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Longitudinal Evolution of Uroflowmetry Patterns From Childhood to Puberty After Hypospadias Repair: A 12-Year Cohort Study

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A B S T R A C T

Objective: To evaluate long-term changes in uroflowmetry patterns from childhood to puberty after hypospadias repair and identify boys with abnormal urinary flow who may require surgery.

Materials and Methods: This retrospective cohort included patients who underwent hypospadias repair with creation of a neourethra at a tertiary center between 2000 and 2006, with minimum follow-up of 12 years. Patients were grouped by hypospadias severity and assessed with uroflowmetry at prepubertal age and during puberty. Flow patterns were classified according to International Children's Continence Society criteria, and flow index was calculated to adjust maximum flow rate for voided volume.

Results: Forty-seven patients (20 distal, 27 proximal) were included. Prepubertal plateau-shaped flows occurred in 23 patients (48.9%). Among these, spontaneous improvement occurred in 15, surgery for symptomatic obstruction was required in 6 (26.1%), and plateau-shaped flow persisted without symptoms in 2. In patients with prepubertal plateau-shaped flow not requiring surgery, median maximum flow rate increased from 11.2 mL/s prepuberty to 21.4 mL/s during puberty ($P < .001$), with a corresponding rise in flow index. No significant differences in long-term uroflowmetry outcomes were observed between distal and proximal hypospadias.

Conclusion: Most plateau-shaped flow patterns after hypospadias repair improve spontaneously during puberty, supporting conservative management in asymptomatic patients. Surgery should be reserved for boys with persistent abnormal flow and urinary symptoms.

Hypospadias is a congenital anomaly characterized by hypoplasia of the tissues forming the ventral side of the penis, resulting in ectopic placement of the urethral meatus. It affects approximately 1 in 200 male live births, making it one of the most common congenital urological conditions. The condition is often associated with additional abnormalities, such as ventral penile curvature (chordee) and an incomplete preputial fold, which can affect both urinary and sexual function if left untreated. Surgical correction is typically performed in infancy or early childhood to restore normal anatomy and function, with the primary goals being the achievement of normal voiding and a straight erection, and creation of a cosmetically acceptable appearance.

While short-term outcomes of hypospadias repair are often favorable, long-term complications remain a significant concern. These complications include urethral stricture, fistula formation, recurrent curvature, and functional urinary issues such as obstructive voiding patterns. Such complications can emerge years after surgery, particularly during puberty when anatomical changes occur.[1,2]

Proximal hypospadias repairs are especially prone to higher complication rates compared to distal repairs due to the complexity of reconstruction and the limited availability of good-quality tissue for urethroplasty.

Uroflowmetry, a noninvasive diagnostic tool that measures urinary flow rate and pattern, has become a cornerstone in the long-term functional assessment of patients following hypospadias repair. It provides objective data to detect abnormal flow patterns (eg, plateau-shaped curves) and reduced maximum flow rate (Qmax), which may correlate with functional complications after hypospadias repair.[3,4]

Studies have shown that while some hypospadias patients exhibit obstructive flow patterns (eg, plateau-shaped curves) after surgery, these may spontaneously normalize during puberty as the reconstructed urethra adapts to growth and anatomical changes.[5,6]

However, in some cases, surgical intervention is required to address persistent obstruction or stenosis.

Despite its importance, long-term studies on uroflowmetry outcomes in hypospadias patients are limited. Many existing studies suffer from high rates of loss to follow-up or lack standardized methodologies for evaluating urinary function over time.[7,8]

Most previous studies have reported absolute flow rates and visual curve shapes without using volume-adjusted uroflow parameters, and volume-corrected indices such as the flow index have only recently been introduced and rarely applied in the context of hypospadias follow-up.[4,9]

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This study aimed to describe the longitudinal evolution of uroflowmetry patterns and the Franco flow index from childhood to after puberty in boys who underwent hypospadias repair with creation of a neourethra, to compare outcomes between distal and proximal repairs, and to explore whether prepubertal uroflow parameters differ between boys who subsequently required revision surgery and those who did not.

MATERIALS AND METHODS

This retrospective cohort study was conducted at the Department of Pediatric Urology of a tertiary academic center. The study focused exclusively on the longitudinal evolution of uroflowmetry patterns in patients who underwent hypospadias repair between 2000 and 2006 at prepubertal age. The study underwent an independent institutional quality review to ensure compliance with regulations on informed consent procedures, data management, privacy, and legal aspects. The study did not require approval from an accredited medical ethics committee and was classified as non-WMO research according to applicable legislation and institutional policies.

Patients included in the study were those who had undergone hypospadias correction with the creation of a neo-urethra and had a minimum follow-up of 12 years.

