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The 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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4 **Title: The effectiveness of penile ventral curvature correction and the trend of**
5 **hypospadias repair: A prospective study of the national center in China**
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38 **Abstract**

39
40 **Background:** Hypospadias repair is a challenging surgery mainly including penile
41 ventral curvature (VC) correction and urethroplasty. We aim to evaluate the
42 effectiveness of VC correction by different strategies and trends of hypospadias repair
43 at the national center in China.
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47 **Methods:** We prospectively collected the data of hypospadias from 2019 to 2020. The
48 effectiveness of VC correction was evaluated according to the change of VC degrees in
49 different strategies. We also analyzed the choice of surgical techniques for different
50 types of hypospadias repair.
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54 **Results:** A total of 434 patients were included, with the median degree of preoperative
55 VC being 50° (35°, 70°). All patients achieved straight penis, 15.2% of patients with
56 degloving, 28.6% underwent degloving and dorsal plication (DP), 13.1% underwent
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29 degloving and urethral plate transection (UPT), and 43.1% underwent degloving, UPT
30 and DP. Degloving was sufficient for VC correction in 57.6% of patients with VC less
31 than 30°. In our analysis, the correction obtained by DP after UPT was 25°, higher than
32 20° of DP after degloving alone ($P<0.001$). This study identified current trends in
33 hypospadias repair. Tubularized incised plate urethroplasty (TIP) was the most common
34 technique used in distal hypospadias repair with 70.6% of patients, and surgeons
35 preferred the transverse preputial island flap urethroplasty (TPIFU) (63.0%) for
36 proximal hypospadias repair.

37 **Conclusions:** Degloving was effective in VC less than 30°. More than half of the
38 patients underwent UPT in our center, and the correction obtained by DP after UPT was
39 higher than DP after degloving. Additionally, TIP is preferred in distal hypospadias, and
40 TPIFU is preferred in proximal hypospadias repair.

41 **Keywords:** hypospadias, VC correction, surgical techniques

43 **Key messages**

44 The effectiveness of VC correction by different strategies and trends of
45 hypospadias repair have limitedly been reported. we prospectively collected the data to
46 present our results and experience in managing hypospadias. The results of this study
47 on the effectiveness of different strategies for VC correction can reflect the causes of
48 VC in the Chinese population. We aim to provide evidence-based for the future
49 management of hypospadias.

52 **INTRODUCTION**

53 Hypospadias is one of the most common congenital urethral abnormalities in 1 of
54 250-300 live births, and the incidence is rising[1]. Hypospadias repair includes ventral
55 curvature (VC) correction, urethral, glans, and penile skin reconstruction[2]. Adequate
56 VC correction is an essential step of successful hypospadias repair. Different strategies
57 are used to treat VC, depending on the underlying cause, surgeon preferences, and the

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4 58 goals of the repair. Procedures from the past decades are performed following a
5
6 59 stepwise order during surgery: begin with the dissection of skin and subcutaneous
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8 60 dartos (broadly labeled as degloving), urethral plate mobilization or transection, and
9
10 61 finally to the management of corpora disproportion[3]. The urethral plate mobilization
11
12 62 has been removed in the latest modified stepwise approach as suggested by Castagnetti
13
14 63 et al. because it increases the risk of curvature recurrence[4]. However, the effectiveness
15
16 64 of VC correction by different strategies has limitedly been reported. Strategies used for
17
18 65 VC correction affect the technique used for subsequent urethroplasty as urethral plate
19
20 66 transection (UPT) involves the need for a substitution urethroplasty. Despite many
21
22 67 different surgical techniques and their modifications for hypospadias repair, no
23
24 68 technique has been adopted as the golden standard because no conclusive evidences
25
26 69 have shown the superiority of one technique over another[5].
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29 71 In the present study, we prospectively collected the clinical data of patients, and
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31 72 evaluated the effectiveness of different strategies for VC correction, which can reflect
32
33 73 the causes of VC in the Chinese population. In addition, we analyzed the choice of
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35 74 surgical techniques for different types of hypospadias repair at National Center for
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37 75 Children's Health in China. We hypothesize that there are differences in the
38
39 76 effectiveness of VC correction by different strategies, and the type of hypospadias will
40
41 77 influence the choice of techniques. The aim is to provide evidence-based for the future
42
43 78 management of hypospadias.
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80 **METHODS**

81 We prospectively collected the clinical data of patients who underwent repair of
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83 82 hypospadias from 2019 to 2020. We excluded patients with history of urethral surgeries,
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85 83 and 434 patients were included in this study. The study was conducted in accordance
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87 84 with the Declaration of Helsinki (as revised in 2013) [6]. This prospective study was
88
89 85 approved by the ethics committee of Beijing Children's Hospital, Capital Medical
90
91 86 University, National Center for Children's Health (IEC-C-008-A08-V.05.1) and
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4 87 informed consent was obtained from parents of the children. The clinical trial was
5 88 registered at ClinicalTrials.gov (09/05/2019, ChiCTR1900023055).
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90 **Surgical techniques**

91 The surgical techniques for VC correction are briefly described. The degree of VC
92 can be due to any possible combination of the skin and/or subcutaneous dartos tethering,
93 a short urethral plate, and an intrinsic corpora disproportion. Therefore, we used a
94 systematic stepwise approach. Begin with skin degloving and subcutaneous dartos, and
95 the dissection should be extended proximally to the bulbar urethra. UPT was used if a
96 curvature more than 30° persists after degloving. Dorsal plication (DP) was mainly used
97 for VC less than 30° after each step in our center, which was performed by lifting the
98 neurovascular bundle, and suturing the tunica albuginea at both sides of the penis
99 without incision the albuginea. In our center, the surgical techniques for hypospadias
100 repair without UPT included Meatal Advancement and Glanuloplasty (MAGPI),
101 Methieu urethroplasty (Methieu), Onlay preputial flap urethroplasty (Onlay), and
102 Tubularized Incised Plate urethroplasty (TIP)[7-10]. The surgical techniques for
103 hypospadias repair with UPT included transverse preputial island flap urethroplasty
104 (TPIFU, the Duckett's technique), TPIFU combined with Duplay urethroplasty (TPIFU
105 + Duplay), Koyanagi urethroplasty (Koyanagi), staged Byars flap urethroplasty (Staged
106 Byars) and staged transverse preputial island flap urethroplasty (Staged TPIFU)[11-15].
107 In addition to whether UPT, surgical techniques selection was influenced by factors
108 such as position of meatus after VC correction, degree of VC, conditions of the urethral
109 plate (width and elasticity), urethral defect length, surgeon's preference, and experience.

