Uro-Technology Journal 2026; 10(2): 36-46 ***36***
DOI: 10.31491/UTJ.2026.06.058

RESEARCH

Comparative evaluation of results, frequency of complications and identification of risk factors for their development of different types of urethroplasty in patients with urethral strictures

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Abstract

The observation period covered the years 2005–2024. Six observation groups were formed. The first group (N = 69) consisted of patients who underwent urethro-urethroanastomosis (UUA); the second group (N = 89) underwent buccal mucosa graft urethroplasty (BMGUP); the third group (N = 16) underwent skin flap urethroplasty (SFUP). Groups 4 and 6 were created by regrouping the main pool of patients (N = 174). The fourth group (N = 108) included patients with Clavien-Dindo grade 0–I complications after urethroplasty; the fifth group (N = 36) had grade II–IIIa complications; and the sixth group (N = 30) had grade IIIb–IV complications. The length of the urethral stricture (SU) in group 1 was significantly shorter (2.9 ± 1.9 cm) than in groups 2 (5.9 ± 4.2 cm) and 3 (5.3 ± 3.9 cm). Accordingly, the number of SU localized in the bulbar section is significantly higher in group 1 (UUA) (82.6%) than in groups 2 (46.7%) and 3 (31.2%), and SU localized in the penile section is not represented in group 1 (UUA). But in group 3 (SFUP) SU localized in the penile section are significantly more (68.7%) than in group 2 (BMGUP) (32.2%). It is important that the SU in group 1 (UUA) are significantly simpler (6.3 ± 2.4 points) than the SU presented in group 2 (BMGUP) (8.4 ± 1.5 points) and group 3 (SFUP) (8.0 ± 1.6 points). A significantly longer (P = 0.001) postoperative bed-day was found in patients in group 1 (UUA) (17.7 ± 9.4 days), compared to patients in groups 2 (BMGUP) (10.3 ± 5.2 days) and 3 (SFUP) (11.4 ± 7.5 days). The success of BMGUP (92.1%) is statistically significantly higher compared to those performed by UUA (79.7%) and SFUP (75.0%) (χ^2 = 6.5, df = 2, P = 0.023 for group 1 *vs*. 2; P = 0.039 for group 2 *vs*. 3). A prognostic assessment of clinical parameters of patients without and with early or late postoperative complications was also performed in order to identify probable risk factors for their development. The following risk factors were significant: localization (of stricture prostatic and penile urethra), type of urethroplasty (BMGUP), patient age, disease duration. According to the calculations, when SU is localized in the prostatic urethra, the risk of Clavien-Dindo grade IIIb–IV complications increases by 5.89 and in the penile urethra, the risk of Clavien IIIb–IV complications decreases by 72%. When performing BMGUP, the risk of Clavien IIIb–IV complications decreases by 58% and 75% compared to Clavien class 0–I and II–IIIa complications, respectively. The age of patients under 45 years reduces the risk of Clavien class IIIb–IV complications by 78%, and over 45 years increases the risk by 4.48 times. The duration of the disease for more than 7 years increases the risk of developing complications of class IIIb–IV according to Clavien by 4.16 times, and the duration of less than 7 years reduces the risk of developing this class of complications by 76%.

Keywords: Buccal mucosa graft urethroplasty, skin flap urethroplasty, urethra, risk factors

Introduction

The problem of treating patients with urethral stricture (SU) and urethral obliterations (OU) has been relevant for many years. Over the past few years, the number of patients with this disease has increased due to the war in Ukraine. It is believed that the leading role in the formation of traumatic urethral strictures is played by the negative impact of urine on the tissues surrounding the urethra and the emerging infection. Damage (inflammation or

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Received: 13 March 2026 / Revised: 14 April 2026
Accepted: 21 May 2026 / Published: 30 June 2026

trauma) triggers this multi-stage pathological process [1]. The identification of spongiofibrosis—the main process in the formation of strictures—made it possible to explain the reasons for the ineffectiveness of urethral bougienage and evaluate the results of internal optical urethrotomy, during which radical removal of sclerotic-changed tissues of the urinary canal is not performed. The only pathogenetically determined method of treating urethral strictures is urethroplasty, in which the narrowing is excised within healthy tissues, and today there are some types of surgical technique.

The prognosis for patients with post-traumatic distraction defects of the urethra (*i.e.*, urethral obliteration) is poor, with a 40–50% risk of recurrence. At the same time, 2.5–3.6% of patients have a lifelong cystostomy tube or perineal urethrostomy with female-type urination, which may worsen the patients' quality of life.

In recent years, a number of effective urethroplasties have been proposed that increase the lumen of the urethra due to free and displaced flaps and grafts [2]. In SI "Academician O.F. Vosianov Institute of Urology of NAMS of Ukraine" since 2005, registration of the examination and treatment of patients with strictures/obliterations of the urinary tract of various etiologies and complexity has been underway. From 2005 to 2024, 1301 surgical interventions were performed for SU. In 174 (13.4%) cases, patients underwent various types of open urethroplasty.

The purpose of the study is to perform a comparative analysis of the results of different types of urethroplasty, assessment of postoperative complications with identification of risk factors.

