


Effectiveness of penile ventral curvature correction and the trend of hypospadias repair: a prospective study of the national center in China

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ABSTRACT

Background Hypospadias repair is a complex surgical procedure that involves correcting penile ventral curvature (VC) and performing urethroplasty. This study aims to evaluate the effectiveness of different strategies for VC correction and analyse the trends in hypospadias repair at a national centre in China.

Methods Prospective data collection was conducted from 2019 to 2020 for patients undergoing hypospadias repair. The effectiveness of VC correction was assessed based on the degree of VC change with different strategies. Furthermore, the choice of surgical techniques for different types of hypospadias repair was analysed.

Results A total of 434 patients were included, with a median preoperative VC degree of 50° (35°, 70°). All patients achieved a straight penis postoperatively, with 15.2% undergoing degloving, 28.6% undergoing degloving and dorsal plication (DP), 13.1% undergoing degloving and urethral plate transection (UPT), and 43.1% undergoing degloving, UPT and DP. Degloving alone was effective in correcting VC in 57.6% of patients with VC less than 30°. In our analysis, DP after UPT resulted in a higher degree of correction (25°) compared with DP after degloving alone (20°) ($p < 0.001$). The study identified the current trends in hypospadias repair, with tubularised incised plate urethroplasty (TIP) being the most common technique used in distal hypospadias repair (70.6% of patients) and transverse preputial island flap urethroplasty (TPIFU) being preferred for proximal hypospadias repair (63.0%).

Conclusions Degloving alone is effective for correcting VC less than 30°. The majority of patients in our centre underwent UPT, and DP after UPT yielded better results compared with DP after degloving alone. Distal hypospadias repair commonly used TIP, while TPIFU was favoured for proximal hypospadias repair.

Trial registration number ChiCTR1900023055.

INTRODUCTION

Hypospadias is one of the most common congenital urethral abnormalities in 1 of 250–300 live births, and the incidence is rising.¹ Hypospadias repair encompasses various surgical procedures, including ventral curvature (VC) correction, urethral reconstruction, glans

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Limited information is available regarding the effectiveness of different strategies for ventral curvature (VC) correction and trends in hypospadias repair. This study aims to contribute by presenting our findings and experiences in managing hypospadias.

WHAT THIS STUDY ADDS

⇒ Our study provides a comprehensive analysis of the effectiveness of various strategies for correcting penile VC and highlights the trends in hypospadias repair specific to China, which differ from international results.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study aims to provide evidence-based insights for the future management of hypospadias, potentially influencing research, clinical practice and policy decisions in this field.

reconstruction and penile skin reconstruction.² Achieving adequate VC correction is a crucial step in ensuring successful hypospadias repair. The selection of strategies for VC correction depends on factors such as the underlying cause of the curvature, surgeon preferences and the desired treatment goals. In previous decades, surgical procedures followed a stepwise sequence, typically involving initial dissection of the skin and subcutaneous dartos (commonly referred to as degloving), followed by urethral plate mobilisation or transection, and finally addressing any issues related to corporal disproportion.² However, the latest modified stepwise approach, as suggested by Castagnetti and El-Ghoneimi, has eliminated urethral plate mobilisation due to an increased risk of curvature recurrence.³ Despite the importance of VC correction, limited reporting exists on the effectiveness of different strategies employed for this purpose. The strategies used for VC correction

also influence the subsequent choice of techniques for urethroplasty, particularly when urethral plate transection (UPT) is performed, as it necessitates substitution urethroplasty. Despite the numerous surgical techniques and their modifications available for hypospadias repair, no technique has been universally accepted as the gold standard due to a lack of conclusive evidence demonstrating the superiority of one technique over another.⁴

In this prospective study, we collected clinical data from patients and assessed the effectiveness of various strategies for VC correction. Our analysis aimed to reflect the underlying causes of VC in the Chinese population and examine the selection of surgical techniques for different types of hypospadias repair at the National Center for Children's Health in China. We hypothesised that there would be variations in the effectiveness of VC correction depending on the strategy employed, and that the specific type of hypospadias would influence the choice of surgical techniques. The ultimate goal of this study is to provide evidence-based insights that can inform the future management of hypospadias.

