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Risk factors for postoperative urethral diverticulum following hypospadias repair with disconnection of the urethral plate

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Abstract

Background Urethral diverticulum (UD) may arise subsequent to hypospadias repair, potentially causing issues such as stone formation, frequent urination, urinary tract infections, urine dripping, and hematuria. We reviewed our previous experiences regarding hypospadias complications to identify the relevant factors affecting the occurrence of UD after hypospadias surgery and adjust management strategies accordingly.

Methods A retrospective analysis was performed on the clinical data of 159 pediatric patients who underwent urethroplasty with disconnection of the urethral plate (DUP) in our department from January 2020 to December 2022. The collected information included patient demographics such as age, weight, Body Mass Index (BMI), Hemoglobin (Hb), Hematocrit (HCT), Albumin (ALB), Prealbumin (PALB), Procalcitonin (PCT), the employed surgical methods, whether the procedure was performed in stages, glans width, urethral stricture, penile curvature after correction, length of urethral defect, length of reconstructed urethra, indwelling catheter size and duration. The study population was divided into a group with UD and a group without UD, and univariate and multivariate analyses were performed.

Results Among 159 patients with a mean follow-up of 31.87 ± 10.32 months, 14 (8.64%) patients developed UD after urethroplasty surgery. According to the univariate analysis, a narrower glans width ($P=0.018$), a higher BMI ($P=0.019$), the application of a modified onlay island flap (MOIF, $P=0.003$), and urethral stricture ($P=0.010$) were significantly associated with postoperative UD. Glans width ($P=0.023$, OR = 0.444, 95% confidence interval [CI]: 0.220–0.895), BMI ($P<0.001$, odds ratio [OR] = 1.808, 95% CI: 1.318–2.481), the application of MOIF ($P=0.007$, OR = 10.670, 95% CI: 1.913–59.505) and urethral stricture ($P=0.015$, OR = 10.010, 95% CI: 1.554–64.470) were independent factors for postoperative UD.

Conclusions A narrower glans width, a higher BMI, the application of MOIF, and urethral stricture are significant factors contributing to the development of UD in patients with hypospadias following DUP.

Keywords Hypospadias, Disconnection of the urethral plate, Urethral diverticulum, Risk factors

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Introduction

Hypospadias is the most common congenital malformation of the pediatric reproductive system. Between 1980 and 2010, there was a continuous global increase in the incidence of hypospadias [1]. Surgical intervention remains the sole effective treatment for this condition. However, postoperative complication rates range from 8 to 56% [2, 3]. These complications include urethral fistula, urethral stricture, urethral diverticulum (UD), residual curvature, distal rupture, inadequate exposure during surgery, and scrotal transposition. Numerous studies have explored risk factors associated with postoperative complications following hypospadias repair surgery, mainly focusing on surgical age, hypospadias type, anesthesia technique employed, urethral length reconstruction, and postoperative constipation [4–10]. Nevertheless, studies focusing on the risk factors and management strategies that influence the occurrence of UD are still relatively scarce. Urethral diverticula can cause stone formation, incomplete voiding, infection, postvoid dribbling, hematuria and other complications [11]. The factors that increase the risk of diverticulum include proximal defects, the use of inadequately supported tissue for transplant insertion, and distal stenosis that leads to relative obstruction or elevated outlet pressure [12].

Herein, we conducted a review over the past three years regarding complications associated with hypospadias repair by identifying patients who developed diverticula while analyzing related factors as well as examining management approaches and outcomes.

Methods

Patients

We conducted a retrospective analysis of the clinical data relevant to 159 pediatric patients with hypospadias who underwent their initial surgical treatment in our department between January 2020 and December 2022. This study was performed in accordance with the principles outlined in the Declaration of Helsinki (as revised in 2013). The Ethics Committee of the Children's Hospital of Nanjing Medical University granted approval for this study (approval number: 2022101986) and waived the requirement for informed consent due to its retrospective design.

Definitions

The detection limit of the blood procalcitonin (PCT) value is 0.02 ng/mL.

A senior physician with over three years of experience as a deputy chief physician, who has consistently performed more than 30 urethroplasties annually.

Patients with dysuria, thinning of the urinary stream, prolonged voiding waiting time and voiding time, and significantly increased resistance at the time of urethral dilation surgery were considered to have urethral stricture.