Material and methods

Study design and patients

A retrospective assessment of the medical histories of 174 patients who underwent urethrourethral anastomosis (UUA), buccal mucosa graft urethroplasty (BMGUP) or skin flap urethroplasty (SFUP) was conducted at our institution. The diagnosis was verified according to the data of preoperative urethrocystoscopy, in the presence of epicystostomy—cystoscopy through the cystostomy passage. In the medical documentation of the clinic, based on anamnestic data, information was obtained about the patient's age, age at the onset of the disease, etiology of urethral stricture, duration of the disease. Special attention was paid to the type and number of previous surgical interventions.

The patient signed a voluntary written consent to treatment (primary medical record form No. 003-6/o). Informed consent for the use of medical data for research purposes was obtained from all patients.

Surgical techniques and perioperative management

According to the data of instrumental examinations before the urethral reconstruction (retrograde urethrocystography, voiding cystourethrography, MRI/CT, uroflowmetry, urethrocystoscopy), the length of the affected part of the urethra, its localization, the presence of urethral diverticula (after previous reconstructions), bladder diverticula, tumors and bladder stones were determined.

Blood loss during urethroplasty was calculated directly by measuring the fluid volume in the suction canister and adding 10% for blood absorbed by gauze pads.

Postoperative complications were recorded by analyzing the protocols of operations, anesthesia charts, diaries, records of consultations of related specialists, epicrisis, data of laboratory and instrumental examinations of the operated patients.

Outcome measures and definitions

The time of postoperative catheterization was defined as the time interval from the date of urethral reconstruction to the date when the control postoperative urethrocystoscopy was performed.

Recurrent strictures were defined as cases in which the patient had undergone prior surgical treatment (endoscopic or reconstructive) elsewhere and was hospitalized only after disease relapse.

Complications that were detected in the postoperative period were assessed in accordance with the approach to their treatment according to the Clavien-Dindo classification [3]. Early postoperative complications were assessed 4–7 days after urethroplasty and late postoperative complications 6 months after urethroplasty. Regarding the recurrence of SU after urethroplasty, it was ascertained during urethrocystoscopy. A narrowed section of the urethra up to 1.5 cm long was classified as Class IIIa of complications according to Clavien-Dindo and visual optic urethrotomy (VOUT) was performed to correct this narrowing. If the length of the recurrent SU was more than 1.5 cm, it was classified as Clavien-Dindo grade IV according to Clavien-Dindo and repeated urethroplasty was recommended for such patients.

Statistical analysis

Statistical analysis was performed using the licensed specialized software package Stata 12.1 (StataCorp LLC). Initially, the assessment of compliance with the normal distribution for quantitative indicators was carried out using the Shapiro-Wilk criterion. Descriptive statistics for qualitative parameters were presented through the analysis of frequency distributions with the determination of the number of patients and distributions in percentages. For quantitative parameters subject to the law of normal distribution, the arithmetic mean (M) and standard deviation (SD) were determined. Under other conditions (in case of non-compliance with the normal distribution), the median (Me) and interquartile range [Q1, Q3] were calculated [4]. To assess the statistical significance of the difference when comparing two independent groups, an independent samples t-test was used (if the parameters of the normal distribution were met). When comparing three groups, an analysis of variance (ANOVA) was used with the *F*-test. In multiple intergroup comparisons of quantitative characteristics, the Scheffe method (correction) was used to minimize the chances of detecting differences between groups in their absence. The Scheffe method is also re-

sistant to unequal samples and when comparing complex (combined) groups. When comparing subgroups by their frequency characteristics (qualitative characteristics), the Bonferroni correction was used to reduce the risk of type I error. If nonparametric criteria were needed, the Mann-Whitney test was used. To compare the distributions of nominal (categorical) data, the Pearson Chi-square (χ^2) test was used, and Fisher's exact test was used when the expected frequency in any cell was < 5. The criterion for assessing the statistical significance of the results of the comparative analysis was considered to be a marginal risk of error of less than 5% ($P < 0.05$). The prognostic assessment of individual clinical parameters for the risk of complications according to Clavien-Dindo was determined with the calculation of the odds ratio (OR) and 95% confidence interval [4].

Results and discussion

Baseline characteristics of patients

Period of observation was 2005–2024. Six observation groups were formed. Some clinical parameters of patients in groups 1, 2, and 3 are presented in Table 1.

When comparing age of patient, age of disease onset and disease duration, no significant difference was found in the compared groups. In patients of group 1, the average age of patients was 43.6 ± 15.8 years ($P = 0.999$ for group 1 *vs*. 2; $P = 0.990$ for group 1 *vs*. 3), in group 2 was 43.6 ± 18.5 years ($P = 0.989$ for group 2 *vs*. 3), in group 3 was 42.9 ± 15.6 years. The age at disease onset was 39.3 ± 15.5 years in group 1 ($P = 0.683$ for group 1 *vs*. 2; $P = 0.617$ for group 1 *vs*. 3), in groups 2 and 3 was 36.7 ± 20.7 years and 34.2 ± 20.5 years, respectively ($P = 0.887$ for group 2 *vs*. 3). The data obtained on the age of patients and the onset of the disease are consistent with the data of world studies. In most studies, the average age of patients with strictures corresponds to 35–45 years [5, 6]. It is believed that after 45 years of age, the incidence of SU decreases significantly [7, 8].

By etiology, the study groups distinguished SU: post-traumatic, post-inflammatory and iatrogenic. When comparing between groups, a statistically significant difference was found when comparing the etiology of SU in

Table 1. Clinical and anamnestic parameters of patients (Me, 95% CI for Me, [Q25%]; [Q75%]).