METHODS

We conducted a prospective study where we collected clinical data from patients who underwent hypospadias repair between 2019 and 2020. Patients with a history of previous urethral surgeries were excluded, resulting in a total of 434 patients included in the study. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki (revised in 2013).⁵

Surgical techniques

The surgical techniques for VC correction are briefly described. The degree of VC can be due to any possible combination of the skin and/or subcutaneous dartos tethering, a short urethral plate, and an intrinsic corpora disproportion. Therefore, we used a systematic stepwise approach. Begin with skin degloving and subcutaneous dartos, and the dissection should be extended proximally to the bulbar urethra. UPT was used if a curvature more than 30° persists after degloving. Dorsal plication (DP) was mainly used for VC less than 30° after each step in our centre, which was performed by lifting the neurovascular bundle, and suturing the tunica albuginea at both sides of the penis without incision the albuginea. In our centre, the surgical techniques for hypospadias repair without UPT included meatal advancement and glanuloplasty (MAGPI), Mathieu urethroplasty (Mathieu), onlay preputial flap urethroplasty (Onlay) and tubularised incised plate urethroplasty (TIP).⁶⁻⁹ The surgical techniques for hypospadias repair with UPT included transverse preputial island flap urethroplasty (TPIFU, the Duckett's technique), TPIFU combined with Duplay urethroplasty (TPIFU+Duplay), Koyanagi urethroplasty (Koyanagi), staged Byars flap urethroplasty (Staged Byars) and Staged TPIFU.¹⁰⁻¹⁴ In addition to whether UPT, surgical techniques selection was influenced by factors such as position of meatus after VC

correction, degree of VC, conditions of the urethral plate (width and elasticity), urethral defect length, surgeon's preference and experience.

Data collection and definition

Data collected included age, degree of preoperative VC, strategies for VC correction, degree of VC after degloving, degree of VC after UPT, position of meatus after VC correction, and surgery techniques to repair hypospadias. An orthopaedic protractor was used to access VC in the artificial erection. The angle created by the interception of two central axes of the proximal portion of the shaft and distal portion passing through the navicular fossa, the vertex is the point of greatest curvature. The degree of VC was evaluated through an artificial erection preoperatively, and after each step for VC correction. According to the American Academy of Pediatrics survey, mild curvature was defined as VC less than 30°, severe curvature was defined as VC more than 45°. ¹⁵ The goal of complete VC correction is to obtain a satisfactory straight penis (no degrees of VC). According to Barcat classification, the position of the meatus after VC correction was classified as distal, middle and proximal. ¹⁶ In our centre, measurement of parameters and procedures for hypospadias repair were standardised between six surgeons, who were high-volume surgeons (more than 50 hypospadias operations per year) with at least 15 years of experience in hypospadias surgery. ¹⁷

Statistical analysis

Statistical analysis was performed using R software (V.4.2.1, <http://www.r-project.org>). Normalcy was analysed using the Shapiro-Wilk test. Continuous variables that conform to a normal distribution are presented as $\bar{x} \pm SD$ and were analysed using the t-test. Median and quartile spacing as M (P25, P75) were used to describe the measurement data that did not obey normal distribution. Ordered data and measurement data that do not conform to the normal distribution use non-parametric tests (Mann-Whitney U test). Statistical data were described by number of cases and percentage (n, %), and χ^2 test or Fisher's exact test was used for comparison between groups. A $p < 0.05$ was considered statistically significant.

RESULTS

Clinical data of all patients

During the period from 2019 to 2020, a total of 434 patients were included in the study. **Table 1** provides a summary of the clinical characteristics of these patients. The median age at the time of surgery was 24 months, ranging from 10 to 142 months. The median degree of preoperative VC was 50° (35°, 70°), while the median degree of VC after degloving was 30° (15°, 40°). Following UPT, the median degree of VC further reduced to 20° (15°, 25°).

Among the included patients, 311 (71.7%) underwent DP for VC correction, and 244 (56.2%) patients

Table 1 Clinical characteristics of patients

	n=434
Age (month)	24 (19, 35)
Degree of preoperative VC (°)	50 (35, 70)
Degree of VC after degloving (°)	30 (15, 40)
Degree of VC after UPT (°)	20 (10, 25)
DP	311 (71.7%)
UPT	244 (56.2%)
Position of meatus after VC correction	
Distal	109 (25.1%)
Middle	96 (22.1%)
Proximal	229 (52.8%)
Surgery techniques	
MAGPI	12 (2.8%)
Mathieu	8 (1.8%)
Onlay	45 (10.4%)
TIP	125 (28.8%)
TPIFU	177 (40.8%)
TPIFU+Duply	18 (4.2%)
Koyanagi	10 (2.3%)
Staged Byars	10 (2.3%)
Staged TPIFU	29 (6.7%)