The inclusion criteria were as follows: (1) patients were diagnosed with hypospadias; (2) patients underwent their first urethroplasty surgery using the disconnection of the urethral plate (DUP) in our hospital; and (3) patients were followed up at least 1 year after operation.

The exclusion criteria were as follows: (1) patients underwent Byar's two-stage operation; (2) patients were diagnosed with disorders of sex development (DSD); and (3) patients with congenital UD.

Surgical methods

All 159 patients underwent urethroplasty with DUP. The operation methods adopted in this study included three types: transverse preputial island flap (TPIF) [13] (Some patients underwent standard Duckett surgery to establish a glans tunnel, whereas others underwent double-face onlay-tube-onlay transverse preputial island flap (DFOTO) [14]); modified transverse preputial island flap (MTPIF) [15, 16]; and modified onlay island flap (MOIF) [17]. These surgical interventions were conducted in one or multiple stages. The specific surgical techniques employed are detailed below.

The common surgical procedures in the initial stage include the suspension of traction lines on the glans, catheter insertion, incision of the membranous urethra, creation of a U-shaped incision along the external orifice of the urethra while preserving the distal urethral plate, annular incision along the coronal groove, foreskin retraction, and artificial erection to assess lower penile curvature. DUP is performed beneath the coronal groove or at sites where curvature is most pronounced. Subsequently, dissociation of the urethral plate occurs followed by another measurement of the lower curvature via artificial erection. If necessary, the dorsal fascia is folded to correct any downward curve. The length of the urethral defect is measured accordingly.

In the standard Duckett procedure, the inner skin of the dorsal foreskin is used to make an island flap. A coiled tube is formed into a new urethra and proximally transferred to anastomose with the original urethra on the ventral side of the penis. A glans tunnel is established at the distal end.

In the DFOTO procedure, dissection entails incising through the glans while preserving the urethral plate of the distal glans and covering its distal end with an island flap.

In the MTPIF procedure, the urethral plate at the distal glans is preserved. The island flap is transferred to the ventral surface of the penis and V-shaped incisions are made at both ends. Both ends of the flap are aligned with

the distal urethral plate and the proximal natural urethra. The flap is rolled to form a new urethra.

In the MOIF procedure, the urethral plate is incised obliquely at the most prominent point of penile curvature, and the distal and proximal urethral plates are anastomosed to extend the length of the urethral plate. The inner skin of the dorsal foreskin is transferred to cover the urethral plate, thereby forming a new urethra.

Subsequent common procedures include covering the urethra with local skin flaps or Buck's fascia, shaping the glans, shaping the penile body, shaping the penoscrotal angle, fixing the urinary catheter, and applying pressure for bandaging.

The first stage of surgery involves the complete execution of the aforementioned steps, whereas the staged procedure involves creating a stoma approximately 1 cm in diameter at the original retracted external urethral opening. The second stage of surgery, which focuses on repairing the stoma, is conducted after a period of six months.

Data collection

Outpatient visits, telephone follow-ups, and an electronic medical records system were used to gather data related to the study participants, such as patient age, weight, Body Mass Index (BMI), Hemoglobin (Hb), Hematocrit (HCT), Albumin (ALB), Prealbumin (PALB), PCT, anemia, the seniority of surgical doctors, whether the procedure was staged, glans width, urethral stricture, the position of the urethral opening after straightening, the adopted surgical methods, penile curvature after degloving, the length of the urethral defect, the length of the reconstructed urethra, the indwelling catheter diameter and duration, and the proportion of patients with UD after urethroplasty. Patients were categorized into those with UD and those without UD after the operation.

Statistical analysis

Statistical analyses were conducted using IBM SPSS software 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation, and categorical variables are expressed as proportions. The t-test was used to compare the means of normalized quantitative data between two groups, and Welch's t-test was used to compare the means of other quantitative datasets. The chi-square test was used to assess differences in proportions between two groups, whereas one-way ANOVA was used for comparisons among multiple groups. Variables with $P<0.2$ from the univariate analysis were incorporated into the multivariate logistic regression analysis. $P<0.05$ was considered statistically significant.