Indicators	Group 1 UUA ($N = 69$)	Group 2 BMGUP ($N = 89$)	Group 3 SFUP ($N = 16$)	χ^2 Pearson F Fisher	*P*-value
Etiology					
Post-traumatic (%)	55 (79.7)	36 (40.4)	4 (25.0)	$\chi^2 = 41.7$ (df = 4)	$P = 0.0001^*$ $P = 0.0001^*$ (for group 1 *vs*. 2) $P = 0.0001^*$ (for group 1 *vs*. 2) $P = 0.086$ (for group 2 *vs*. 3)
Post-inflammatory (%)	1 (1.4)	25 (28.1)	9 (56.2)		
Iatrogenic (%)	13 (18.8)	28 (31.5)	3 (18.7)		
Localization					
Penile (%)	0 (0.0)	29 (32.2)	11 (68.8)	$\chi^2 = 48.6$ (df = 6)	$P = 0.0001^*$ $P = 0.0001^*$ (for group 1 *vs*. 2) $P = 0.0001^*$ (for group 1 *vs*. 3) $P = 0.031^*$ (for group 2 *vs*. 3)
Bulbar (%)	57 (82.6)	42 (46.7)	5 (31.2)		
Membranous (%)	9 (13.1)	16 (17.8)	0 (0.0)		
Prostatic (%)	3 (4.3)	3 (3.3)	0 (0.0)		
Length					
up to 2 cm (%)	60 (86.9)	8 (8.9)	2 (12.5)	$\chi^2 = 111.9$ (df = 4)	$P = 0.0001^*$ $P = 0.0001^*$ (for group 1 *vs*. 2) $P = 0.0001^*$ (for group 1 *vs*. 3) $P = 0.906$ (for group 2 *vs*. 3)
2-7 cm (%)	9 (13.0)	18 (20.2)	3 (18.7)		
7 cm (%)	0 (0.0)	63 (70.8)	11 (68.7)		
Age (years)	43.6 ± 15.8	43.6 ± 18.5	42.9 ± 15.6	$F = 0.1$	$P = 0.989$ $P = 0.999$ (for group 1 *vs*. 2) $P = 0.990$ (for group 1 *vs*. 3) $P = 0.989$ (for group 2 *vs*. 3)
Age at disease onset (years).	39.3 ± 15.5	36.7 ± 20.7	34.2 ± 20.5	$F = 0.66$	$P = 0.521$ $P = 0.683$ (for group 1 *vs*. 2) $P = 0.617$ (for group 1 *vs*. 3) $P = 0.887$ (for group 2 *vs*. 3)
Duration of the disease (month)	4.7 ± 8.3	7.3 ± 8.5	9.0 ± 9.8	$F = 2.58$	$P = 0.078$ $P = 0.169$ (for group 1 *vs*. 2) $P = 0.199$ (for group 1 *vs*. 3) $P = 0.769$ (for group 2 *vs*. 3)
Average length (cm)	1.9 ± 1.9	5.9 ± 4.2	5.3 ± 3.9	$F = 15.3$	$P = 0.001^*$ $P = 0.001^*$ (for group 1 *vs*. 2) $P = 0.046^*$ (for group 1 *vs*. 3) $P = 0.797$ (for group 2 *vs*. 3)

Note: Comparisons between groups were performed using the Pearson χ^2 test (with degrees of freedom, df), one-way ANOVA followed by the Scheffé method for multiple comparisons, and the Mann–Whitney U test. An asterisk (*) indicates a statistically significant difference between groups ($P < 0.05$).

patients of groups 1 and 2 ($P < 0.001$ for group 1 *vs*. 2), as well as groups 1 and 3 ($P < 0.001$ for group 1 *vs*. 3). In turn, in group 1, the proportion of post-traumatic SU was 79.7% ($N = 55$), in group 2 their share was 40.4% ($N = 36$), and in group 3 25% ($N = 4$). Accordingly, in group 1, there were significantly more patients with post-traumatic SU than in groups 2 and 3 ($P < 0.001$). The proportion of post-inflammatory SU in group 1 was 1.4% ($N = 1$), 28.1% ($N = 25$) in group 2, 56.2% ($N = 9$) in group 3. Accordingly, in group 1, there were statistically significantly fewer patients with post-inflammatory SU than in groups 2 and 3 ($P < 0.001$). This distribution of SU by groups according to etiology can be explained by the fact that post-traumatic SU, in most cases, are formed when the urethra is ruptured. Such strictures/obliterations are short, although they are accompanied by pronounced spongiofibrosis. With short 1.5–2 cm SU, the formation of UUA is possible. In contrast, post-inflammatory SU is usually long (> 2.5 cm), and graft urethroplasty using buccal mucosa or skin-fascial flaps was chosen to correct such strictures. No significant difference was found when comparing groups 2 and 3 by etiological affiliation ($P = 0.086$ for group 2 *vs*. 3; $\chi^2 = 41.7$, df = 4).

