under surveillance for 5 years. *Dyssyn*, dyssynergy. *Abs Innerv*, absent innervation. *Unch*, unchanged. *DYS*, dyssynergy. *FU*, followup. *SYN*, synergy. *, 1 patient changed from normal innervation to partial then complete denervation. **, 4 patients changed from normal innervation to partial denervation.

tion and anticholinergic agents (oxybutynin) was instituted in 1985, only 8% of children at risk developed these radiologic changes [32]. Moreover, the need for augmentation cystoplasty to reduce detrusor hypertonicity and improve upper urinary tract drainage and/or continence has been drastically reduced from 26% in the observation group to 7% in the prophylactically treated patients [9]. The bladder wall maintains excellent compliance without developing the inelasticity that is so often seen in these children when it comes time to attempt to achieve continence.

Urodynamic studies in early infancy have revealed that as many as 40% of children experience a change in their neurologic picture during the first 3 to 5 years of life [35,49]. Physical examination changes in the lower extremities can be a late finding and then, they are often subtle. In addition, these changes can occur independently from alterations in sacral function when the spinal cord becomes tethered [10,35]. Magnetic resonance imaging of the spinal cord demonstrates a low conus almost universally but does not reveal a change in function [42,52]. Therefore, urodynamic studies are the most precise way to detect neurologic changes secondary to tethering. Early detection of a urodynamic change and secondary surgical intervention has resulted in improved sacral cord function in 60% of those operated on [35].

The approach to children with so-called "occult" neurospinal dysraphisms has also changed with the use of urodynamic studies [33]. Fifteen per cent of newborns with normal neurologic examinations have abnormalities on urodynamic testing. When these babies are operated on in early infancy the rate of improvement of function is as high as 60% while less than 10% exhibit any sign of deterioration [33]. As a result, most pediatric neurosurgeons are now advocating early correction of these defects before any damage can occur instead of waiting until the lesions become unsightly or more likely, manifest obvious neurological disturbances. Long-term surveillance of children operated on in early infancy, has not revealed a significant number requiring reoperation to correct secondary spinal cord tethering [45].

Sacral agenesis is a rare disease of the spine that affects the innervation of the sphincter mechanisms of the lower urinary and gastrointestinal tracts [28].

Table 1. Urodynamic findings in children with sacral agenesis

Lesion	% Affected
Supra-sacral	34 %
Sacral	29 %
Both	31 %
Normal	6 %

Because sensation and motor function of the legs are unaffected the disease is often missed until urinary and fecal incontinence prompts an evaluation [23]. Absence of one or more vertebral bodies may produce abnormalities of sacral spinal cord function but the nature of the lesions is unpredictable from the number of affected vertebrae even though one would expect denervation in the sacral reflex arc (Table 1) [46].

Significant advances in the management of children with imperforate anus have been made with the advent of the posterior sagittal anorectoplasty [43]. Fecal continence is easy to achieve when the rectal pull-through is accomplished through this approach. Urinary incontinence following this procedure is less commonly encountered than when a combined abdominal-perineal operation was employed to exteriorize the rectum, because pelvic nerve injury is less likely to occur. However, lower urinary tract dysfunction is still seen in a substantial number of children postoperatively. Occult spinal dysraphism can be seen in 40% of affected children with neurogenic bladder dysfunction occurring in as many as 30% [31,47]. The type of abnormalities noted on preoperative urodynamic testing include denervation of the external urethral sphincter, detrusor areflexia, detrusor hyper-reflexia and detrusor sphincter dyssynergia, all of which can cause incontinence while the latter may be responsible for hydroureteronephrosis and reflux [22,30]. Urodynamic testing prior to correction of the imperforate anus identifies those children with abnormal lower urinary tract function and sets the stage for treatment of their incontinence and the potential risk to their kidneys in the immediate postoperative period [13].

Cerebral palsy is an increasingly common problem because more very premature, low birth weight infants are surviving in neonatal intensive care units [41]. As these children mature they are being mainstreamed into normal childhood social settings. The degree of their impairment will vary from being

minimal, with mild learning disabilities, fine motor incoordination, non-familial left handedness and/or an attention deficit disorder, to obvious signs of spasticity and expressive difficulties. Even the most handicapped children develop control over micturition, albeit at a later than normal age, but some individuals will have persistent urinary incontinence and/or infection [39]. Urodynamic testing in these affected children has shown that 86% have findings consistent with an upper motor neuron lesion consisting of uninhibited contractions and detrusor sphincter dyssynergy, hyperactive sacral reflexes and loss of voluntary control [14]. Surprisingly, signs of lower motor neuron dysfunction can be detected in the sphincter in almost 15% of children, indicating that damage to the spinal cord as well as the higher areas of the central nervous system may have occurred during the perinatal insult that lead to the cerebral dysfunction. Awareness of these lesions will help the clinician to adequately manage the children.