DP, dorsal plication; Koyanagi, Koyanagi urethroplasty; MAGPI, meatal advancement and glanuloplasty; Mathieu, Mathieu urethroplasty; Onlay, onlay preputial flap urethroplasty; Staged Byars, staged Byars flap urethroplasty; TIP, tubularised incised plate urethroplasty; TPIFU, transverse preputial island flap urethroplasty; UPT, urethral plate transection; VC, ventral curvature.

underwent UPT after degloving. The position of the meatus after VC correction was categorised as distal in 109 patients (25.1%), middle in 96 patients (22.1%) and proximal in 229 patients (52.8%).

Various surgical techniques were employed for hypospadias repair. These techniques included MAGPI (2.8%), Mathieu (1.8%), Onlay (10.4%), TIP (28.8%), TPIFU (40.8%), TPIFU combined with Duplay (4.2%), Koyanagi (2.3%), staged Byars (2.3%) and staged TPIFU (6.7%).

The effectiveness of VC correction by different strategies

The effectiveness of VC correction by different strategies was evaluated in the study. All patients achieved a straight penis after the repair. In the overall cohort, 66 patients (15.2%) achieved a satisfactory straight penis through complete degloving alone, with a median preoperative VC of 25° (15°, 35°). Among the patients, 124 (28.6%) had persistent VC less than 30° after degloving and subsequently underwent DP, with a median preoperative VC of 35° (30°, 50°). Additionally, 57 patients (13.1%) underwent VC correction after UPT without other procedures, with a median preoperative VC of 55° (45°, 80°). However, 187 patients (43.1%) still had residual curvature after UPT, with a median preoperative VC of 60°

Table 2 VC correction by different strategies

	Patients	Preoperative VC degree (°)
Degloving	66 (15.2%)	25 (15, 35)
Degloving+DP	124 (28.6%)	35 (30, 50)
Degloving+UPT	57 (13.1%)	55 (45, 80)
Degloving+UPT+DP	187 (43.1%)	60 (50, 83)

DP, dorsal plication; UPT, urethral plate transection; VC, ventral curvature.

(50°, 83°), and they required subsequent DP to achieve satisfactory straightening (table 2).

Degloving alone was effective for straightening the penis in 34 patients (57.6%) with mild preoperative VC (less than 30°), 25 patients (20.8%) with preoperative VC ranging from 30° to 45° and 7 patients (3.7%) with severe preoperative VC (more than 45°), as summarised in table 3. The degloving procedure resulted in a median correction of 20° (10°, 35°) of VC in all patients, which was calculated as the difference between the preoperative VC degree and the VC degree after degloving. Furthermore, DP led to a correction of 20° (15°, 30°) of VC, and there was a significant difference between DP after degloving alone and DP after UPT ($p < 0.001$). Regarding UPT, a median correction of 20° (10°, 30°) of VC was achieved (table 4).

Surgery techniques in different types of hypospadias

In distal hypospadias repair, the most commonly used surgical technique was TIP urethroplasty, which accounted for 70.6% of cases. Other techniques used in this category included MAGPI, Mathieu and Onlay.

For middle hypospadias repair, the primary surgical techniques employed were Onlay (25.3%), TIP (38.4%) and TPIFU (34.3%). Mathieu technique was also used in some cases.

In proximal hypospadias repair, the predominant technique was single-stage TPIFU, which accounted for 63.0% of cases. Additional surgical options for this type of hypospadias included Onlay, TIP, TPIFU+Duplay, Koyanagi, staged Byars and staged TPIFU. It is worth noting that staged techniques (including staged Byars and staged TPIFU) were exclusively performed for proximal hypospadias cases (table 5).

Table 3 The effect of degloving on different degrees of preoperative VC

Preoperative VC	Patients	No degrees of VC after degloving
Less than 30°	59	34 (57.6%)
30°–45°	120	25 (20.8%)
More than 45°	255	7 (3.7%)

VC, ventral curvature.