In group 1, no strictures were found in the penile urethra; 57 (82.6%) were in the bulbar urethra, 9 (13.1%) in the membranous urethra, and 3 (4.3%) in the prostatic urethra. In group 2, the distribution was as follows: penile urethra, 29 (32.2%); bulbar urethra, 42 (46.7%); membranous urethra, 16 (17.8%); and prostatic urethra, 3 (3.3%).. In group 3, there were 11 (68.8%) cases of SU localized in the penile urethra, 5 (31.2%) in the bulbar urethra, while no cases of SU localization in the membranous and prostatic urethra were detected. When comparing the studied groups, a statistically significant difference was found between groups 1 and 2 ($P < 0.001$), groups 1 and 3 ($P < 0.001$) and groups 2 and 3 ($P = 0.086$), ($\chi^2 = 48.6$, df = 6). Accordingly, in group 1 there were significantly fewer SU, compared to groups 2 and 3, with localization in the penile urethra, but in group 1 there were significantly more SU localized in the bulbar urethra than in groups 2 and 3. Strictures of patients in group 3 were significantly more often localized in the penile urethra ($P < 0.001$), but in this group there were no SU of the posterior urethra.

This distribution by localization can be explained by the fact that UUA (group 1) was performed when urethral strictures/obliterations were localized in the bulbar and posterior urethral sections (100%) without disruption of blood supply and tension of the edges of the anastomosis, which can lead to its failure in the early post-operative period. UUA is contraindicated for penile strictures because it may cause penile shortening and penile curvature on erection in the late postoperative period. While BMGUP (group 2) was performed in SU of all localizations. And in group 3 (SFUP), SU were localized in 100% of cases in the penile and bulbar sections due to the possibility of thrombosis of the vascular pedicle with its excessive tension if the skin flap is localized in the posterior urethra.

A statistically significant difference in SU length was found between groups. In group 1, strictures ≤ 2 cm accounted for 86.9%, compared with only 8.9% in group 2 and 12.5% in group 3. The SU with a length of 2–7 and more than 7 cm was only 13% significantly. Such a division of SU into groups also fits the explanation of the division of the SU by localization and etiology, which are indicated above.

A similar result was obtained when determining the average SU length in the compared groups. The mean SU length was 1.9 ± 1.9 cm in group 1, 5.9 ± 4.2 cm in group 2, and 5.3 ± 3.9 cm in group 3. The length in group 1 was significantly shorter than in groups 2 and 3 ($P < 0.001$; group 1 *vs*. 2: $P = 0.001$; group 1 *vs*. 3: $P = 0.046$). Intraoperative and postoperative data of patients in the study groups are presented in Table 2. When comparing the average intraoperative blood loss in the studied groups, no statistically significant difference was found. In group 1, blood loss was 122.8 ± 64.4 mL; in group 2, it was 147 ± 77.3 mL; and in group 3, it was 120.6 ± 61.2 mL ($F = 2.61$; $P = 0.076$).

Perioperative and functional outcomes

When comparing the average duration of urethral drainage, which in group 1 was 18.9 ± 5.1 days, in group 2 was 19.7 ± 8.3 days and in group 3 was 21.4 ± 7.2 days, no statistically significant difference was found between the compared groups ($F = 0.95$; $P = 0.389$). According to Martins and De Oliveira [9], maintaining the urethral catheter for 8–10 days after urethroplasty is considered sufficient. However, in 6% of patients, extravasation of urine was observed after catheter removal during this period, which is a predictor of rapid SU recurrence and may lead to repeated urethroplasty [10]. Therefore, the surgeons of the clinic recommend maintaining the urethral catheter for about 3 weeks to prevent this complication (Table 2).

The mean postoperative hospital stay was 17.7 ± 9.4 days in group 1, 10.3 ± 5.2 days in group 2, and 11.4 ± 7.5 days in group 3. This prolonged postoperative hospital stay is largely due to the treatment of recurrent obliterations at our clinic and the inclusion of patients from remote regions of Ukraine. When comparing between groups, it was found that there is a statistically significant difference ($F = 20.6$) between postoperative hospital stay in groups 1 and 2 ($P < 0.001$) and groups 1 and 3 ($P = 0.010$ for group 1 *vs*. 3). When comparing the indicators of groups 2 and 3, no significant difference was found ($P = 0.840$ for group 2 *vs*. 3). Therefore, it can be stated that patients in group 1 in the postoperative period were in the hospital significantly longer than patients in groups 2 and 3 ($P < 0.01$).

The results of urethroplasty in the studied groups were compared. A successful result in group 1 (UUA) was in 55 (79.7%) patients, in group 2 (BMG) was 82 (92.1%) patients, and in group 3 (Flap) there were 12 (75.0%) successful urethroplasty, which is consistent with the literature data [9, 10]. Unsuccessful outcomes were observed in 14 patients (20.3%) in group 1, 7 patients (7.9%) in group 2 (recurrence of SU), and 4 patients (25.0%) in group 3. When determining the intergroup statistical significance using Pearson's χ^2, it was found that $\chi^2 = 6.5$, (df = 2) and this indicates the presence of a statistical difference

Table 2. Intraoperative and postoperative parameters of patients in groups 1, 2 and 3.