Results

Study population

A total of 159 participants were enrolled in the study, with ages ranging from 6 months to 83 months at the time of the initial surgery, resulting in a mean age of 24.13 ± 16.30 months. The average duration of hospitalization was 13.08 ± 2.36 days, while the mean follow-up period was 31.87 ± 10.32 months. Among the participants, 50 patients (31.45%) underwent TPIF, 44 patients (27.67%) received MTPIF, and 65 patients (40.88%) underwent MOIF. Additionally, one-stage repair was performed on 85 patients (53.46%), whereas two-stage surgery was conducted on 74 patients (46.54%). The average duration for the first urethroplasty procedure was recorded as 110.97 ± 25.34 min.

Treatment of UD

A total of 14 patients (8.64%) developed UD following urethroplasty surgery, including 1 patient (7.14%) in the TPIF group, 2 patients (14.29%) in the MTPIF group, and 11 patients (78.57%) in the MOIF group. Among these patients, 10 underwent primary surgery (71.43%), whereas 4 patients received staged surgical intervention (28.57%). The onset of UD occurred within the range of 1 to 22 months after the last surgical procedure, with a mean duration of 8.50 ± 6.61 months after surgery.

The clinical symptoms included penile ventral bulging in 14 patients (100%), bifurcated showerhead-like urination in 9 patients (64.29%), a skewed urine stream in 4 patients (28.57%), difficulty urinating due to a narrowed urine stream in 4 patients (28.57%), irritative symptoms associated with urinary tract infection in 2 patients (14.29%), and urethral stones in 1 patient (7.14%).

Patients with UD underwent a total of between 1 and 4 surgeries, with an average of approximately 2.43 ± 0.94 procedures per patient. After the diagnosis of UD, 9 patients (64.29%) received related surgical treatment, whereas 5 patients (35.71%) opted for conservative management. One patient underwent multiple urethral dilatations.

The diagnostic and therapeutic strategies for UD are illustrated in Fig. 1. Among the 9 patients who underwent surgical intervention for UD, 6 patients (66.67%) achieved complete resolution without any urinary complications or urethral fistulas during follow-up; 2 patients (22.22%) exhibited mild residual UD but reported no urination difficulties and demonstrated improvement compared with their preoperative condition. One patient (11.11%) developed a postoperative urethral fistula, along with local abscess infections in the penis and scrotum, which were managed through urethral fistula repair and incision drainage of the abscess.

Among the 5 patients receiving conservative treatment, 4 patients (80%) had UD without any significant

