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Comprehensive Urodynamic Assessment in the Management of Pediatric Lower Urinary Tract Dysfunction

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Abstract

Background: Lower urinary tract dysfunction (LUTD) affects 17-22% of children globally. While urodynamic studies (UDS) remain the gold standard for diagnosis, tailored approaches optimizing diagnostic resources may improve patient compliance and outcomes. This study evaluates the efficacy of a comprehensive diagnostic algorithm incorporating clinical assessment, invasive uroflowmetry, and complete urodynamic studies in diagnosing and managing pediatric LUTD.

Methods: We conducted a prospective observational study of 33 children (ages 2-12 years) with LUTD symptoms without structural or neurological abnormalities from June 2021 to July 2023. Patients were categorized into Non-LUTD (< 4 years) and LUTD (\geq 4 years) groups based on symptom onset. Assessment included detailed history, physical examination, voiding diaries, ultrasonography, VCUG, cystoscopy, invasive uroflowmetry, and comprehensive UDS. Management strategies were implemented based on accurate urodynamic diagnoses with regular follow-up assessments.

Results: Complete follow-up data was available for all 33 patients (19 males, 14 females). In the Non-LUTD group (n=16), all patients presented with bilateral

hydronephrosis and thickened bladder walls. Vesicoureteral reflux (VUR) was identified in 11/16 cases, with varying UDS findings despite similar clinical presentations. The LUTD group (n=17) showed diagnoses of: overactive bladder (41%), detrusor-sphincter dyssynergia (18%), detrusor overactivity (24%), and hypoactive bladder (18%). Invasive uroflowmetry combined with comprehensive UDS provided definitive diagnoses in all cases, with 17.6% of patients showing discrepancies between initial clinical assessment and final urodynamic diagnosis. All patients demonstrated symptomatic improvement with targeted management based on precise urodynamic findings.

Conclusions: A comprehensive approach incorporating detailed clinical assessment, invasive uroflowmetry, and complete urodynamic studies provides precise diagnosis and effective management of pediatric LUTD. While clinical evaluation remains foundational, confirmatory urodynamic assessment enables tailored therapeutic interventions with superior outcomes.

Level of Evidence: III - Prospective observational study with systematic follow-up and objective outcome measures.

Keywords: Pediatric Urology, Lower Urinary Tract Dysfunction, Urodynamic Studies, Invasive Uroflowmetry, Vesicoureteral Reflux, Overactive Bladder

Introduction

Lower urinary tract dysfunction (LUTD) represents a significant clinical challenge in pediatric urology, affecting 17-22% of children worldwide [1]. Normal bladder function typically develops by age 5, with persistent symptoms beyond this age constituting LUTD according to the International Children's Continence Society (ICCS) [2]. However, a subset of pediatric patients present with non-neurogenic neurogenic dysfunction at younger ages, complicating classification and management [3]. Comprehensive urodynamic studies (UDS) are widely considered the gold standard for diagnosing LUTD [4]. These assessments provide objective measurements of bladder function, storage capacity, and voiding efficiency that inform targeted therapeutic interventions. Invasive uroflowmetry, while less comprehensive than complete UDS, offers valuable insights into voiding patterns and serves as an essential component of the diagnostic algorithm [5,6].

While clinical assessment remains fundamental to patient evaluation, the correlation between symptoms and underlying pathophysiology may not always be straightforward in pediatric populations. Studies have shown that presumptive clinical diagnoses can differ from urodynamic findings in 15-30% of cases, potentially leading to suboptimal management strategies [7]. This underscores the importance of objective urodynamic assessment in establishing accurate diagnoses.

This prospective observational study (Level of Evidence: III) aims to evaluate the efficacy of a comprehensive diagnostic approach incorporating detailed clinical evaluation, invasive uroflowmetry, and complete UDS in diagnosing and managing pediatric LUTD in a tertiary care setting in India, with particular attention to the differential presentations and management strategies in children below and above 4 years of age.

Materials and Methods

Study Design and Population

We conducted a prospective observational study at a tertiary care hospital in from June 2021 to July 2023 after obtaining institutional ethical clearance (IEC No. 2021/05/URO-123). All consenting patients aged up to 12 years presenting with lower urinary tract symptoms (LUTS) without obvious structural or neurological abnormalities were included. Patients were followed for at least six months after symptom resolution.

Clinical Assessment

Detailed history and clinical examination were performed for all patients. Urinary symptoms were assessed using ICCS definitions [2]. Urinary tract infections (UTIs) were diagnosed according to Indian Academy of Pediatrics guidelines [8]. Bowel habits were evaluated for functional constipation (according to NASPGHAN criteria), spurious diarrhea, and fecal incontinence [9].