**Table 4** Correction of chordee by separate procedure

	Degree of correction (°)
Degloving	20 (10, 35)
DP	20 (15, 30)
DP after degloving	20 (15, 25)
DP after UPT	25 (15, 30)
P value	<0.001
UPT	20 (10, 30)

DP, dorsal plication; UPT, urethral plate transection.

DISCUSSION

Correcting VC is a critical initial step in hypospadias repair and has a direct impact on the subsequent choice of urethroplasty techniques. The strategies for VC correction and the selection of surgical techniques for hypospadias repair have evolved over the years. However, there is limited information available on the effectiveness of VC correction using different strategies, as well as objective analyses of surgical options for different types of hypospadias. As the National Center of Children's Health and a referral centre for complex hypospadias in China, we aim to present our findings and expertise in managing hypospadias. In this prospective study, we collected comprehensive clinical data from 434 patients who underwent hypospadias repair. The results of this study on the effectiveness of different VC correction strategies will provide valuable insights into the causes of VC in the Chinese population.

Management of VC

The surgical procedures for VC correction in hypospadias aim to address the underlying causes of the curvature. A stepwise approach is followed, starting with skin degloving and dartos dissection. If a curvature greater

Table 5 Surgery techniques for different types of hypospadias repair

Surgery techniques	Distal (n=109)	Middle (n=99)	Proximal (n=227)
MAGPI	12 (11.0%)	0	0
Mathieu	6 (5.5%)	2 (2.0%)	0
Onlay	14 (12.9%)	25 (25.3%)	6 (2.6%)
TIP	77 (70.6%)	38 (38.4%)	11 (4.9%)
TPIFU	0	34 (34.3%)	143 (63.0%)
TPIFU+Duplay	0	0	18 (7.9%)
Koyanagi	0	0	10 (4.4%)
Staged Byars	0	0	10 (4.4%)
Staged TPIFU	0	0	29 (12.8%)

Koyanagi, Koyanagi urethroplasty; MAGPI, meatal advancement and glanuloplasty; Mathieu, Mathieu urethroplasty; Onlay, onlay preputial flap urethroplasty; Staged Byars, staged Byars flap urethroplasty; TIP, tubularised incised plate urethroplasty; TPIFU, transverse preputial island flap urethroplasty.

than 30° persists, UPT without mobilising the urethral plate is recommended. If the curvature persists by more than 30° after UPT, ventral penile lengthening (VPL) is performed.³ However, in our centre, VPL is not commonly used due to concerns regarding potential adverse effects such as erectile dysfunction, haemorrhage and scar healing issues related to the albuginea incision. Long-term studies evaluating the outcomes of VPL are lacking.^{3,18} When there is significant bleeding during the incision or the need for closure with a flap or graft, it may affect the surgical procedure and postoperative urethral healing. A study conducted in 2017 reported that UPT combined with DP achieved satisfactory straightening in all cases of severe hypospadias, without the requirement for VPL.¹⁹

In our study, we observed a higher proportion of severe preoperative VC and proximal hypospadias compared with previous reports.^{20,21} Similar to our result, Snodgrass and Prieto have found that 19% of patients achieved a straight penis after degloving alone, 31% had VC less than 30° after degloving and underwent DP, and 50% had VC more than 30°.²² These results suggest that persistent VC after degloving may indicate a shortened urethral plate and/or corporal disproportion.

Skin degloving is an important step in hypospadias repair and can improve VC.^{23,24} However, the effectiveness of degloving alone for achieving penile straightening varies across studies. One study using lateral photographs to assess curvature reported complete VC correction by degloving in 100% of cases with VC less than 45° and 74% of cases with VC greater than 90°.²⁵ On the other hand, Weber *et al* found that degloving alone was sufficient for VC correction in 77% of mild cases (less than 30°), 30% of cases with 30°–45° and only 2% of cases with VC greater than 45°.²⁶ Therefore, the efficacy of degloving appears to be inversely related to the severity of preoperative VC, which aligns with the trends observed in our study. We found that more than half of patients with mild preoperative VC achieved a straight penis after degloving, but it was not as effective for correcting severe VC.

In our analysis, we found that the correction achieved by DP after UPT was higher than DP after degloving alone. This suggests that DP may be more effective and durable after UPT, as the continuous ventral tethering caused by the elasticity of the urethra and urethral plate is relieved.¹⁹ This finding is consistent with a study that reported a lower rate of recurrent VC after DP with UPT compared with DP without UPT (0% vs 36.5% of patients, $p=0.002$).²⁷ DP is generally recommended for VC less than 30°, and the effectiveness observed in this study exceeds that standard. However, the potential risk of recurrent VC after DP necessitates long-term follow-up in future research.