Hypospadias repair was performed using standard techniques appropriate for the meatal position, including tubularized incised plate (Snodgrass), Mathieu and onlay island flap (Onlay-Duckett) urethroplasties. All repairs in the proximal group were carried out as single-stage procedures, without ventral urethral plate transection and without the use of buccal mucosa grafts. Ventral curvature, when present, was corrected by dorsal plication as required.

Exclusion criteria included glandular or subcoronal hypospadias corrected with meatal advancement and glandoplasty (MAGPI) or glandular urethroplasty procedures, as well as patients with other urological conditions affecting micturition (eg, spina bifida).

Patients were classified into two groups based on the location of the urethral meatus at surgery: distal hypospadias (distal or midpenile) and proximal hypospadias (proximal penile/penoscrotal, scrotal, or perineal).

Micturition symptoms (including frequency, urgency, nocturia, dysuria, hesitancy, intermittency, straining, weak stream, and post-micturition dribbling) and incontinence were scored as documented in the medical record, based on physician, parent, or patient report during follow-up. Incontinence was defined as any involuntary urinary loss, including post-micturition dribbling. Urinary tract infection (UTI) was defined as a clinically diagnosed episode, either recorded in the medical record or reported by parents or patients at follow-up. If no mention of incontinence or UTI was found in the dossier, it was assumed these symptoms were absent. Uroflowmetry assessments were performed during routine follow-up visits around 5 years of age (pre-puberty) and after puberty (age 12-21 years). Flow patterns were categorized as bell-shaped, plateau-shaped, staccato, or interrupted according to International Children's Continence Society (ICCS) criteria.

To correct for differences in voided volume between prepubertal and post-pubertal stages, we calculated the flow index (FI) for each uroflowmetry measurement. The flow index was defined as the maximum flow rate (Qmax, in mL/s) divided by the expected Qmax ($Qmax_{exp}$) based on the total bladder capacity.[10]

$$\text{Flow index (FI)} = Qmax / Qmax_{exp},$$

$$\text{where } Qmax_{exp} = 11.26 + 0.0701*TBC - 0.0000423*TBC^2$$

This adjustment allows for a more accurate comparison of Qmax between time points and among patients, since Qmax naturally increases with larger voided volumes. By normalizing Qmax to the voided volume, the flow index provides an objective, volume-corrected measure of urinary flow that reduces the influence of bladder capacity and growth-related changes. This method, as described by Franco et al, has been validated in pediatric cohorts and helps to standardize the interpretation of uroflowmetry patterns across different ages and developmental stages.[10]

The primary outcome was the evolution of uroflowmetry patterns in children operated for hypospadias from childhood to after puberty. Outcomes of patients with distal and proximal hypospadias were compared.

Data analysis was performed using SPSS version 30.0. Continuous variables were analyzed using Mann-Whitney U tests while categorical variables were assessed using Chi-square tests. Statistical significance was set at $P < .05$.

RESULTS

Patient Characteristics

Forty-seven patients were included, 20 with distal and 27 with proximal hypospadias. The median age at the first operation was 14 months (IQR: 8-42 months), and the median age at follow-up was 15 years (IQR: 12-21 years) and an additional evaluation was performed before puberty, around the age of 5 years. There were no significant differences in baseline patient characteristics between the distal and proximal hypospadias groups (Table 1). Proximal hypospadias cases had a higher frequency of preoperative testosterone use (18/27, 66.7%, vs 3/20, 15.0%, $P < .001$) and curvature correction (23/27, 85.1%, vs 4/20, 20.0%, $P < .001$).

UROFLOWMETRY PATTERNS

Before Puberty

Plateau-shaped flow patterns were observed in 23 patients (48.9%), including 10 distal cases (50.0%) and 13 proximal cases (48.1%).

After Puberty

The incidence of plateau-shaped flows significantly decreased to two patients (4.2%, $P < .001$), one in each group (5.0% distal, n = 1; and 3.8% proximal, n = 1), see also Table 2. Among those with prepubertal plateau-shaped flows (n = 23), spontaneous normalization occurred in 15 patients (65.2%). Surgical intervention for symptomatic obstruction was required in six patients (26.1%), equally distributed between distal (3/10, 30.0%) and proximal (3/13, 23.1%) cases. Two patients (8.7%) retained plateau-shaped flows but remained asymptomatic. Of the prepubertal asymptomatic patients with a plateau-shaped flow, 15/17 (88.2%) improved spontaneously. When comparing distal and proximal hypospadias, this was 6/7 (85.7%) and 9/10 (90.0%) improving without further surgical intervention.

Table 1
Baseline characteristics.