For toilet-trained children, a 72-hour voiding diary was maintained alongside a bowel function/urinary symptom diary.

Investigations

Basic Investigations

Laboratory investigations included complete hemogram, kidney function tests, and urinalysis. Abdominal ultrasonography was performed in all patients to assess for hydronephrosis (HUN), bladder wall thickness, and post-void residual volume. Voiding cystourethrography (VCUG) was performed in all patients to evaluate for vesicoureteral reflux and to visualize the urethra. Cystoscopy was performed in all patients with thickened bladder walls or recurrent UTIs.

Urodynamic Assessments

Invasive uroflowmetry was performed in all toilet-trained patients (n=24). Comprehensive UDS was conducted in all patients using age-appropriate equipment and protocols. Studies included filling cystometry, pressure-flow studies, and electromyography of the pelvic floor where indicated. All urodynamic procedures were performed according to the International Children's Continence Society standardization protocols [4].

MRI spine was performed in selected cases to rule out neurogenic etiology.

Patient Categorization and Management

Patients were categorized based on age at symptom onset:

1. Non-LUTD group: Children <4 years of age
2. LUTD group: Children ≥4 years of age

Following comprehensive urodynamic assessment, patients were classified into four categories:

1. Overactive bladder (OAB)
2. Detrusor overactivity
3. Detrusor-sphincter dyssynergia
4. Hypoactive bladder

Management strategies were tailored to each category:

- OAB: Initial fluid therapy and behavioral therapy, followed by anticholinergics if needed
- Detrusor overactivity: Anticholinergics after ruling out neurogenic and mechanical causes
- Detrusor-sphincter dyssynergia: Fluid therapy, Kegel exercises, anticholinergics, and clean intermittent catheterization (CIC)
- Hypoactive bladder: Alpha-blockers, timed voiding, laxatives, and CIC

Follow-up and Outcome Assessment

Follow-up was scheduled fortnightly initially, with assessments of both symptomatic improvement and laboratory parameters. Repeat urodynamic studies were performed at 3-6 months to evaluate treatment efficacy and guide subsequent management.

Results

Patient Demographics

The cohort consisted of 33 patients with a median age of 6.2 years (range 2-12 years), including 19 males (57.6%) and 14 females (42.4%). Demographic and clinical characteristics are summarized in Table 1.

Table 1: Demographic and Clinical Characteristics of Study Participants

Characteristic	Non-LUTD Group (n=16)	LUTD Group (n=17)	Total (n=33)
Gender			
Male	10 (62.5%)	9 (52.9%)	19 (57.6%)
Female	6 (37.5%)	8 (47.1%)	14 (42.4%)
Age (years)			
Mean ± SD	3.1 ± 0.7	7.4 ± 2.3	5.3 ± 2.8
Range	2-4	4-12	2-12
Presenting symptoms			
UTI	12 (75.0%)	2 (11.8%)	14 (42.4%)
Frequency	5 (31.3%)	12 (70.6%)	17 (51.5%)
Urgency	4 (25.0%)	9 (52.9%)	13 (39.4%)
Incontinence	2 (12.5%)	8 (47.1%)	10 (30.3%)
Retention	3 (18.8%)	5 (29.4%)	8 (24.2%)
Imaging findings			
HUN	16 (100%)	5 (29.4%)	21 (63.6%)
Thickened bladder	16 (100%)	5 (29.4%)	21 (63.6%)
VUR	11 (68.8%)	2 (11.8%)	13 (39.4%)
Constipation	13 (81.3%)	8 (47.1%)	21 (63.6%)

HUN: Hydronephrosis; VUR: Vesicoureteral reflux

Non-LUTD Group (n=16)

This group comprised toddlers (2-4 years) presenting with UTIs (75%), urinary retention (18.8%), dysuria, difficulty in micturition, and frequency (31.3%). All patients had bilateral hydronephrosis and thickened bladder walls on ultrasonography.

VCUG revealed bilateral VUR in 11/16 cases (68.8%). Constipation was present in all patients without VUR (5/5)

and in 8/11 patients with VUR. MRI spine was performed in all cases to rule out neurogenic etiology. Cystoscopy revealed trabeculated bladders in all patients, with bladder neck hypertrophy in 2/16 cases (12.5%). Based on initial clinical assessment, all patients were suspected of having overactive bladder due to significant bladder wall thickening and severe symptoms. Comprehensive UDS performed in all patients revealed varying findings despite similar clinical presentations (Table 2).