110

111 **Data collection and definition**

112 Data collected included age, degree of preoperative VC, strategies for VC
113 correction, degree of VC after degloving, degree of VC after UPT, position of meatus
114 after VC correction, and surgery techniques to repair hypospadias. An orthopedic
115 protractor was used to access VC in the artificial erection. The angle created by the

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4 116 interception of two central axes of the proximal portion of the shaft and distal portion
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6 117 passing through the navicular fossa, the vertex is the point of greatest curvature. The
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8 118 degree of VC was evaluated through an artificial erection preoperatively, and after each
9
10 119 step for VC correction. According to the American Academy of Pediatrics survey, mild
11
12 120 curvature was defined as VC less than 30°, severe curvature was defined as VC more
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14 121 than 45°[16]. The goal of complete VC correction is to obtain a satisfactory straight
15
16 122 penis (no degree of VC). According to Barcat classification, the position of the meatus
17
18 123 after VC correction was classified as distal, middle, and proximal[17]. In our center,
19
20 124 measurement of parameters, and procedures for hypospadias repair were standardized
21
22 125 between six surgeons, who were high-volume surgeons (more than 50 hypospadias
23
24 126 operations per year) with at least 15 years of experience in hypospadias surgery[18].

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28 128 **Statistical Analysis**

29 129 Statistical analysis was performed using R software (version 4.2.1, [http://www.r-](http://www.r-project.org)
30
31 130 [project.org](http://www.r-project.org)). Normalcy was analyzed using the Shapiro-Wilk test. Continuous variables
32
33 131 that conform to a normal distribution are presented as $\bar{x} \pm SD$ and were analyzed using
34
35 132 the t-test. Median and quartile spacing as $M (P25, P75)$ were used to describe the
36
37 133 measurement data that did not obey normal distribution. Ordered data and measurement
38
39 134 data that do not conform to the normal distribution use non-parametric tests (*Mann-*
40
41 135 *Whitney U test*). Statistical data were described by number of cases and percentage
42
43 136 ($n, \%$), and chi-square test or Fisher was used for comparison between groups. $P < 0.05$
44
45 137 was considered statistically significant.

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49 139 **RESULTS**

50 140 **Clinical data of all patients**

51
52 141 A total of 434 patients were included during the period from 2019 to 2020. The
53
54 142 clinical characteristics of the patients are summarized in Table 1. The median age at
55
56 143 surgery was 24 months, ranging from 10 to 142 months. The median degree of
57
58 144 preoperative VC was 50° (35°, 70°), the median degree of VC after degloving was 30°

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4 145 (15°, 40°), and the median degree of VC after UPT was 20° (15°, 25°). 311 patients
5 146 (311/434, 71.7%) used DP, and 244 (244/434, 56.2%) patients underwent UPT after
6 147 degloving. Patients were divided into categories based on the position of the meatus
7 148 after VC correction as distal (109/434, 25.1%), middle (96/434, 22.1%), and proximal
8 149 (229/434, 52.8%). The surgical techniques for hypospadias repair included MAGPI
9 150 (2.8%), Methieu (1.8%), Onlay (10.4%), TIP (28.8%), TPIFU (40.8%), TPIFU +
10 151 Duplay (4.2%), Koyanagi (2.3%), Staged Byars (2.3%), and Staged TPIFU (6.7%).
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19 153 **The effectiveness of VC correction by different strategies**

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21 154 In the overall cohort, a satisfactory straight penis was achieved after complete
22 155 degloving alone in 66 patients (66/434, 15.2%), with the median preoperative VC of
23 156 25° (15°, 35°). There were 124 patients (124/434, 28.6%) had persistent VC less than
24 157 30° after degloving and then underwent DP, with the median preoperative VC of 35°
25 158 (30°, 50°). 57 patients (57/434, 13.1%) corrected VC after UPT without other
26 159 procedures, with the median preoperative VC of 55° (45°, 80°). However, 187 patients
27 160 (187/434, 43.1%) had residual curvature after UPT with the median preoperative VC
28 161 of 60° (50°, 83°), they underwent subsequent DP to achieve the satisfactory
29 162 straightening (Table 2).
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41 164 Degloving alone was sufficient for straightening the penis in 34 patients (34/59,
42 165 57.6%) with mild preoperative VC (less than 30°), 25 patients (25/120, 20.8%) with 30°
43 166 to 45° preoperative VC, and seven patients (7/255, 3.7%) with severe preoperative VC
44 167 (more than 45°). A median of 20° (10°, 35°) of VC was corrected by degloving used in
45 168 all patients, which was calculated by the difference between the degree of preoperative
46 169 VC and degree of VC after degloving. In addition, the correction obtained by DP was
47 170 20° (15°, 30°), and there was the difference between DP after degloving alone and DP
48 171 after UPT (20° (15°, 25°) vs 25° (15°, 30°), $P < 0.001$). As for UPT, the median of 20°
49 172 (10°, 30°) of VC was corrected.
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174 **Surgery techniques in different types of hypospadias**

175 In distal hypospadias, the most common technique was TIP (77/109, 70.6%).
176 Other choices included MAGPI (12/109, 11.0%), Methieu (6/109, 5.5%), and Onlay
177 (14/109, 12.9%). In middle hypospadias, the main surgery techniques were Onlay
178 (25/99, 25.3%), TIP (38/99, 38.4%), and TPIFU (34/99, 34.3%), Other choice included
179 Methieu (2/99, 2.0%). In proximal hypospadias, the most common technique was
180 single-stage TPIFU (143/227, 63.0%), other choices included Onlay (6/227, 2.6%), TIP
181 (11/227, 4.9%), TPIFU + Duplay (18/227, 7.9%), Koyanagi (10/227, 4.4%), staged
182 Byars (10/227, 4.4%), and staged TPIFU (29/227, 12.8%). Staged techniques
183 (including staged Byars and staged TPIFU) were only performed for the proximal
184 hypospadias (Table 3). Figure 1 shows the surgery techniques as percentages for
185 different types of hypospadias repair.