Indicators	Group 1 UUA ($N = 69$)	Group 2 BMGUP ($N = 89$)	Group 3 SFUP ($N = 16$)	χ^2 Pearson F Fisher	*P*-value
Blood loss (mL)	122.8 ± 64.4	147 ± 77.3	120.6 ± 61.2	$F = 2.61$	$P = 0.076$ $P = 0.108$ for group 1 *vs*. 2 $P = 0.994$ for group 1 *vs*. 3 $P = 0.396$ for group 2 *vs*. 3
Postoperative bed-day (day)	17.7 ± 9.4	10.3 ± 5.2	11.4 ± 7.5	$F = 20.6$	$P = 0.001^*$ $P = 0.001^*$ for group 1 *vs*. 2 $P = 0.010^*$ for group 1 *vs*. 3 $P = 0.840$ for group 2 *vs*. 3
Average duration of urethral drainage (day)	18.9 ± 5.1	19.7 ± 8.3	21.4 ± 7.2	$F = 0.95$	$P = 0.389$ $P = 0.736$ for group 1 *vs*. 2 $P = 0.417$ for group 1 *vs*. 3 $P = 0.672$ for group 2 *vs*. 3
Average operation time (min)	136.5 ± 47.8	179.2 ± 66.5	174.7 ± 64.9	$F = 10.4$	$P = 0.0001^*$ $P = 0.0001^*$ for group 1 *vs*. 2 $P = 0.072$ for group 1 *vs*. 3 $P = 0.963$ for group 2 *vs*. 3
Successful result (%)	55 (79.7)	82 (92.1)	12 (75.0)	$\chi^2 = 6.5$ (df = 2)	$P = 0.039^*$ $P = 0.023^*$ for group 1 *vs*. 2 $P = 0.678$ for group 1 *vs*. 3 $P = 0.039^*$ for group 2 *vs*. 3
Unsuccessful result (%)	14 (20.3)	7 (7.9)	4 (25.0)	—	—

Note: Comparisons between groups were performed using the Pearson χ^2 test (with degrees of freedom, df), one-way ANOVA followed by the Scheffé method for multiple comparisons, and the Mann–Whitney U test. An asterisk (*) indicates a statistically significant difference between groups ($P < 0.05$).

between groups 1and 2 and between group 2 and 3 ($P = 0.023$ for group 1 *vs*. 2; $P = 0.039$ for group 2 *vs*. 3). Accordingly, the success rate of urethroplasty in patients of group 2 is statistically significantly higher than in patients of group 1, and the presence of recurrence of SU in group 1 is significantly higher than in group 2 ($P = 0.039$). A similar trend is observed when comparing the success and failure of urethroplasty in groups 2 and 3. In patients of group 3, the failure rate of urethroplasty is statistically significantly higher than in patients in group 2 ($P = 0.039$). When comparing groups 1 and 3 ($P = 0.678$), no significant difference in the success rate of urethroplasty was found. In summary, the success rate of BMGUP was statistically significantly higher compared to UUA and SFUP.

Comparison with published literature

One of the similar studies to ours is the publication of Markiewicz *et al*. [8]. The authors selected and analyzed 39 studies from 1267 papers published between 1974 and 2006, according to the criteria, on the results of using the oral mucosa (cheek and tongue) for urethral strictures and hypospadias/epispadias. The overall rate of positive results of augmentation urethroplasty for urethral strictures in 22 papers, including 724 patients, was 76.4%. The onlay technique ($N = 642$) had an efficiency of 79.2%. The ventral onlay technique (10 papers, $N = 325$) was effective in 87.7%, and the dorsal onlay technique (7 papers, $N = 267$) had a success rate of 68.2% ($P < 0.001$).

In 2019, the study Trends in Urethral Stricture Disease Etiology and Urethroplasty Techniques from a Multi-institutional Surgical Outcomes Research Group was published, which showed the dynamics of changes in the choice of treatment method for patients with urethral strictures and obliterations from 2010 to 2017 [11].

According to the data of this study, the level of use of scar excision and anastomosis formation between the normal ends of the urethra decreased by 31%. The number of dorsal buccal urethroplasties increased by 95%, and the number of ventral buccal urethroplasties increased by 75%.

The use of free skin flaps and skin flaps on the pedicle (Flap) has also decreased over time. According to Dubey, the results of treatment of 27 patients who underwent urethroplasty using skin flaps on the pedicle and 28 patients after buccal urethral plasty were analyzed since 2007. The success rate in these two groups was 87% and 90%, respectively. The patient satisfaction rate in the skin flap group was 64% and in the BPU group was 89%. Patients also reported dribbling in 9 patients in the skin flap group versus 4 cases in men after buccal urethral plastic surgery [12]. According to another study by Martins *et al*, the success rate of urethroplasty using pedicle skin flaps (Orandi Flap, McAninch Flap) was 77% with a follow-up time of 99 months [9].

Postoperative complications

To assess postoperative complications in the second stage of the study, patients were regrouped. The fourth group ($N = 108$) included patients after urethroplasty during 2005–2024 and they had complications in the postoperative period according to the Clavien-Dindo classification of class 0–I, the fifth group ($N = 36$) included patients with postoperative complications of class II–IIIa according to Clavien-Dindo; the sixth group ($N = 30$) with postoperative complications according to the Clavien-Dindo classification of class IIIb–IV.

Table 3. Complications in groups 1, 2 and 3.