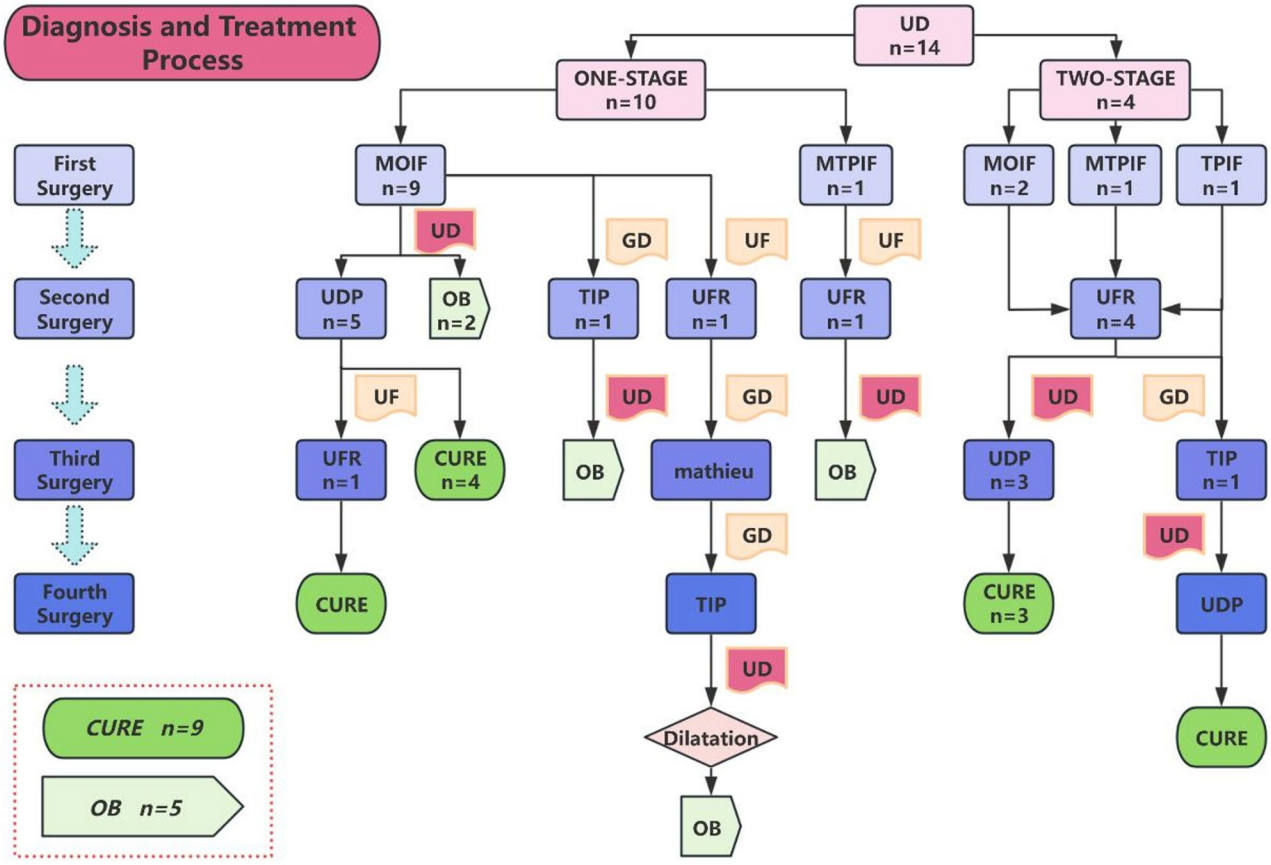

Fig. 1 Diagnosis and treatment process of urethral diverticulum after the repair of hypospadias involving disconnection of the urethral plate
Abbreviations: MOIF, modified onlay island flap; MTPIF, modified transverse preputial island flap; TPIF, transverse preputial island flap; TIP, tubularized incised plate; UD, urethral diverticulum; GD, glans dehiscence; UF, urethral fistula; UFR, urethral fistula repair; UDP, urethral diverticuloplasty; OB, observation

urination difficulties, urinary stream stenosis, or recurrent urinary tract infections, and they were regularly monitored. One patient (20%) experienced a narrowing of the urine stream. Following routine application of an F8 urethral dilator to expand the narrowed urethra, UD demonstrated substantial improvement. This patient requires further follow-up monitoring.

Urethral stricture

Among patients with UD, 4 patients (28.57%) presented with urethral stricture, all of which were identified as stenoses at the urethral meatus or near the coronal sulcus. The onset of UD occurred approximately one month after the detection of distal urethral stricture and narrowing of urine stream. Three patients underwent surgical intervention, while 1 patient received conservative management involving urethral dilation. In contrast, among patients without UD, 8 patients (5.41%) presented with concomitant urethral stricture. Specifically, 5 patients had stenosis at the anastomotic site between the new and old urethra, 2 patients experienced stenosis at the external urethral opening, and 1 patient presented with multiple sites of stenosis.

Univariate analysis

The 159 patients included in the study were divided into two groups on the basis of the presence or absence of UD. We compared various parameters, including age at initial surgery, birth weight, initial surgical weight, BMI, Hb, HCT, ALB, PALB, PCT, duration of indwelling catheterization, catheter diameter, penile curvature after degloving, length of urethral defect, and glans width between the two groups. The results indicated that patients with UD had significantly narrower glans width ($P = 0.018$) and higher BMI ($P = 0.019$).

Further univariate analysis was performed to assess factors such as low birth weight, anemia, surgical staging, surgeon seniority, penis dorsal plication, concomitant urethral stricture, surgical methods employed, and position of the urethral opening post straightening between both patient groups. The findings indicated that the adoption of MOIF ($P = 0.003$) and urethral stricture ($P = 0.010$) were significant risk factors for the occurrence of UD. Detailed information can be found in Table 1.