186

187 **DISCUSSION**

188 Hypospadias repair is a challenging field of urogenital reconstructive surgery,
189 including VC correction, urethroplasty, glans reconstruction and penile skin
190 reconstruction. The VC correction is the first and important step in the repair.
191 Management of the VC can affect the technique used for subsequent urethroplasty. Over
192 the past decades, opinions about strategies for VC correction and choice of surgery
193 techniques for hypospadias have changed. However, the effectiveness of correcting VC
194 by different strategies and objective analysis of different types of hypospadias surgical
195 options have limitedly been reported. As the National Center of Children's Health and
196 the referral center for complex hypospadias in China, we aim to present our results and
197 experience in managing hypospadias. In this study, we prospectively collected the
198 clinical data of 434 patients who underwent hypospadias repair. The results of this study
199 on the effectiveness of different strategies for VC correction can reflect the causes of
200 VC in the Chinese population.

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202 **Management of VC**

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4 203 VC is multifactorial, and the same degree can be due to any possible combination of
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6 204 skin and/or subcutaneous dartos tethering, a short urethral plate, and an intrinsic corpora
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8 205 disproportion. Surgical procedures aim to address any possible causes of VC, then
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10 206 stepwise approach was used: begins with skin degloving and dartos dissection, if a
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12 207 curvature over 30° persists, UPT without mobilizing the urethral plate is recommended,
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14 208 more than 30° VC persistence after UPT is treated by VPL. DP is considered for mild
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16 209 curvatures (VC less than 30°) at any stage [4]. In our center, VPL is not commonly used,
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18 210 the concerns is the occurrence of adverse effects after VPL, such as erectile
19
20 211 dysfunction, hemorrhage, and scar healing of the albuginea incision, lack of long-term
21
22 212 studies[19]. A 2017 study described all severe hypospadias repairs achieved
23
24 213 straightening by UPT combined with DP, without the need for VPL in any patient[20].
25
26 214 Our center preferred to use TPIFU for hypospadias repair after UPT, hemorrhage
27
28 215 caused by VPL will affect the surgery and postoperative urethral healing.

29 216 In this study, the median degree of preoperative VC was 50° (35°, 70°). According
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31 217 to the position of the meatus after VC correction, proximal hypospadias was the most
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33 218 common type (229/434, 52.8%), higher than previous reports[21, 22]. As the national
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35 219 referral center for complex hypospadias in China, more patients with severe
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37 220 hypospadias were transferred to our center. Snodgrass et al. reported that 19% of
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39 221 patients get straight penis after degloving, 31% of patients had less than 30° VC after
40
41 222 degloving and corrected by DP, and 50% of patients had more than 30° VC [23]. In the
42
43 223 present study, a satisfactory straight penis was achieved after degloving in 15.2% of
44
45 224 patients, 28.6% of patients had persistent mild curvature after degloving and then
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47 225 underwent DP, and 56.2% of patients underwent UPT after degloving. The results show
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49 226 that persistent VC after degloving may reflect a shortened urethral plate and/or
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51 227 corporeal disproportion.

52 228 Skin degloving can improve VC and remain the first step of any hypospadias
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54 229 repair[24, 25]. Nevertheless, the effectiveness of skin degloving alone for penile
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56 230 straightening is variable in different studies. One study using lateral photographs for
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58 231 the assessment of curvature observed that complete VC correction by degloving in 100%

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4 232 of VC less than 45° and 74% of VC more than 90°. The authors concluded that
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6 233 straightening could be achieved in most of these patients by skin degloving alone[26].
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8 234 However, Weber et al. reported that degloving alone was sufficient for VC correction
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10 235 in 77% mild cases (less than 30°), 30% cases with 30° to 45°, and 2% cases with more
11
12 236 than 45°[27]. Therefore, the efficacy of degloving seems to be inversely related to the
13
14 237 severity of preoperative VC. The same trends were observed in the present study. In the
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16 238 results of our study, degloving was sufficient for straightening in 57.6% of patients with
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18 239 preoperative VC less than 30°, 20.8% of those with 30° to 45°, and 3.7% of those with
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20 240 more than 45°. Our study shows that more than half of patients with mild preoperative
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22 241 VC got straight penis after degloving. In more severe cases (more than 45 °), degloving
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24 242 was not effective enough to correct the VC.

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26 243 In our analysis, there was a difference between the correction obtained by DP after
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28 244 degloving alone and DP after UPT (20° (15°, 25°) vs 25° (15°, 30°), P<0.001). Although
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30 245 DP can always achieve penile straightening in mild cases while preserving the urethral
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32 246 plate, it may be more effective and durable after UPT because the continuous ventral
33
34 247 tethering due to the elasticity of the urethra and the urethral plate was relieved[20].
35
36 248 Consistently, one study reported recurrent VC at the 2-year follow-up point after DP
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38 249 with UPT versus DP without UPT in 0% versus 36.5% of patients (P = 0.002)[28]. At
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40 250 present, there is limited study to clarify the effectiveness of DP for VC correction. DP
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42 251 used for VC less than 30° is a consensus recommendation, and this study is higher than
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44 252 this standard. Because of the potential risk of recurrent VC after DP, long-term follow-
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46 253 up results needs in further research.

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48 254 It was thought in the 1980s and 1990s that UPT might not substantially improve
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50 255 curvature[29]. In a 2017 study, UPT alone achieved penile straightening in 35% of
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52 256 cases[30]. In proximal hypospadias, the penis can reportedly be straightened without
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54 257 UPT in between 13% and 74% of cases[26, 30]. In our series, a straight penis was
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56 258 obtained without UPT in 43.8% (190/434) of cases. In the 56.2% (224/434) of patients
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58 259 who underwent UPT, the penis straightened in 13.1% (57/434), 43.1% (187/434) had
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60 260 residual curvature after UPT and was followed by DP. These observations indicated that

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4 261 shortened urethral plate could contribute to VC, which may be the major etiology in
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6 262 some cases. Acimi et al. reported that ranging from 0° to 20° VC correction obtained
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8 263 by the mobilization of urethral plate. In this study, the VC correction obtained by UPT
9
10 264 was 20° (10°, 30°). Overall, in the stepwise approach for VC management, UPT was in
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12 265 demand and effective.

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14 266

15 267 **Surgery techniques for hypospadias repair**

16
17 268 The origin of hypospadias surgery was established by Thiersch and Duplay during the
18
19 269 second part of the 19th century[2]. Since then, hundreds of techniques have evolved.
20
21 270 The variety of the different types of hypospadias repair techniques can also be seen in
22
23 271 our study. However, comparable functional results can be achieved with different
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25 272 techniques, and a large number of surgical techniques can also lead to a high risk of
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27 273 complications[31].