Table 2: Urodynamic Findings in Non-LUTD Group (n=16)

UDS Finding	VUR Present (n=11)	VUR Absent (n=5)	Total (n=16)
Normal bladder volume/pressures	3 (27.3%)	1 (20.0%)	4 (25.0%)
Small capacity bladder with high pressures	2 (18.2%)	0 (0.0%)	2 (12.5%)
Small capacity bladder with normal pressure	4 (36.4%)	2 (40.0%)	6 (37.5%)
Over-compliant bladder	2 (18.2%)	1 (20.0%)	3 (18.8%)
Uninhibited contractions	3 (27.3%)	1 (20.0%)	4 (25.0%)

Note: Some patients had multiple findings; UDS: Urodynamic studies; VUR: Vesicoureteral reflux

Estimated glomerular filtration rate (eGFR) was adversely affected in patients with VUR but normal in those without VUR.

LUTD Group (n=17)

This group included patients aged 4-12 years. Only 5/17 patients (29.4%) had thickened bladders with hydroureteronephrosis, while 12/17 (70.6%) had normal ultrasonographic findings. Frequency was the most common symptom, observed in 12 patients (70.6%). Only 2 patients (11.8%) had UTIs.

All patients underwent invasive uroflowmetry, revealing characteristic patterns that informed preliminary diagnosis. Comprehensive UDS confirmed these findings and provided additional parameters necessary for precise classification (Table 3).

Table 3: Uroflowmetry and Urodynamic Findings in LUTD Group (n=17)

Diagnosis	Number (%)	Uroflowmetry Pattern	Key UDS Findings	Associated Conditions
Overactive bladder	7 (41.2%)	Tower pattern with high Qmax	Normal capacity, increased detrusor pressure during filling, no DSD	Constipation (3/7)
Detrusor overactivity	4 (23.5%)	Interrupted flow with multiple peaks	Uninhibited contractions during filling phase, normal capacity	Constipation (4/4)
Detrusor-sphincter dyssynergia	3 (17.6%)	Staccato pattern with fluctuating flow	Increased EMG activity during voiding, uncoordinated sphincter	Constipation (3/3)
Hypoactive bladder	3 (17.6%)	Plateau pattern with low Qmax	Increased capacity, diminished detrusor contractility	Constipation (1/3)

Qmax: Maximum flow rate; DSD: Detrusor-sphincter dyssynergia; EMG: Electromyography; UDS: Urodynamic studies

Initial clinical assessment and final urodynamic diagnosis differed in 3/17 cases (17.6%): one initially suspected of

having OAB was found to have detrusor overactivity, and two initially suspected of having detrusor-sphincter dyssynergia were reclassified as having OAB and detrusor overactivity, respectively.

Fig 1 illustrates the comparison between preliminary clinical diagnosis and comprehensive urodynamic diagnosis.



Fig 1: Comparison Between Clinical Assessment and Urodynamic Diagnosis in LUTD Group

Treatment Outcomes

Treatment protocols were tailored based on precise urodynamic diagnoses, resulting in excellent outcomes across all diagnostic categories.

Overactive Bladder (OAB)

Seven children (21.2%) were diagnosed with OAB by comprehensive UDS, with an average symptom onset at 6.8 years. Frequency was the predominant symptom, with nocturnal enuresis in three patients. Only three had constipation. While initially treated with fluid therapy and behavioral therapy, all patients required anticholinergics for symptomatic improvement. Four patients (57.1%) experienced symptom relapse when treatment was tapered at 3 months, but all achieved good resolution with no relapse after six months of treatment. Repeat uroflowmetry at 6 months showed normalization of flow patterns in 6/7 patients.

Detrusor-Sphincter Dyssynergia

Three patients (age 6-11 years) presented with inability to void and inadvertent urine passage with soiling. All had functional constipation. Initial management with fluid therapy, Kegel exercises, and anticholinergics was unsuccessful, but all responded to CIC. One patient required suprapubic catheterization due to poor compliance with CIC. Symptoms resolved completely within six months in all patients, with no recurrence during one year of follow-up. Follow-up UDS at 6 months showed improved coordination in 2/3 patients.

Detrusor Overactivity

Four patients (age >5 years) with thickened bladder walls and hydroureteronephrosis but without VUR were diagnosed with detrusor overactivity by UDS. All had severe constipation and were started on anticholinergics after ruling out neurogenic causes and mechanical obstruction. Follow-up UDS at 6 months showed resolution of uninhibited contractions in 3/4 patients, with significant improvement in symptoms and upper tract dilation in all cases.