Table 1 Univariate analysis results

Variable	Total	Group with UD ($n=14$)	Group without UD ($n=145$)	t/χ2	*P*-value
Age of initial surgery (months)	24.13 ± 16.30	20.07 ± 18.14	24.52 ± 16.12	-0.98	0.331
Weight of initial surgery (kg)	12.24 ± 4.89	12.50 ± 8.20	12.21 ± 4.49	0.21	0.834
BMI (kg/m2)	16.53 ± 2.25	18.49 ± 2.96	16.34 ± 2.09	2.65	**0.019**
Hb (g/L)	123.27 ± 9.21	120.14 ± 11.49	123.57 ± 8.95	-1.33	0.184
HCT (%)	36.31 ± 2.47	35.39 ± 2.86	36.40 ± 2.42	-1.47	0.143
ALB (g/L)	45.80 ± 2.91	45.65 ± 3.77	45.81 ± 2.82	-0.20	0.840
PALB (g/L)	0.18 ± 0.04	0.18 ± 0.04	0.18 ± 0.04	-0.55	0.582
PCT (ng/ml)	0.05 ± 0.04	0.05 ± 0.03	0.05 ± 0.04	-0.14	0.885
Primary operation time (min)	110.97 ± 25.34	111.43 ± 27.83	110.93 ± 25.19	0.07	0.944
Indwelling catheter time (d)	21.73 ± 3.46	21.00 ± 2.32	21.80 ± 3.55	-0.83	0.410
Catheter diameter (F)	6.86 ± 0.99	6.57 ± 0.94	6.88 ± 1.00	-1.18	0.255
Degree of penile curvature (°)	30.97 ± 6.81	32.14 ± 6.42	30.86 ± 6.86	0.67	0.503
Urethral defect length (mm)	33.38 ± 9.88	30.29 ± 10.93	33.68 ± 9.76	-1.23	0.221
Glans width (mm)	10.72 ± 1.37	10.00 ± 1.04	10.79 ± 1.39	-2.62	**0.018**
Birth weight < 2500 g, n (%)					
Yes	56	3 (5.3)	53 (94.7)	0.70	0.402
No	103	11 (10.7)	92 (89.3)		
Anemia					
Yes	11	2 (18.2)	9 (81.8)		0.250
No	148	12 (8.1)	136 (91.9)		
Staged operation					
Yes	74	4 (5.4)	70 (94.6)	1.99	0.158
No	85	10 (11.8)	75 (88.2)		
Seniority					
Senior	136	13 (9.6)	123 (90.4)	0.18	0.676
Junior	23	1 (4.3)	22 (95.7)		
Penis dorsal plication					
Yes	133	12 (9.0)	121 (91)	0.00	1.000
No	26	2 (7.7)	24 (92.3)		
Urethral stricture					
Yes	12	4 (33.3)	8 (66.7)	6.70	**0.010**
No	147	10 (6.8)	137 (93.2)		
MOIF					
Yes	65	11 (16.9)	54 (83.1)	9.02	**0.003**
No	94	3 (3.2)	91 (96.8)		
Position of the urethral opening					
Middle segment of penis	8	1 (12.5)	7 (87.5)	2.52	0.466
Proximal segment of penis	34	1 (2.9)	33 (97.1)		
Scrotum	115	12 (10.4)	103 (89.6)		
Perineum	2	0 (0.0)	2 (100.0)		

Abbreviations: BMI, Body Mass Index; Hb, Hemoglobin; HCT, Hematocrit; ALB, Albumin; PALB, Prealbumin; PCT, Procalcitonin

Multivariate analysis

Multivariate logistic regression analysis involving variables with $P<0.2$ in univariate analysis revealed that glans width ($P=0.023$, odds ratio (OR) = 0.444, 95% confidence interval [95% CI]: 0.220–0.895), BMI ($P<0.001$, OR = 1.808, 95% CI: 1.318–2.481), choice of MOIF ($P=0.007$, OR = 10.670, 95% CI: 1.913–59.505), and urethral stricture ($P=0.015$, OR = 10.010, 95% CI: 1.554–64.470) were independent risk factors for postoperative UD (Table 2).

Discussion

Hypospadias is a prevalent malformation in pediatric urology. For hypospadias patients where the penile curvature exceeds 30 degrees after penile degloving, DUP is often employed as the surgical method [18]. For hypospadias with a penile curvature ranging from 20 to 30 degrees, DUP surgery is selectively utilized. The DUP methods reported in the literature mainly consist of TPIF (also termed Duckett) and Koyanagi. On the Basis of whether the operation can be staged, it can be divided into one-stage and two-stage operations. The