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31 275 The TIP has become the treatment of choice in distal and middle hypospadias with
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33 276 sufficient urethral plate and good glandular and adequate ventral tissue because of its
34
35 277 reliability and high success rate shown in large series[32-36]. For distal hypospadias, a
36
37 278 range of other techniques is available (e.g., MAGPI, Mathieu)[37, 38]. The Onlay
38
39 279 technique uses a preputial island flap if a plate is unhealthy or too narrow[3]. The trends
40
41 280 were seen in our series, TIP was the most common technique used in distal hypospadias
42
43 281 repair with 70.6% of patients, and only used in 4.9% of proximal hypospadias repair.
44
45 282 In middle hypospadias, the main surgery techniques were Onlay (25.3%), TIP (38.4%),
46
47 283 and TPIFU (34.3%) in this study. If the continuity of the urethral plate cannot be
48
49 284 preserved, single-stage or staged repairs are used. For the former, TPIFU, alternatively
50
51 285 the Koyanagi technique are used in our center [11,13]. In our center, staged surgery was
52
53 286 only performed for the proximal hypospadias included staged TPIFU and staged Byars.
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55 287 In a worldwide survey of the preference of pediatric urologists, pediatric surgeons,
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57 288 urologists, and plastic surgeons, the staged repair was the preferred option for proximal
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59 289 hypospadias repair chosen by up to 76.6% of responders[18]. Nevertheless, we chose
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4 290 staged repair for proximal hypospadias repair in 17.2% of patients. A staged approach
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6 291 seems to have a lower complication rate but commits patients to two surgical
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8 292 procedures, while a second procedure might be avoided in about two-thirds of patients
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10 293 who undergo a single-stage approach[39]. However, most of our surgeons preferred the
11
12 294 single-stage TPIFU (143/227, 63.0%) for proximal hypospadias repair when the
13
14 295 preputial flap is sufficient to repair the urethra defect, we believe the lower need for
15
16 296 additional surgical procedures may be particularly for patient.

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19 298 **Limitations**

21 299 The main limitation of this study is the interobserver variability with multiple
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23 300 surgeons for VC evaluation in the artificial erection. Additionally, VC measurement
24
25 301 methods are not completely same in previous studies, resulting in a bias when
26
27 302 comparing results between studies. Furthermore, the outcome may be affected because
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29 303 patients were uniformly distributed in the different strategies for VC correction.
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31 304 Additionally, we have only presented the data regarding the surgical of hypospadias
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33 305 repair and lack of follow-up data. Long-term national multi-center prospective studies
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35 306 include close monitoring, and long-term follow-up are necessary.

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37 307

38 308 **CONCLUSIONS**

40 309 The prospective study demonstrated that the effectiveness of different strategies
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42 310 for VC correction by stepwise approach are appropriate and diverse, which can reflect
43
44 311 the causes of VC in the Chinese population. Degloving alone was sufficient for VC
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46 312 correction in 57.6% of patients with mild preoperative VC. More than half of the
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48 313 patients underwent UPT. And the correction obtained by 25° of DP after UPT, higher
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50 314 than 20° of DP after degloving alone (P<0.001). In addition, we identified current trends
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52 315 in hypospadias repair at our center. The TIP (70.6%) is the preferred technique in distal
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54 316 hypospadias. Moreover, surgeons preferred the single-stage TPIFU (63.0%) for
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56 317 proximal hypospadias repair. However, future research must focus on national multi-
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58 318 center, prospective, controlled trials.

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12
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14
15 325 SQF, ZHL, KZS, YJX, HZW, and HL participated in data acquisition. WPZ, HCS and
16
17 326 NS contributed to review the results, discussion, and conclusion, and made critical
18
19 327 revision and edition of the contents. All authors read and approved the final manuscript.
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25 328 **Patient consent**

26
27 329 This study was conducted in accordance with the principles of the Declaration of
28
29 330 Helsinki, and this study was approved by the ethics committee of Beijing Children's
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31 331 Hospital, Capital Medical University, National Center for Children's Health (IEC-C-
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33 332 008-A08-V.05.1) and informed consent was obtained from parents of children (patients
34
35 333 were all younger than 16 years old). The clinical trial is registered at ClinicalTrials.gov
36
37 334 (09/05/2019, ChiCTR1900023055).

38
39 335 **Availability of data**

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41 336 The datasets used and analysed during the current study are available from the
42
43 337 corresponding author on reasonable request.
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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%)

VC: Ventral Curvature; DP: Dorsal Plication; UPT: Urethral Plate Transection; MAGPI: Meatal Advancement and Glanuloplasty; Methieu: Methieu urethroplasty; Onlay: Onlay preputial flap urethroplasty; TIP: Tubularized Incised Plate urethroplasty; TPIFU: transverse preputial island flap urethroplasty; TPIFU + Duplay: TPIFU combined with Duplay urethroplasty; Koyanagi: Koyanagi urethroplasty; Staged Byars: staged Byars flap urethroplasty; Staged TPIFU: staged transverse preputial island flap urethroplasty

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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)

VC: Ventral Curvature; DP: Dorsal Plication; UPT: Urethral Plate Transection;

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Table 3. Surgery techniques for different types of hypospadias repair