Patients with relevant complications	Group 1 UUA (*N* = 69)	Group 2 BMGUP (*N* = 89)	Group 3 SFUP (*N* = 16)	χ^2 Pearson	*P*-value
Gross hematuria (%)	5 (7.2)	7 (7.9)	2 (12.5)	0.493 (df = 2)	*P* = 0.782
Perineal and/or cheek hematoma (%)	6 (8.7)	9 (10.1)	—	0.090 (df = 1)	*P* = 0.763
Wound infection and secondary tension healing (%)	6 (8.7)	5 (5.6)	—	0.568 (df = 1)	*P* = 0.451
Penile skin necrosis, without necrectomy (%)	—	—	4 (25.0)	—	—
Bladder hemotamponade (%)	4 (5.8)	4 (4.5)	—	0.137 (df = 1)	*P* = 0.711
Scrotal hematoma, with wound revision (%)	4 (5.8)	6 (6.7)	—	0,059 (df = 1)	*P* = 0.809
Penile skin necrosis with necrectomy (%)	—	—	5 (31.3)	—	—
Recurrence of urethral stricture with urethrotomy (%)	6 (8.7)	9 (10.0)	—	0.091 (df = 1)	*P* = 0.763
Necrosis of the buccal flap (%)	—	3 (3.4)	—	—	—
Urethral necrosis (%)	1 (1.4)	1 (1.1)	—	0.033 (df = 1)	*P* = 0.856
Recurrence with repeat urethroplasty (%)	14 (20.3)	7 (7.9)	4 (25.0)	19.24 (df = 2)	*P* = 0.01*

Group 4 included patients without postoperative complications and with class I complications: macrohematuria, perineal hematoma and hematoma in the area of buccal graft removal that did not require surgical treatment, postoperative wound infection and wound healing with secondary tension, acute orchoepididymitis, penile skin necrosis that did not require surgical treatment.

Group 5 included patients with postoperative complications of Clavien-Dindo class II–IIIa: bladder hemotamponade, scrotal hematoma requiring opening and surgical revision of the postoperative wound, urinoma, penile skin necrosis requiring necrotectomy, recurrence of SU requiring internal optical urethrotomy.

Group 6 included patients with postoperative complications of Clavien-Dindo class IIIb–IV: necrosis and rejection of the buccal flap, urethral necrosis, recurrence of SU or obliteration requiring repeated urethroplasty. In our study, the number of events (complications) corresponds to the number of patients.

As can be seen from Table 3, there is no statistically significant difference in the number of detected postoperative complications. In group 1, macrohematuria was present in 5 (7.2%) patients, in group 2–7 (7.9%) patients, in group 3 there were 2 (12.5%) such patients (χ^2 = 0.493, df = 2; *P* = 0.782). Treatment of macrohematuria was not carried out. Perineal hematoma occurred in 6 (8.7%) patients in group 1, and 9 (10.1%) patients in group 2 (χ^2 = 0.090, df = 1; *P* = 0.763). In patients in group 3, this type of complication was not detected. Infection of the wound and wound healing by secondary tension were observed in 6 (8.7%) patients in group 1, and in 9 (10.1%) patients in group 2, in group 3 such a complication was not observed in patients (χ^2 = 0.568, df = 1; *P* = 0.451). Only 4 (25.0%) patients in group 3 had necrosis of the skin of the penis, which did not require necrectomy. Hematotamponade of the bladder occurred in 4 (5.8%) patients in group 1 and 4 (4.5%) patients in group 2 (χ^2 = 0.137, df = 1; *P* = 0.782). These patients underwent hemotamponade washing. In patients included in group 3, such a complication was not observed.

Hematoma of the scrotum and perineum, which required opening and revision, was present in 4 (5.8%) patients of group 1 and 6 (6.7%) patients of group 2 (χ^2=0.059, df = 1; *P* = 0.809). In group 3, such a complication was not detected. However, only in group 3 patients was necrosis of the skin of the penis observed with the need for further necrotectomy: there were 5 (31.3%) such cases.

In case of recurrence of urethral narrowing, which was up to 1.5 cm in length (such narrowing was most often localized at the site of fixation of the buccal flap with normal urethral mucosa), internal urethrotomy was performed. In group 1, there were 6 (8.7%) such patients, and in group 2, there were 9 (10.1%), in group 3, complications of this type were not observed (χ^2 = 0.091, df = 1; *P* = 0.763).

Buccal flap necrosis was observed only in group 2, affecting 8 patients (9.0%). The incidence was 1.4% in group 1 and 1.1% in group 2 (χ^2 = 0.033, df = 1; *P* = 0.856).

Recurrence of urethral stricture/obliteration, which required repeated urethral reconstruction, was classified as class IV complications according to the Clavien-Dindo classification. In group 1 there were 14 such cases (20.3%). In group 2–7 (7.9%), and in group 3–4 (25.0%). And a significant difference was found between the studied groups (χ^2 = 19.24, df = 2; *P* = 0.01). This result confirms the calculated and indicated above rate of urethroplasty failure, which indicates a significantly lower failure rate of BMGUP (group 2) than UUA (group 1) and SFUP (group 3) (*P* = 0.023 for group 1 *vs.* 2; *P* = 0.039 for group 2 *vs.* 3).

Comparison by complication severity

Table 4 presents a comparison of patients in groups 4, 5, and 6 according to clinical indicators. When determining and distributing SU by localization, it was found that there

Table 4. Clinical, anamnestic and operational indicators of groups 4, 5 and 6.