It was thought in the 1980s and 1990s that UPT might not substantially improve curvature.²⁸ However, a 2017 study reported that UPT alone achieved penile straightening in 35% of cases.²⁹ In proximal hypospadias, it has been reported that the penis can be straightened without

UPT in 13%–74% of cases.^{25–29} In our series, a straight penis was achieved without UPT in 43.8% of cases. These observations suggest that a shortened urethral plate could contribute to VC, which may be the primary aetiology in some cases. Acimi *et al*²⁵ reported VC correction ranging from 0° to 20° obtained by mobilising the urethral plate. In our study, the VC correction achieved by UPT was 20° (10°, 30°). Overall, UPT was in demand and effective in the stepwise approach for managing VC.

Surgery techniques for hypospadias repair

The field of hypospadias surgery originated in the late 19th century with the contributions of Thiersch and Duplay.^{30–31} Since then, numerous surgical techniques have been developed. Our study also demonstrates the variety of techniques used for hypospadias repair. However, it is important to note that comparable functional outcomes can be achieved with different techniques, and a large number of surgical options can increase the risk of complications.³²

The TIP technique has become the preferred treatment for distal and middle hypospadias due to its reliability and high success rates as demonstrated in large series.^{33–37} For distal hypospadias, alternative techniques such as MAGPI and Mathieu procedures are also available.^{38–39} The Onlay technique involves using a preputial island flap when the urethral plate is unhealthy or too narrow.² Our study reflects similar trends, with TIP being the most commonly used technique for distal hypospadias repair, while Onlay, TIP and TPIFU are the main surgical techniques for middle hypospadias repair. According to a worldwide survey, staged repair was the preferred option for proximal hypospadias repair, chosen by up to 76.6% of respondents.¹⁷ However, in our centre, a staged approach was chosen for only 17.2% of patients. While a staged approach may have a lower complication rate, it requires two surgical procedures, whereas a single-stage approach can avoid the need for a second procedure in approximately two-thirds of patients.⁴⁰ Therefore, most of our surgeons prefer the single-stage TPIFU technique for proximal hypospadias repair when the preputial flap is sufficient to repair the urethral defect. We believe that reducing the need for additional surgical procedures may be particularly beneficial for the patients.

Limitations

This study has several limitations that should be acknowledged. First, there may be interobserver variability in the evaluation of VC due to the involvement of multiple surgeons in assessing VC during artificial erection. This variability could introduce bias into the results. Additionally, there may be variations in VC measurement methods among previous studies, making it challenging to directly compare the findings. Another limitation is the uniform distribution of patients among the different strategies for VC correction. This may affect the outcomes and limit the ability to draw definitive conclusions about the effectiveness of each strategy. Furthermore, this study only presents

data on the surgical procedures for hypospadias repair and lacks long-term follow-up data. These limitations should be taken into consideration when interpreting the results of this study and further research with larger sample sizes and comprehensive follow-up is needed to provide more robust evidence in the field of hypospadias surgery.

CONCLUSIONS

This prospective study provided insights into the effectiveness of different strategies for VC correction in hypospadias repair. The stepwise approach demonstrated appropriate and diverse outcomes, with degloving alone being effective for mild VC but showing limited improvement for severe cases. UPT played a significant role in improving the effectiveness of DP, resulting in higher correction rates. The preference for single-stage TPIFU for proximal hypospadias repair reflects current trends among surgeons in our referral centre. However, further research is needed to assess the role of VPL in hypospadias repair. It is recommended to conduct national multicentre, prospective randomised controlled studies to enhance the evaluation of VPL and its long-term outcomes in the management of hypospadias.

Contributors ZY and JL participated in the study design, performed the literature review and contributed to data analysis and drafted the manuscript. PL, YF, XW, SF, ZL, ZS, YX, ZW and HL participated in data acquisition. WZ, HS and NS contributed to review the results, discussion, and conclusion, and made critical revision and edition of the contents. All authors read and approved the final manuscript. WZ as guarantor.

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Competing interests None.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the ethics committee of Beijing Children's Hospital, Capital Medical University, National Center for Children's Health (IEC-C-008-A08-V.05.1). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

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