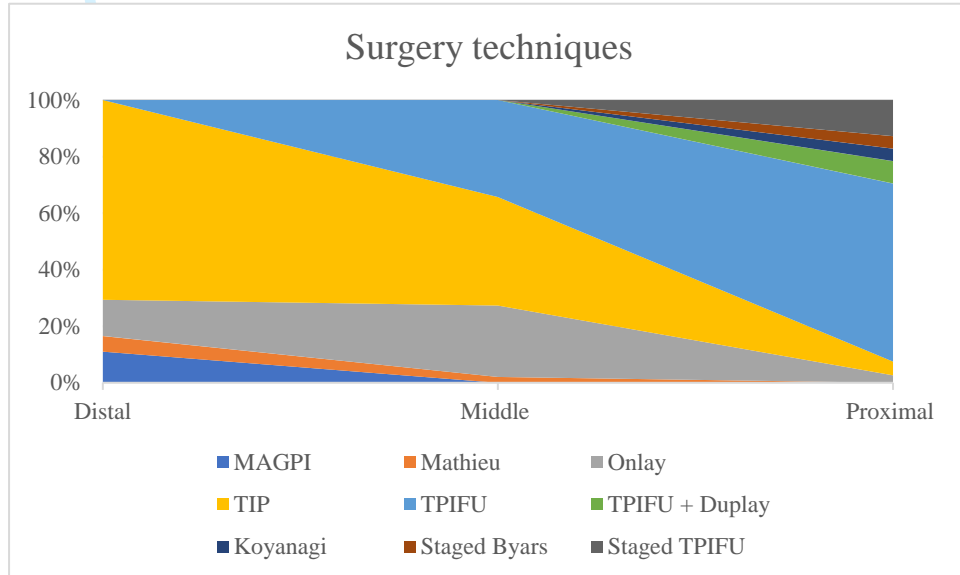
Surgery techniques	Distal (n=109)	Middle (n=99)	Proximal (n=227)
MAGPI	12 (11.0%)	0	0
Mathieu	6 (5.5%)	2 (2.0%)	0
Onlay	14 (12.9%)	25(25.3%)	6 (2.6%)
TIP	77 (70.6%)	38 (38.4%)	11 (4.9%)
TPIFU	0	34 (34.3%)	143 (63.0%)
TPIFU + Duplay	0	0	18 (7.9%)
Koyanagi	0	0	10 (4.4%)
Staged Byars	0	0	10 (4.4%)
Staged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

Meatal Advancement and Glanuloplasty; Methieu: Methieu urethroplasty;

Onlay: Onlay preputial flap urethroplasty; TIP: Tubularized Incised Plate

urethroplasty; TPIFU: transverse preputial island flap urethroplasty; TPIFU + Duplay: TPIFU combined with Duplay urethroplasty; Koyanagi: Koyanagi urethroplasty; Staged Byars: staged Byars flap urethroplasty; Staged TPIFU: staged transverse preputial island flap urethroplasty

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470

471 Figure 1. Surgery techniques in different types of hypospadias

472 Meatal Advancement and Glanuloplasty; Methieu: Methieu urethroplasty; Onlay:
 473 Onlay preputial flap urethroplasty; TIP: Tubularized Incised Plate urethroplasty; TPIFU:
 474 transverse preputial island flap urethroplasty; TPIFU + Duplay: TPIFU combined with
 475 Duplay urethroplasty; Koyanagi: Koyanagi urethroplasty; Staged Byars: staged Byars
 476 flap urethroplasty; Staged TPIFU: staged transverse preputial island flap urethroplasty

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The 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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1 **Title: The effectiveness of penile ventral curvature correction and the trend of**
2 **hypospadias repair: A prospective study of the national center in China**

3
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16
17 **Abstract**

18 **Background:** Hypospadias repair is a complex surgical procedure that involves
19 correcting penile ventral curvature (VC) and performing urethroplasty. This study aims
20 to evaluate the effectiveness of different strategies for VC correction and analyze the
21 trends in hypospadias repair at a national center in China.

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

26 **Results:** A total of 434 patients were included, with a median preoperative VC degree
27 of 50° (35°, 70°). All patients achieved a straight penis postoperatively, with 15.2%

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4 28 undergoing degloving, 28.6% undergoing degloving and dorsal plication (DP), 13.1%
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6 29 undergoing degloving and urethral plate transection (UPT), and 43.1% undergoing
7
8 30 degloving, UPT, and DP. Degloving alone was effective in correcting VC in 57.6% of
9
10 31 patients with VC less than 30°. In our analysis, DP after UPT resulted in a higher degree
11
12 32 of correction (25°) compared to DP after degloving alone (20°) (P<0.001). The study
13
14 33 identified the current trends in hypospadias repair, with tubularized incised plate
15
16 34 urethroplasty (TIP) being the most common technique used in distal hypospadias repair
17
18 35 (70.6% of patients) and transverse preputial island flap urethroplasty (TPIFU) being
19
20 36 preferred for proximal hypospadias repair (63.0%).

21
22 37 **Conclusions:** Degloving alone is effective for correcting VC less than 30°. The
23
24 38 majority of patients in our center underwent UPT, and DP after UPT yielded better
25
26 39 results compared to DP after degloving alone. Distal hypospadias repair commonly
27
28 40 utilized TIP, while TPIFU was favored for proximal hypospadias repair.

29
30 41 **Keywords:** hypospadias, VC correction, surgical techniques

31
32
33 43 **Key messages**

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35
36 44 What is already known on this topic

37
38 45 Limited information is available regarding the effectiveness of different strategies for
39
40 46 ventral curvature (VC) correction and trends in hypospadias repair. This study aims to
41
42 47 contribute by presenting our findings and experiences in managing hypospadias.

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44 48 What this study adds

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46 49 Our study provides a comprehensive analysis of the effectiveness of various strategies
47
48 50 for correcting penile ventral curvature and highlights the trends in hypospadias repair
49
50 51 specific to China, which differ from international results.

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52 52 How this study might affect research, practice or policy

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54 53 This study aims to provide evidence-based insights for the future management of
55
56 54 hypospadias, potentially influencing research, clinical practice, and policy decisions in
57
58 55 this field.

56

57 **INTRODUCTION**

58 Hypospadias is one of the most common congenital urethral abnormalities in 1 of
59 250-300 live births, and the incidence is rising[1]. Hypospadias repair encompasses
60 various surgical procedures, including ventral curvature (VC) correction, urethral
61 reconstruction, glans reconstruction, and penile skin reconstruction [2]. Achieving
62 adequate VC correction is a crucial step in ensuring successful hypospadias repair. The
63 selection of strategies for VC correction depends on factors such as the underlying
64 cause of the curvature, surgeon preferences, and the desired treatment goals. In previous
65 decades, surgical procedures followed a stepwise sequence, typically involving initial
66 dissection of the skin and subcutaneous dartos (commonly referred to as degloving),
67 followed by urethral plate mobilization or transection, and finally addressing any issues
68 related to corporal disproportion[3]. However, the latest modified stepwise approach,
69 as suggested by Castagnetti et al., has eliminated urethral plate mobilization due to an
70 increased risk of curvature recurrence[4]. Despite the importance of VC correction,
71 limited reporting exists on the effectiveness of different strategies employed for this
72 purpose. The strategies used for VC correction also influence the subsequent choice of
73 techniques for urethroplasty, particularly when urethral plate transection (UPT) is
74 performed, as it necessitates substitution urethroplasty. Despite the numerous surgical
75 techniques and their modifications available for hypospadias repair, no technique has
76 been universally accepted as the gold standard due to a lack of conclusive evidence
77 demonstrating the superiority of one technique over another [5].