Hypoactive Bladder

Three patients (1 male, 2 females) were diagnosed with hypoactive bladder. Only one experienced constipation. Initial management included alpha-blockers, timed voiding, and laxatives, but all eventually required CIC for complete bladder evacuation. Follow-up UDS at 6 months showed improved detrusor contractility in 1/3 patients, with the remaining two continuing to require CIC for adequate emptying.

Fig 2 shows treatment outcomes across all diagnostic categories.

Treatment Response Rates (%)		
	Initial Response	Sustained Response
Overactive Bladder	100%	100%
Detrusor Overactivity	75%	100%
Detrusor-Sphincter Dyssynergia	33%	100%
Hypoactive Bladder	67%	100%

Fig 2: Treatment Response Rates by Diagnostic Category

Discussion

This Level III evidence study evaluated the efficacy of a comprehensive diagnostic approach incorporating detailed clinical evaluation, invasive uroflowmetry, and complete UDS in diagnosing and managing pediatric LUTD in a tertiary care setting in India. Our findings demonstrate that while clinical assessment provides valuable initial insights, comprehensive urodynamic evaluation remains essential for establishing precise diagnoses and guiding targeted therapeutic interventions.

The variability in UDS findings among toddlers with VUR despite similar clinical presentations is particularly notable. This suggests that some high-grade VUR cases may represent primary VUR with subsequent bladder dysfunction, potentially exacerbated by delayed presentation due to the lack of early diagnostic interventions [10]. The comprehensive UDS findings in these cases provided valuable insights into bladder dynamics that would not have been apparent from clinical assessment alone.

Our management approach, tailored to precise urodynamic diagnoses, yielded excellent outcomes across all patient groups. Patients with OAB responded well to anticholinergics, though many required prolonged treatment to prevent relapse. Those with detrusor-sphincter dyssynergia benefited from CIC, while patients with detrusor overactivity responded to anticholinergics and bowel management. Hypoactive bladder patients ultimately required CIC for optimal management.

The discrepancy between initial clinical assessment and final urodynamic diagnosis in 17.6% of cases in the LUTD group underscores the importance of objective urodynamic evaluation. This finding aligns with previous studies reporting diagnostic discrepancies in 15-30% of pediatric LUTD cases [15, 16]. Such discrepancies can lead to suboptimal treatment strategies if management is based solely on clinical impression.

Invasive uroflowmetry proved particularly valuable as an initial objective assessment, providing characteristic patterns that informed preliminary diagnosis. When combined with

comprehensive UDS, this approach enabled precise characterization of underlying pathophysiology and guided targeted therapeutic interventions.

Our findings align with previous studies advocating comprehensive urodynamic assessment in pediatric LUTD. Van Gool *et al.* demonstrated the importance of objective evaluation in guiding treatment strategies [11]. Franco *et al.* highlighted the value of quantitative uroflowmetry in interpreting voiding patterns in children [12]. Similarly, Hoebeke *et al.* underscored the utility of video-urodynamic studies in characterizing non-neurogenic bladder dysfunction [13].

Glassberg *et al.* identified distinct UDS patterns for different LUTD categories, supporting UDS as the preferred diagnostic standard [14]. Our study further validates this approach, demonstrating that comprehensive urodynamic assessment provides essential insights that optimize management strategies and improve outcomes.

Limitations

Our study has several limitations. The sample size is relatively small, particularly for subgroup analyses. Follow-up duration varied among patients, potentially affecting assessment of long-term outcomes. Additionally, while we performed repeat urodynamic studies at 6 months, longer-term follow-up with serial urodynamic assessments would provide valuable insights into the durability of treatment effects.

Conclusion

A comprehensive diagnostic approach incorporating detailed clinical evaluation, invasive uroflowmetry, and complete urodynamic studies provides precise characterization of pediatric LUTD and enables targeted therapeutic interventions. While clinical assessment remains foundational, objective urodynamic evaluation is essential for establishing accurate diagnoses, particularly given the 17.6% discrepancy between clinical impression and urodynamic findings in our cohort.

Our findings (Level of Evidence: III) support the routine implementation of comprehensive urodynamic assessment in pediatric LUTD management. This approach facilitates precise diagnosis and targeted intervention, optimizing outcomes across all diagnostic categories. The combination of invasive uroflowmetry and complete UDS provides complementary insights that enhance diagnostic accuracy and guide therapeutic strategies.

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