Table 2 Multivariate logistic regression analysis

Variable	Group	B	S.E.	Wald	*P*-value	OR	95%CI
BMI (kg/m2)		0.592	0.161	13.464	**< 0.001**	1.808	1.318–2.481
Hb (g/L)		0.071	0.099	0.513	0.474	1.074	0.884–1.305
HCT (%)		-0.422	0.384	1.207	0.272	0.656	0.309–1.392
Glans width (mm)		-0.812	0.358	5.158	**0.023**	0.444	0.220–0.895
Staged operation	One stage*						
	Two stage	1.298	0.772	2.827	0.093	0.273	0.060–1.240
Urethral stricture	No*						
	Yes	-2.304	0.95	5.875	**0.015**	10.010	1.554–64.470
MOIF	No*						
	Yes	-2.367	0.877	7.29	**0.007**	10.670	1.913–59.505

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio; BMI, Body Mass Index; Hb, Hemoglobin; HCT, Hematocrit

*Reference

main two-stage methods include Byars' flap operation, Bracka operation and partial reconstruction of proximal urethrostomy. The two-stage methods employed in this study were all the latter. The incidence of complications following DUP is high, and the main complications include urethral fistula, urethral stenosis and UD. DUP surgery presents a challenge for every pediatric urologist.

Our department has performed over 1000 surgeries related to hypospadias within the past three years. Onlay is the predominant surgical technique for non-DUP in our practice, whereas TPIF, MTPIF, and MOIF are the principal surgical methods for treating DUP. Traditional TPIF surgery continues to be conducted extensively, with 24 patients (48%) modified according to the DFOTO procedure. Kathy et al. [14]. reported that DFOTO can preserve an excellent blood supply to the skin flap, and a success rate of 96% can be attained after 1.8 surgical treatments. Chen et al. [15]. noted that MTPIF can guarantee wedge-shaped anastomosis between the proximal urethral orifice and the new urethra, elongate the width of the urethral plate at the anastomotic and external urethral orifices, and reduce the risk of urethral stricture. Huang et al. [17]. regarded MOIF as a safe and feasible approach for treating hypospadias with mild to moderate penile curvature after penile degloving. Each surgical method presents its own advantages and disadvantages. MTPIF is relatively complex because of extensive suturing techniques, which may pose challenges in mastery compared with MOIF, which is comparatively straightforward. If the blood supply of the skin flap material is satisfactory and the skin used for covering the penis body is sufficient, one-stage surgical treatment can be chosen. Conversely, if the material of the dorsal pedicle flap is inadequate, the length of the urethral defect cannot be achieved, the blood supply of the flap material is suboptimal, and there is a scarcity of skin material for covering the penis body, a first-stage surgery can be selected to enable the distal reconstruction of the urethra to recover, and a second-stage surgery can be conducted to repair the urethral stoma. In this way, surgery is relatively simple, and the overall incidence of complications is lower than that of one-stage surgery.

UD is a common complication after DUP surgery, with reported incidence rates ranging from 1.5 to 14% [14, 19–24]. In this study, the incidence rate of UD was 8.64%, which was slightly higher than that reported in previous studies, possibly because only DUP patients were included in this study. The occurrence of UD is attributed mainly to the distal urethral stricture, uneven width of the newly constructed urethra, and insufficient coverage and support of the newly constructed urethra [18]. In our cohort, there were 4 patients (28.57%) presented with UD in combination with distal urethral stricture, and UD was detected approximately 1 month after the discovery of thinning of the urinary line and difficulty urinating. Among them, 3 patients underwent surgical confirmation of distal urethral stricture while 1 patient exhibited significant resistance during dilation attempts at the distal segment. Our results revealed that the incidence of urethral stricture in the UD group was greater than that in the non-UD group, which indicated that external urethral stricture could lead to secondary UD. The remaining 10 patients presented no evident distal urethral stricture. Subjectively, the patients had no record of obvious difficulty urinating, a significantly thinner urine stream, or intermittent dribbling during urination. However, they did not undergo objective urethral imaging or urine flow rate testing because of family compliance issues and the difficulty in obtaining accurate data at such a young age. Six patients were capable of having a urinary catheter placed smoothly, followed by UD excision and urethral reconstruction. The remaining 4 patients are currently undergoing regular follow-up.