78

79 In this prospective study, we collected clinical data from patients and assessed the
80 effectiveness of various strategies for VC correction. Our analysis aimed to reflect the
81 underlying causes of VC in the Chinese population and examine the selection of
82 surgical techniques for different types of hypospadias repair at the National Center for
83 Children's Health in China. We hypothesized that there would be variations in the
84 effectiveness of VC correction depending on the strategy employed, and that the

85 specific type of hypospadias would influence the choice of surgical techniques. The
86 ultimate goal of this study is to provide evidence-based insights that can inform the
87 future management of hypospadias.

88

89 **METHODS**

90 We conducted a prospective study where we collected clinical data from patients
91 who underwent hypospadias repair between 2019 and 2020. Patients with a history of
92 previous urethral surgeries were excluded, resulting in a total of 434 patients included
93 in the study. The study was conducted in accordance with the principles outlined in the
94 Declaration of Helsinki (revised in 2013) [6]. Ethical approval for this study was
95 obtained from the ethics committee of Beijing Children's Hospital, Capital Medical
96 University, National Center for Children's Health (IEC-C-008-A08-V.05.1), and
97 informed consent was obtained from the parents of the children. The study protocol was
98 registered at ClinicalTrials.gov (registration number: ChiCTR1900023055, registered
99 on 09/05/2019).

100

101 **Surgical techniques**

102 The surgical techniques for VC correction are briefly described. The degree of VC
103 can be due to any possible combination of the skin and/or subcutaneous dartos tethering,
104 a short urethral plate, and an intrinsic corpora disproportion. Therefore, we used a
105 systematic stepwise approach. Begin with skin degloving and subcutaneous dartos, and
106 the dissection should be extended proximally to the bulbar urethra. UPT was used if a
107 curvature more than 30° persists after degloving. Dorsal plication (DP) was mainly used
108 for VC less than 30° after each step in our center, which was performed by lifting the
109 neurovascular bundle, and suturing the tunica albuginea at both sides of the penis
110 without incision the albuginea. In our center, the surgical techniques for hypospadias
111 repair without UPT included Meatal Advancement and Glanuloplasty (MAGPI),
112 Methieu urethroplasty (Methieu), Onlay preputial flap urethroplasty (Onlay), and
113 Tubularized Incised Plate urethroplasty (TIP)[7-10]. The surgical techniques for

1
2
3
4 114 hypospadias repair with UPT included transverse preputial island flap urethroplasty
5 115 (TPIFU, the Duckett's technique), TPIFU combined with Duplay urethroplasty (TPIFU
6
7 116 + Duplay), Koyanagi urethroplasty (Koyanagi), staged Byars flap urethroplasty (Staged
8
9 117 Byars) and staged transverse preputial island flap urethroplasty (Staged TPIFU)[11-
10
11 118 15]. In addition to whether UPT, surgical techniques selection was influenced by factors
12
13 119 such as position of meatus after VC correction, degree of VC, conditions of the urethral
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15 120 plate (width and elasticity), urethral defect length, surgeon's preference, and experience.
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17 121

122 **Data collection and definition**

123 Data collected included age, degree of preoperative VC, strategies for VC
124 correction, degree of VC after degloving, degree of VC after UPT, position of meatus
125 after VC correction, and surgery techniques to repair hypospadias. An orthopedic
126 protractor was used to access VC in the artificial erection. The angle created by the
127 interception of two central axes of the proximal portion of the shaft and distal portion
128 passing through the navicular fossa, the vertex is the point of greatest curvature. The
129 degree of VC was evaluated through an artificial erection preoperatively, and after each
130 step for VC correction. According to the American Academy of Pediatrics survey, mild
131 curvature was defined as VC less than 30°, severe curvature was defined as VC more
132 than 45°[16]. The goal of complete VC correction is to obtain a satisfactory straight
133 penis (no degrees of VC). According to Barcat classification, the position of the meatus
134 after VC correction was classified as distal, middle, and proximal[17]. In our center,
135 measurement of parameters, and procedures for hypospadias repair were standardized
136 between six surgeons, who were high-volume surgeons (more than 50 hypospadias
137 operations per year) with at least 15 years of experience in hypospadias surgery[18].

138 139 **Statistical Analysis**

140 Statistical analysis was performed using R software (version 4.2.1, [http://www.r-](http://www.r-project.org)
141 [project.org](http://www.r-project.org)). Normalcy was analyzed using the Shapiro-Wilk test. Continuous variables
142 that conform to a normal distribution are presented as $\bar{x} \pm SD$ and were analyzed using

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4 143 the t-test. Median and quartile spacing as $M (P25, P75)$ were used to describe the
5
6 144 measurement data that did not obey normal distribution. Ordered data and measurement
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8 145 data that do not conform to the normal distribution use non-parametric tests (*Mann-*
9
10 146 *Whitney U test*). Statistical data were described by number of cases and percentage
11
12 147 ($n, \%$), and chi-square test or Fisher was used for comparison between groups. $P < 0.05$
13
14 148 was considered statistically significant.

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16 149

17 150 **RESULTS**

18 151 **Clinical data of all patients**

21 152 During the period from 2019 to 2020, a total of 434 patients were included in the
22
23 153 study. Table 1 provides a summary of the clinical characteristics of these patients. The
24
25 154 median age at the time of surgery was 24 months, ranging from 10 to 142 months. The
26
27 155 median degree of preoperative VC was $50^\circ (35^\circ, 70^\circ)$, while the median degree of VC
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29 156 after degloving was $30^\circ (15^\circ, 40^\circ)$. Following UPT, the median degree of VC further
30
31 157 reduced to $20^\circ (15^\circ, 25^\circ)$.

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33 158 Among the included patients, 311 (71.7%) underwent DP for VC correction, and
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35 159 244 (56.2%) patients underwent UPT after degloving. The position of the meatus after
36
37 160 VC correction was categorized as distal in 109 patients (25.1%), middle in 96 patients
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39 161 (22.1%), and proximal in 229 patients (52.8%).