Posterior urethral valves have a broad spectrum of presentation [25]. Today, the majority are being detected as a result of prenatal screening while older boys are diagnosed following an evaluation for persistent day and night wetting or urinary infection. Despite successful valve resection, the outlet obstruction can have a profound effect on bladder function causing persistent incontinence and/or hydroureteronephrosis [20]. Urodynamic testing has demonstrated several patterns of bladder dysfunction which is impossible to predict from the history, the age at diagnosis and treatment, or preoperative presence of reflux (Table 2) [44]. Even boys detected and treated at an early age as a result of prenatal screening may have these bladder changes [29].

When voiding cystography reveals what has been labeled as non-obstructing or minor posterior urethral valves, urodynamic testing often demonstrates significant alterations in function with detrusor hyperreflexia, high voiding pressures and low urinary flow rates, consistent with significant bladder outlet obstruction [3]. Thus, urodynamic testing plays a pivotal role in detecting abnormalities of function and in guiding an effective treatment protocol for boys whose posterior urethras are not dilated secondary to the valves.

Table 2. Bladder function in boys with persistent voiding dysfunction after valve ablation

Type bladder dysfunction	% Affected
Myogenic failure	34 %
Hypertonic (poorly compliant)	27 %
Hyper-reflexic	24 %
High voiding pressure	5 %
Sphincter incompetence	2 %
Normal	7 %
	N=41

Table 3. Abnormalities of lower urinary tract function in neurologically normal children

Spectrum
Small capacity hypertonic bladder
Hyper-reflexic bladder
Large capacity hypotonic bladder (Lazy bladder syndrome)
Non-neurogenic neurogenic bladder (Hinman syndrome)

Urinary incontinence or infection in neurologically normal children can be caused by a variety of abnormal bladder conditions that are not readily diagnosed by radiologic imaging alone. Urodynamic studies in these children have shown several patterns of dysfunction [6]. A spectrum of abnormalities has been defined (Table 3). The small capacity hypertonic bladder may be congenital in origin but more likely it is the result of repeated urinary infection which causes inflammatory changes in the detrusor, reducing its compliance and capacity. This condition may be the precursor of intersititial cystitis in the adult female [24,37].

The hyper-reflexic bladder is detected when small uninhibited contractions are noted during the filling phase of a cystometrogram [6]. The children often squat or have a characteristic curtsey to prevent urination [35]. This condition may be congenital because a history reveals other family members with similar voiding patterns [51]. In some children, however, it is probably an acquired condition from either a perinatal cerebral insult causing a degree of loss of central inhibitory control, fecal retention syndromes that increase bladder hyperactivity or detrusor changes from repeated urinary infection [40,56].

The large capacity hypotonic or lazy bladder syndrome is a condition that develops after toilet training because it is extremely rare to find a larger than expected bladder in pre-toilet trained children [6,15]. The children learn not to void or defecate because they try to avoid using a bathroom once they

master toilet training. By imposing controls over evacuation, the distended bladder loses its ability to empty and the children, mostly girls, exhibit stress incontinence and recurrent infection [53]. Sometimes, the children learn this behavior when they mimic their parents' voiding patterns.

Some children have learned to retain urine and feces to such a degree that it affects their upper urinary tract [26]. The primary lesions is a learned failure to relax the external urethral sphincter in response to a bladder contraction because the children are fearful of having an accident [1]. Punishments, both vebral and physical, inflicted by one or both parents leads to a behavior pattern whereby the child makes every effort to not wet. As a result they keep their sphincter muscle tightly closed. The closed urethral sphincter becomes habitually contracted even when the child wants to voluntarily void. The ensuing retention produces profound structural changes in the urinary tract with severe hydroureteronephrosis, vesico-ureteral reflux, a thick-walled trabeculated bladder and a narrowed external sphincter region noted on radiologic imaging [6,54]. A KUB often reveals a colon full of stool. Urodynamic testing demonstrates multiple uninhibited contractions and poor compliance during filling, and an ineffective and unsustained bladder contraction with a weak, intermittent stream during voluntary voiding despite pressures in excess of 100 cm H_2O, because the urethral sphincter fails to diminish and actually increases its electrical activity on electromyographic analysis [2,6]. No spinal cord abnormalities have been found in these children on radiologic imaging to suggest a central nervous system disorder [25,54].

Conclusions

Urodynamic testing has been found to be an invaluable tool in understanding and treating children with disorders of the lower urinary tract. Precise characterization of the abnormal function in children with myelomeningocele has led to the prevention of upper urinary tract deterioration while in others it has led to secondary untethering procedures which have preserved neurologic function. In children with occult spinal dysraphisms it has changed the timing of neurosurgical intervention. In children with posterior urethral valves it has explained why the urinary tract may not normalize and why some children have been better defined and more efficiently treated. Some of the principles advocated by Herbert Eckstein have become axioms in the treatment of children with lower urinary tract dysfunction [17].

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