Liu et al. [21]. reported that the degree of hypospadias, the application of TPIF, the length of urethral shape, and the history of postoperative urethral dilation are relevant factors for UD. Zhou et al. [22]. emphasized that the closer position of the urethral opening, one-stage

repair, longer urethral defect, and lower number of surgeries were risk factors for complications following DUP surgery. Hu et al. [23]. demonstrated that the reconstruction of the urethral length and glans width were independent factors for the occurrence of postoperative complications in patients with proximal hypospadias. Yu et al. [25]. concluded that the incidence of postoperative UD in patients with DSD who underwent a staged operation was lower than that in patients who underwent a primary operation. Our results indicated that a narrower glans width, a higher BMI, the adoption of MOIF surgery, and urethral stricture were independent factors contributing to the occurrence of UD. A narrower width of the glans penis implies that there is greater tension in the glans penis when wrapping around the newly constructed urethra, enhancing the probability of urethral stricture at the distal glans and resulting in secondary UD. Our study revealed that the MOIF procedure had a greater incidence of UD compared to the other two surgical methods. The urethral plate at the MOIF oblique cut connection may be relatively narrow, with poor blood flow and local weakness after urethral capping. The incidence of UD in TPIF patients is only 1.96%. However, 12 patients (24%) of TPIF patients had glans dehiscence. Considering that the distal outlet resistance decreased after glans dehiscence, the incidence rate of secondary UD decreased. Michael et al. [26]. demonstrated that children with a high BMI had a significantly increased risk of developing wound complications after urological surgery, which was consistent with our conclusion. This may be related to the production of proinflammatory cytokines by adipose tissue, but the specific reasons require further study [27].

Tang et al. [28]. suggested that surgical intervention is not necessary for stable mild UD. However, significant UD that adversely affects quality of life or leads to reduced expected ejaculation should be considered for surgical treatment. During surgery, it is essential to account for distal obstruction and the presence of urethral fistulae. Wang et al. [29]. recommended that in patients with UD complicated by distal urethral stricture, longitudinal resection of the external urethral orifice may be performed concurrently to minimize postoperative residual UD. Ru et al. [30]. noted that severe penile curvature, urethral stricture, and dehiscence are critical factors demanding reoperation after hypospadias repair. For patients with UD who do not exhibit significant dysuria or symptoms indicative of urinary tract infection and have low family willingness for reoperation, we continue with conservative observation and follow-up treatment. Conservative management remains appropriate when there is minimal change in UD status. In situations where secondary UD emerges due to thinning urine streams and distal urethral strictures, active options encompassing urethral dilation or reoperation are advocated. Notably, because of the poor cooperation among most young patients, only one patient has undergone multiple urethral dilations. The patient received treatment once a week three times, and the UD vanished completely. After the disappearance of UD, the patient continued to undergo three dilation surgeries. There was no recurrence during the long-term follow-up period. Among all patients with UD treated through dilation methods, none subsequently required indwelling urinary catheters. This can be attributed to both the poor compliance of patients and their families as well as concerns regarding potential recurrence following urethral catheter removal after one month of catheterization. Surgical intervention is advocated for those presenting with large UDs accompanied by dysuria, recurrent urinary tract infections, or the presence of urethral stones. In this study, six patients achieved complete resolution following surgical intervention for UD, whereas two others demonstrated significant improvement. Only one patient experienced complications related to a postoperative urethral fistula and infection, which subsequently necessitated further surgical management. These findings suggest that surgical treatment for UD yields favorable outcomes.

Conclusion

A narrower glans width, a higher BMI, the application of MOIF, and urethral stricture are significant factors contributing to the development of UD in patients with hypospadias following DUP. UD can be effectively managed by surgical intervention, and existing distal stenosis may be addressed concurrently.

Abbreviations

UD	Urethral diverticulum
DUP	Disconnection of the urethral plate
BMI	Body Mass Index
Hb	Hemoglobin
HCT	Hematocrit
ALB	Albumin
PALB	Prealbumin
PCT	Procalcitonin
DSD	Disorders of sex development
TPIF	Transverse preputial island flap
DFOTO	Double-face onlay-tube-onlay transverse preputial island flap
MTPIF	Modified transverse preputial island flap
MOIF	Modified onlay island flap
OR	Odds ratio
CI	Confidence interval

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Author contributions

CJC and YFG designed the study. JZW and JD put the design into practice. GM, ZG, YJD, and RGL collected the data. JZW, JD, CJC and YFG analyzed the data and wrote the manuscript. CJC and YFG revised the paper. This manuscript was approved by all authors.

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Data availability
The datasets utilized in the present study can be obtained from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The Ethics Committee of the Children's Hospital of Nanjing Medical University granted approval for this study (approval number: 2022101986). Due to the retrospective nature of the study, the need for informed consent statement was waived.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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