40
41 162 Various surgical techniques were employed for hypospadias repair. These
42
43 163 techniques included MAGPI (2.8%), Methieu (1.8%), Onlay (10.4%), TIP (28.8%),
44
45 164 TPIFU (40.8%), TPIFU combined with Duplay (4.2%), Koyanagi (2.3%), Staged Byars
46
47 165 (2.3%), and Staged TPIFU (6.7%).

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49 166

50 167 **The effectiveness of VC correction by different strategies**

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52 168 The effectiveness of VC correction by different strategies was evaluated in the
53
54 169 study. All patients achieved a straight penis after the repair. In the overall cohort, 66
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56 170 patients (15.2%) achieved a satisfactory straight penis through complete degloving
57
58 171 alone, with a median preoperative VC of $25^\circ (15^\circ, 35^\circ)$. Among the patients, 124

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4 172 (28.6%) had persistent VC less than 30° after degloving and subsequently underwent
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6 173 DP, with a median preoperative VC of 35° (30°, 50°). Additionally, 57 patients (13.1%)
7
8 174 underwent VC correction after UPT without other procedures, with a median
9
10 175 preoperative VC of 55° (45°, 80°). However, 187 patients (43.1%) still had residual
11
12 176 curvature after UPT, with a median preoperative VC of 60° (50°, 83°), and they
13
14 177 required subsequent DP to achieve satisfactory straightening (Table 2).

15
16 178 Degloving alone was effective for straightening the penis in 34 patients (57.6%)
17
18 179 with mild preoperative VC (less than 30°), 25 patients (20.8%) with preoperative VC
19
20 180 ranging from 30° to 45°, and seven patients (3.7%) with severe preoperative VC (more
21
22 181 than 45°), as summarized in Table 3. The degloving procedure resulted in a median
23
24 182 correction of 20° (10°, 35°) of VC in all patients, which was calculated as the difference
25
26 183 between the preoperative VC degree and the VC degree after degloving. Furthermore,
27
28 184 DP led to a correction of 20° (15°, 30°) of VC, and there was a significant difference
29
30 185 between DP after degloving alone and DP after UPT ($P < 0.001$). Regarding UPT, a
31
32 186 median correction of 20° (10°, 30°) of VC was achieved (Table 4).

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34 188 **Surgery techniques in different types of hypospadias**

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37 189 In distal hypospadias repair, the most commonly used surgical technique was TIP
38
39 190 urethroplasty, which accounted for 70.6% of cases. Other techniques utilized in this
40
41 191 category included MAGPI, Methieu, and Onlay.

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43 192 For middle hypospadias repair, the primary surgical techniques employed were
44
45 193 Onlay (25.3%), TIP (38.4%), and TPIFU (34.3%). Methieu technique was also used in
46
47 194 some cases.

48
49 195 In proximal hypospadias repair, the predominant technique was single-stage
50
51 196 TPIFU, which accounted for 63.0% of cases. Additional surgical options for this type
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53 197 of hypospadias included Onlay, TIP, TPIFU + Duplay, Koyanagi, staged Byars, and
54
55 198 staged TPIFU. It's worth noting that staged techniques (including staged Byars and
56
57 199 staged TPIFU) were exclusively performed for proximal hypospadias cases (Table 5).

58 200

201 **DISCUSSION**

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

213

214 **Management of VC**

215 The surgical procedures for VC correction in hypospadias aim to address the
216 underlying causes of the curvature. A stepwise approach is followed, starting with skin
217 degloving and dartos dissection. If a curvature greater than 30° persists, UPT without
218 mobilizing the urethral plate is recommended. If the curvature persists by more than
219 30° after UPT, ventral penile lengthening (VPL) is performed[4]. However, in our
220 center, VPL is not commonly utilized due to concerns regarding potential adverse
221 effects such as erectile dysfunction, hemorrhage, and scar healing issues related to the
222 albuginea incision. Long-term studies evaluating the outcomes of VPL are lacking[4,
223 19]. When there is significant bleeding during the incision or the need for closure with
224 a flap or graft, it may affect the surgical procedure and postoperative urethral healing.
225 A study conducted in 2017 reported that UPT combined with DP achieved satisfactory
226 straightening in all cases of severe hypospadias, without the requirement for VPL[20].

227 In our study, we observed a higher proportion of severe preoperative VC and
228 proximal hypospadias compared to previous reports[21, 22]. Similar to our result,
229 Snodgrass et al. have found that 19% of patients achieved a straight penis after

230 degloving alone, 31% had VC less than 30° after degloving and underwent dorsal
231 plication (DP), and 50% had VC more than 30° [23]. These results suggest that
232 persistent VC after degloving may indicate a shortened urethral plate and/or corporal
233 disproportion.

234 Skin degloving is an important step in hypospadias repair and can improve VC[24,
235 25]. However, the effectiveness of degloving alone for achieving penile straightening
236 varies across studies. One study using lateral photographs to assess curvature reported
237 complete VC correction by degloving in 100% of cases with VC less than 45° and 74%
238 of cases with VC greater than 90°[26]. On the other hand, Weber et al. found that
239 degloving alone was sufficient for VC correction in 77% of mild cases (less than 30°),
240 30% of cases with 30° to 45°, and only 2% of cases with VC greater than 45°[27].
241 Therefore, the efficacy of degloving appears to be inversely related to the severity of
242 preoperative VC, which aligns with the trends observed in our study. We found that
243 more than half of patients with mild preoperative VC achieved a straight penis after
244 degloving, but it was not as effective for correcting severe VC.

245 In our analysis, we found that the correction achieved by DP after UPT was higher
246 than DP after degloving alone. This suggests that DP may be more effective and durable
247 after UPT, as the continuous ventral tethering caused by the elasticity of the urethra and
248 urethral plate is relieved [20]. This finding is consistent with a study that reported a
249 lower rate of recurrent VC after DP with UPT compared to DP without UPT (0% vs.
250 36.5% of patients, $P = 0.002$) [28]. DP is generally recommended for VC less than 30°,
251 and the effectiveness observed in this study exceeds that standard. However, the
252 potential risk of recurrent VC after DP necessitates long-term follow-up in future
253 research.