Indicators	Group 4 Clavien 0–I (*N* = 108)	Group 5 Clavien II–IIIa (*N* = 36)	Group 6 Clavien IIIb–IV (*N* = 30)	χ^2 Pearson F Fisher	*P*-value
Localization					
Penile (%)	20 (18.5)	15 (41.7)	5 (16.7)	$\chi^2 = 16.5$ (df = 6)	$P = 0.011^*$ $P = 0.012^*$ for group 4 *vs*. 5 $P = 0.194$ for group 4 *vs*. 6 $P = 0.062$ for group 5 *vs*. 6
Bulbar (%)	66 (61.1)	19 (52.8)	18 (60.0)		
Membranous (%)	20 (18.5)	1 (2.8)	4 (13.3)		
Prostatic (%)	2 (1.8)	1 (2.8)	3 (10.0)		
Length					
2 cm (%)	5 (4.6)	2 (5.6)	0 (0.0)	$\chi^2 = 2.27$ (df = 4)	$P = 0.685$ $P = 0.687$ for group 4 *vs*. 5 $P = 0.477$ for group 4 *vs*. 6 $P = 0.373$ for group 5 *vs*. 6
2-7 cm (%)	46 (42.6)	18 (50.0)	14 (46.7)		
7 cm (%)	57 (52.8)	16 (44.4)	16 (53.3)		
Type of plastic					
UUA (%)	39 (36.1)	10 (27.8)	16 (53.3)	$\chi^2 = 2.27$ (df = 4)	$P = 0.110$ $P = 0.433$ for group 4 *vs*. 5 $P = 0.119$ for group 4 *vs*. 6 $P = 0.026^*$ for group 5 *vs*. 6
BMGUP (%)	59 (54.6)	24 (66.7)	10 (33.3)		
SFUP (%)	10 (9.3)	2 (5.6)	4 (13.3)		
Etiology					
Iatrogenic (%)	24 (22.2)	11 (30.6)	4 (13.3)	$\chi^2 = 3.28$ (df = 4)	$P = 0.511$ $P = 0.540$ for group 4 *vs*. 5 $P = 0.519$ for group 4 *vs*. 6 $P = 0.196$ for group 5 *vs*. 6
Post-traumatic (%)	58 (53.7)	16 (44.4)	19 (63.3)		
Post-inflammatory (%)	26 (24.1)	9 (25.0)	7 (23.3)		
Average age (years)	41.3 ± 17.4	48.1 ± 15.9	46.3 ± 16.2	$F = 2.70$	$P = 0.070$ $P = 0.111$ for group 4 *vs*. 5 $P = 0.357$ for group 4 *vs*. 6 $P = 0.908$ for group 5 *vs*. 6
Average duration of disease (years)	6.1 ± 8.5	6.9 ± 9.3	7.1 ± 8.6	$F = 0.23$	$P = 0.793$ $P = 0.885$ for group 4 *vs*. 5 $P = 0.849$ for group 4 *vs*. 6 $P = 0.996$ for group 5 *vs*. 6
Presence of epicystostoma	70 (64.8)	26 (72.2)	25 (83.3)	$\chi^2 = 3.95$ (df = 2)	$P = 0.138$ $P = 0.414$ for group 4 *vs*. 5 $P = 0.053$ for group 4 *vs*. 6 $P = 0.203$ for group 5 *vs*. 6
Average stricture length (cm)	4.3 ± 3.1	4.8 ± 4.0	5.8 ± 4.9	$F = 2.09$	$P = 0.127$ $P = 0.725$ for group 4 *vs*. 5 $P = 0.135$ for group 4 *vs*. 6 $P = 0.574$ for group 5 *vs*. 6
Average bed-day (day)	12.1 ± 7.1	13.6 ± 8.4	17.3 ± 10.1	$F = 4.87$	$P = 0.009^*$ $P = 0.646$ for group 4 *vs*. 5 $P = 0.009^*$ for group 4 *vs*. 6 $P = 0.177$ for group 5 *vs*. 6
Average operation time (min)	163.6 ± 62.7	153.2 ± 52.9	166.0 ± 73.8	$F = 0.45$	$P = 0.641$ $P = 0.694$ for group 4 *vs*. 5 $P = 0.983$ for group 4 *vs*. 6 $P = 0.713$ for group 5 *vs*. 6
Average urethral drainage time (days)	18.9 ± 7.1	21.1 ± 7.4	19.8 ± 6.7	$F = 1.31$	$P = 0.273$ $P = 0.283$ for group 4 *vs*. 5 $P = 0.817$ for group 4 *vs*. 6 $P = 0.777$ for group 5 *vs*. 6
Blood loss (mL)	137.2 ± 72.4	135.0 ± 81.5	126.7 ± 56.8	$F = 0.25$	$P = 0.777$ $P = 0.987$ for group 4 *vs*. 5 $P = 0.778$ for group 4 *vs*. 6 $P = 0.896$ for group 5 *vs*. 6

Note: Pearson's χ^2 (df - number of degrees of freedom) and analysis of variance (ANOVA) with Scheffe's correction for multiple comparisons were used to determine intergroup statistical significance; * - the difference between groups is statistically significant.

was a statistically significant difference between groups 4 and 5. That is, in group 4 there were significantly more patients with SU localized in the bulbar department and significantly fewer SU localized in the penile department (χ^2 = 16.5, df = 6; *P* = 0.011; *P* = 0.012 for group 4 *vs*. 5). Accordingly, class 0–I complications occurred more often with SU localization in the bulbar department (61.1%), and complications of class II–IIIa according to Clavien-Dindo occurred significantly more often with localization in the penile department (41.7%). No significance difference was found in localization when comparing other studied groups 4 and 6 (*P* = 0.194), and groups 5 and 6 (*P* = 0.062).

Patients in the study groups were divided into groups according to the length of their urethral strictures and obliterations. No significant difference was found in the intergroup comparison (χ^2 = 2.27, df = 4; *P* = 0.685; *P* = 0.687 for group 4 *vs*. 5; *P* = 0.477 for group 4 *vs*. 6; *P* = 0.373 for group 5 *vs*. 6).