	Distal (n = 20)	Proximal (n = 27)	Total (n = 47)	*P*
Median age at surgery (mo)	15 (8-42)	14 (10-17)	14 (8-42)	.205
Median age at follow up (y)	16 (12-21)	15 (12-21)	16 (12-21)	.948
Curvature correction	4 (20.0%)	23 (85.1%)	27 (57.4%)	< .001
Median number of operations (prepubertal)	2 (1-4)	2 (1-6)	2 (1-6)	.221
Peri-operative testosterone	3 (15.0%)	18 (66.7%)	21 (44.7%)	< .001

Table 2
Flow pattern change during puberty.

		# Plateau Shaped (%)		
		Distal Hypospadias (N = 20)	Proximal Hypospadias (N = 27)	All (N = 47)
Whole group	Pre-puberty	10 (50.0%)	13 (48.1%)	23 (48.9%)
	Post-puberty	1 (5.0%)	1 (3.8%)	2 (4.3%)
	P	.002	< .001	< .001
No intercurrent surgery		N = 17	N = 24	N = 41
	Pre-puberty	7 (41.2%)	10 (41.7%)	17 (41.5%)
	Post-puberty	1 (5.9%)	1 (4.2%)	2 (4.9%)
	P	.017	.002	< .001

Flow Parameters

For the whole group, the median voided volume increased significantly from 190 mL (IQR: 140) pre-puberty to 260 mL (IQR: 210) during puberty ($P = .006$). Similarly, median Qmax increased from 15.0 mL/s (IQR: 8.2) to 23.2 mL/s (IQR: 13.8) ($P < .001$). The median flow index, which corrects Qmax for voided volume differences, increased from 0.67 (IQR: 0.32) to 0.91 (IQR: 0.34) ($P < .001$). These parameters and their changes are summarized in Table 3. No significant differences in uroflowmetry outcomes were observed between distal and proximal hypospadias groups at any time point.

Surgical Interventions

Six patients required additional surgery, including three with distal hypospadias (15.0%, n = 3/20) and three with proximal hypospadias (11.1%, n = 3/27). Indications included weak urinary stream with straining in two patients, spraying in one, visible meatal stenosis in one, urethrocutaneous fistula in one, and persistent ventral curvature in one. Prepubertal uroflowmetry parameters differed between boys who subsequently required additional surgery and those who did not: the surgically treated group had a lower median flow index (0.51 vs 0.71) and a longer median voiding time (30 vs 20 seconds), while median Qmax was also lower (11.5 vs 15.0 mL/s), with statistical significance reached for flow index only ($P = .025$).

DISCUSSION

The most important outcome of this study is that most children with abnormal (plateau-shaped) uroflowmetry pattern after hypospadias repair normalized spontaneously during puberty (15/17, 88.2%), while just over a quarter (6/23, 26%) required surgical intervention due to obstruction.

Our results are in line with previous longitudinal studies. Andersson et al reported normalization of uroflowmetry in 95% of patients after TIP repair by adolescence,[5] while Al Adl et al found that 69% of asymptomatic children with low Qmax at age 5 did not require later surgery.[11] Although our normalization rate is somewhat lower, likely due to stricter criteria for abnormal flow and the inclusion of more proximal cases, the clinical implication remains consistent: most abnormal flows improve over time, and surgery should be reserved for those with persistent symptoms.

In the present cohort, all boys who underwent reoperation had both a plateau-shaped prepubertal uroflowmetry curve and urinary symptoms, whereas most asymptomatic boys with abnormal curves improved spontaneously during puberty. Prepubertal flow index values were significantly lower and voiding times longer in the surgically treated group compared to boys managed conservatively, while differences in Qmax alone did not reach statistical significance. These findings support using uroflowmetry – particularly a low flow index – in combination with symptoms to select boys for further evaluation or revision, rather than treating plateau-shaped curves in isolation.

When comparing distal and proximal hypospadias, we found no significant differences in long-term uroflowmetry outcomes. This challenges earlier reports that suggested poorer functional results for proximal repairs,[12] but aligns with more recent evidence. Ibrahim et al demonstrated that patients with proximal hypospadias repaired using the Mansoura modification of the Koyanagi technique achieved excellent long-term functional outcomes, with mean Qmax values and satisfaction scores comparable to distal repairs.[13] Advances in surgical technique, such as the Snodgrass TIP and staged repairs for severe cases, have likely contributed to these improved and more uniform outcomes across the hypospadias spectrum.[3]

A key clinical implication is that our selective approach—intervening only in patients with both abnormal flow and symptoms—is supported by the literature. Several studies have shown that routine surgery for isolated abnormal uroflowmetry leads to overtreatment and unnecessary morbidity. For example, Piplani et al[9] and Eassa et al[14] demonstrated that most asymptomatic children with abnormal uroflow findings do not require surgery, and that combining symptom

Table 3
Uroflowmetry outcomes before and during puberty.