254 It was thought in the 1980s and 1990s that UPT might not substantially improve
255 curvature[29]. However, a 2017 study reported that UPT alone achieved penile
256 straightening in 35% of cases [30]. In proximal hypospadias, it has been reported that
257 the penis can be straightened without UPT in 13% to 74% of cases [26, 30]. In our
258 series, a straight penis was achieved without UPT in 43.8% of cases. These observations

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4 259 suggest that a shortened urethral plate could contribute to VC, which may be the
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6 260 primary etiology in some cases. Acimi et al. reported VC correction ranging from 0° to
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8 261 20° obtained by mobilizing the urethral plate. In our study, the VC correction achieved
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10 262 by UPT was 20° (10°, 30°). Overall, UPT was in demand and effective in the stepwise
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12 263 approach for managing VC.

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15 265 **Surgery techniques for hypospadias repair**

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17 266 The field of hypospadias surgery originated in the late 19th century with the
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19 267 contributions of Thiersch and Duplay [2]. Since then, numerous surgical techniques
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21 268 have been developed. Our study also demonstrates the variety of techniques used for
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23 269 hypospadias repair. However, it is important to note that comparable functional
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25 270 outcomes can be achieved with different techniques, and a large number of surgical
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27 271 options can increase the risk of complications [31].

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31 273 The TIP technique has become the preferred treatment for distal and middle
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33 274 hypospadias due to its reliability and high success rates as demonstrated in large series
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35 275 [32-36]. For distal hypospadias, alternative techniques such as MAGPI and Mathieu
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37 276 procedures are also available [37, 38]. The Onlay technique involves using a preputial
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39 277 island flap when the urethral plate is unhealthy or too narrow [3]. Our study reflects
40
41 278 similar trends, with TIP being the most commonly used technique for distal
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43 279 hypospadias repair, while Onlay, TIP, and TPIFU are the main surgical techniques for
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45 280 middle hypospadias repair. According to a worldwide survey, staged repair was the
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47 281 preferred option for proximal hypospadias repair, chosen by up to 76.6% of respondents
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49 282 [18]. However, in our center, a staged approach was chosen for only 17.2% of patients.
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51 283 While a staged approach may have a lower complication rate, it requires two surgical
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53 284 procedures, whereas a single-stage approach can avoid the need for a second procedure
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55 285 in approximately two-thirds of patients [39]. Therefore, most of our surgeons prefer
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57 286 the single-stage TPIFU technique for proximal hypospadias repair when the preputial
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59 287 flap is sufficient to repair the urethral defect. We believe that reducing the need for
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4 288 additional surgical procedures may be particularly beneficial for the patients.
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8 290 **Limitations**

9 291 This study has several limitations that should be acknowledged. First, there may
10 292 be interobserver variability in the evaluation of VC due to the involvement of multiple
11 293 surgeons in assessing VC during artificial erection. This variability could introduce bias
12 294 into the results. Additionally, there may be variations in VC measurement methods
13 295 among previous studies, making it challenging to directly compare the findings.
14 296 Another limitation is the uniform distribution of patients among the different strategies
15 297 for VC correction. This may affect the outcomes and limit the ability to draw definitive
16 298 conclusions about the effectiveness of each strategy. Furthermore, this study only
17 299 presents data on the surgical procedures for hypospadias repair and lacks long-term
18 300 follow-up data. These limitations should be taken into consideration when interpreting
19 301 the results of this study and further research with larger sample sizes and comprehensive
20 302 follow-up is needed to provide more robust evidence in the field of hypospadias surgery.
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34 304 **CONCLUSIONS**

35 305 This prospective study provided insights into the effectiveness of different
36 306 strategies for VC correction in hypospadias repair. The stepwise approach
37 307 demonstrated appropriate and diverse outcomes, with degloving alone being effective
38 308 for mild VC but showing limited improvement for severe cases. UPT played a
39 309 significant role in improving the effectiveness of DP, resulting in higher correction rates.
40 310 The preference for single-stage TPIFU for proximal hypospadias repair reflects current
41 311 trends among surgeons in our referral center. However, further research is needed to
42 312 assess the role of VPL in hypospadias repair. It is recommended to conduct national
43 313 multi-center, prospective randomized controlled studies to enhance the evaluation of
44 314 VPL and its long-term outcomes in the management of hypospadias.
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320 review, and contributed to data analysis and drafted the manuscript. PL, YWF, XYW,
321 SQF, ZHL, KZS, YJX, HZW, and HL participated in data acquisition. WPZ, HCS and
322 NS contributed to review the results, discussion, and conclusion, and made critical
323 revision and edition of the contents. All authors read and approved the final manuscript.

324 **Patient involvement** Patients were involved in the outcome measures, but they were
325 not involved in setting the research question, design or implementation of the
326 intervention.

327 **Ethics Approval** This study was conducted in accordance with the principles of the
328 Declaration of Helsinki, and was approved by the ethics committee of Beijing
329 Children's Hospital, Capital Medical University, National Center for Children's Health
330 (IEC-C-008-A08-V.05.1) and informed consent was obtained from patient's guardian
331 (patients were all younger than 16 years old). The clinical trial is registered at
332 ClinicalTrials.gov (09/05/2019, ChiCTR1900023055).

333 **Availability of data** The datasets used and analysed during the current study are
334 available from the corresponding author on reasonable request.

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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%)

VC: Ventral Curvature; DP: Dorsal Plication; UPT: Urethral Plate Transection; MAGPI: Meatal Advancement and Glanuloplasty; Methieu: Methieu urethroplasty; Onlay: Onlay preputial flap urethroplasty; TIP: Tubularized Incised Plate urethroplasty; TPIFU: transverse preputial island flap urethroplasty; TPIFU + Duplay: TPIFU combined with Duplay urethroplasty; Koyanagi: Koyanagi urethroplasty; Staged Byars: staged Byars flap urethroplasty; Staged TPIFU: staged transverse preputial island flap urethroplasty

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	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)

VC: Ventral Curvature; DP: Dorsal Plication; UPT: Urethral Plate Transection;

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

VC: Ventral Curvature

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	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;

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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%)

Meatal Advancement and Glanuloplasty; Methieu: Methieu urethroplasty; Onlay: Onlay preputial flap urethroplasty; TIP: Tubularized Incised Plate urethroplasty; TPIFU: transverse preputial island flap urethroplasty; TPIFU + Duplay: TPIFU combined with Duplay urethroplasty; Koyanagi: Koyanagi urethroplasty; Staged Byars: staged Byars flap urethroplasty; Staged TPIFU: staged transverse preputial island flap urethroplasty

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