		Qmax (mL/s)	Voided Volume (mL)	Flow Index
Whole group (n = 47)	Pre-puberty	15.0	190	0.67
	Post-puberty	23.2	260	0.91
	P-value	< .001	.006	< .001
Initial plateau-flow, no intercurrent surgery (n = 17)	Pre-puberty	11.2	240	0.47
	Post-puberty	21.4	270	0.93
	P-value	< .001	.210	< .001
Initial normal flow (n = 24)	Pre-puberty	17.7	150	0.79
	Post-puberty	24.5	250	0.90
	P-value	.002	.002	.043
P-value of differences in flow parameters between patients with an initial plateau-shaped flow no intercurrent surgery and initial normal initial normal flow.	Pre-puberty	.003	.009	< .001
	Post-puberty	.958	.624	.874

assessment with uroflowmetry best identifies those who genuinely benefit from intervention. In a large pediatric cohort, only 1.9% of post-hypospadias patients had surgery based on uroflowmetry findings coupled with symptoms, while virtually no management changes were made in asymptomatic patients.[2] This evidence supports a conservative, symptom-driven management strategy.

The significant improvements in uroflowmetry parameters observed in our cohort—including increases in voided volume, Qmax, and flow index during puberty—demonstrate the functional adaptability of the reconstructed urethra over time. Sharma et al have reported similar findings, with Qmax values nearly doubling from early postoperative measurements to adolescence after TIP repair.[15] Hormonal changes during puberty, such as increased androgen receptor activity, may promote urethral growth and compliance.

This study's strengths include its long-term follow-up, standardized use of ICCS criteria for flow classification, and application of the flow index to correct for differences in voided volume. Including both distal and proximal cases enhances the generalizability of our findings and challenges historical assumptions about poorer outcomes in proximal repairs.

Nevertheless, several limitations must be acknowledged. The retrospective design introduces potential selection bias, as only patients with complete uroflowmetry data at both time points were included, which may reflect a follow-up indication bias. There was no standardization of flow curve interpretation beyond ICCS criteria, and symptom assessment relied on clinical interviews rather than validated questionnaires. Criteria for revision surgery were not strictly defined and were based on the combination of symptoms and abnormal flow, reflecting real-world clinical practice but limiting reproducibility. In addition, although the median number of prepubertal operations did not differ significantly between distal and proximal hypospadias, the cumulative operative burden may still influence long-term functional outcomes; however, the present sample size did not allow a robust analysis of this potential effect. The predominance of proximal cases in this cohort likely reflects the referral pattern of our tertiary academic center and may further limit the generalizability of our findings to populations with a higher proportion of distal hypospadias. Additionally, our cohort was drawn from a single center, which may limit generalizability to other settings. Similarly, although age at primary surgery did not differ significantly between distal and proximal groups, the study was not designed or powered to determine whether age at surgery independently affects long-term uroflowmetry outcomes, and this question warrants further investigation in larger cohorts. Furthermore, post-void residual urine volume was not included in the analysis, as it was not measured in a standardized manner—often not directly after flow or according to a uniform protocol—which may have limited the completeness of our functional assessment.

Future research should focus on prospective, multicenter studies with standardized protocols for uroflowmetry and symptom assessment, as well as the inclusion of patient-reported outcomes and quality-of-life measures. Alternatively, the establishment of registries could also facilitate large-scale data collection and long-term follow-up, further strengthening the evidence base in this field.

CONCLUSION

This study illustrates that in boys with abnormal uroflowmetry patterns but no urinary symptoms after hypospadias repair, a watchful waiting approach is justified, as most abnormal flows improve spontaneously during puberty. Uroflowmetry should not be used in isolation to determine the need for further surgery. Rather, our findings suggest that uroflowmetry – particularly a low Franco flow index – should be interpreted alongside voiding symptoms to identify the small subset of boys who may benefit from further evaluation or revision, rather than using plateau-shaped curves alone as an indication for surgery.

Disclosures

None.

Ethical Declaration

This retrospective, non-WMO study underwent institutional quality review at UMC Utrecht (reference 22U-0176).

CRediT Authorship Contribution Statement

George Tsachouridis: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Wouter van Dort**: Writing – review & editing, Investigation, Formal analysis, Data curation. **Kyara Kamphorst: Methodology, Investigation, Data curation. Laetitia M.O. De Kort**: Writing – review & editing, Supervision, Project administration, Formal analysis.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

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