Further comparison by type of urethroplasty performed on patients revealed a significant difference between groups 5 and 6 (χ^2 = 2.27, df = 4; *P* = 0.110; *P* = 0.026 for group 5 *vs*. 6). Accordingly, patients who had complications of class II–IIIa in the postoperative period underwent significantly more frequent BMGUP (66.7%) and significantly less frequent SFFP (5.6%) than patients who had complications of class IIIb–IV. No significant difference by urethroplasty type was found between groups 4 and 5 (*P* = 0.433) or between groups 4 and 6 (*P* = 0.119).

The average age of patients in group 4 was 41.3 ± 17.4 years, in patients in group 5 was 48.1 ± 15.9 years, and in group 6 the average age was 46.3 ± 16.2 years. No significant difference was found when comparing the groups (*F* = 2.70; *P* = 0.070; *P* = 0.111 for group 4 *vs*. 5; *P* = 0.357 for group 4 *vs*. 6; *P* = 0.908 for group 5 *vs*. 6). The same conclusion was reached when comparing the average duration of the disease in the studied groups.

In group 6, the average SU length was the largest at 5.8 ± 4.9 cm; in group 4, it was 4.3 ± 3.1 cm; and in group 5, it was 4.8 ± 4.0 cm. No significant difference was found when comparing the average length of the SU (*F* = 2.09; *P* = 0.127; *P* = 0.725 for group 4 *vs*. 5; *P* = 0.135 for group 4 *vs*. 6; *P* = 0.574 for group 5 *vs*. 6).

The result we obtained of a statistically significant difference in the average postoperative bed-day in group 4 and group 6 is quite clear (*F* = 4.87; *P* = 0.009). When

Table 5. Prognostic assessment of individual clinical parameters for the risk of developing postoperative complications of class IIIb–IV according to Clavien-Dindo in comparison with Clavien 0–I and Clavien II–IIIa, (odds ratio [OR] and 95% confidence interval).

Parameters	Clavien IIIb–IV/Clavien 0–I	Clavien IIIb–IV/Clavien II–IIIa
Localization		
Penile	0.88 (0.3–2.8)	0.28 (0.09–0.9)*
Bulbar	0.96 (0.42–2.18)	1,34 (0.5-3.58)
Membranous	0.68 (0.21–2.16)	5,39 (0,57-51,05)
Prostatic	5.89 (0.94–37.02)*	3,89 (0.38-39.5)
Length		
Up to 2 cm	0.31 (0.02–5.74)	0.23 (0.01–4.9)
2-7 cm	1.18 (0.52–2.66)	0,88 (0.33–2.31)
more than 7 cm	1,02 (0.46–2.3)	1,43 (0.54–3.78)
Type of plastic		
UUA	2.02 (0.89–4.58)	2.97 (1.07–8.26)
BMGUP	0.42 (0.18–0.97)*	0,25 (0.09–0.7)*
SFUP	1.51 (0.44–5.2)	2.62 (0.44–15.39)
Etiology		
Iatrogenic	0.54 (0.17–1.69)	0.35 (0.1–1.24)
Post-traumatic	1.49 (0.65–3.43)	2,16 (0.8–5.82)
Post-inflammatory	0.96 (0.37–2.49)	0,91 (0.29–2.84)
Age		
Up to 45 years old	0.22 (0.09–0.54)*	0.38 (0.14–1.06)
Over 45 years old	4.48 (1.86–10.75)*	2.61 (0.94–7.22)
Average urethral drainage time		
up to 17 days	0.59 (0.26–1.33)	0.77 (0.29–2.03)
more than 17 days	1.7 (0.75–3.84)	1.31 (0.49–3.46)
Duration of the disease		
up to 7 years	0.24 (0.1–0.59)*	0.43 (0.16–1.19)
more than 7 years	4.16 (1.7–10.19)*	2.33 (0.84–6.46)

Note: An asterisk (*) indicates a statistically significant difference (*P* < 0.05). UUA = urethrourethroanastomosis; BMGUP = buccal mucosa graft urethroplasty; SFUP = skin flap urethroplasty.

postoperative complications of class IIIb–IV according to the Clavien-Dindo classification occur, the patient stays in the hospital longer than patients without complications. No significant difference in postoperative hospital stay was found between groups 4 and 5 ($P = 0.646$) or between groups 5 and 6 ($P = 0.177$).

According to the study design, a comparative prognostic assessment of clinical parameters of patients without and with early or late postoperative complications was conducted in order to identify probable risk factors for their development. The complications were classified according to Clavien-Dindo and divided into appropriate groups with subsequent calculation of odds ratio (OR) and 95% confidence interval.

Risk factors for severe complications and limitations

The results of the prognostic assessment of individual clinical parameters of the studied groups of patients are presented in Table 5. According to Table 5, when SU is localized in the prostatic urethra, the risk of developing complications of Clavien IIIb–IV increases by 5.89 times compared to complications of Clavien 0–I, and by 3.89 times compared to the Clavien II–IIIa group. The estimate of this indicator is statistically significant (95% CI: 0.94–37.02). SU localized in the penile, bulbar and membranous departments form a tendency to reduce the risk of complications of 12%, 4% and 32%, respectively. For a more visual presentation of the calculation of risks and their confidence intervals, Figure 1 was formed, which graphically presents the results of comparing the risks of complications of Clavien IIIb–IV and Clavien 0–I.

The length of the SU of 2–7 cm and more than 7 cm form

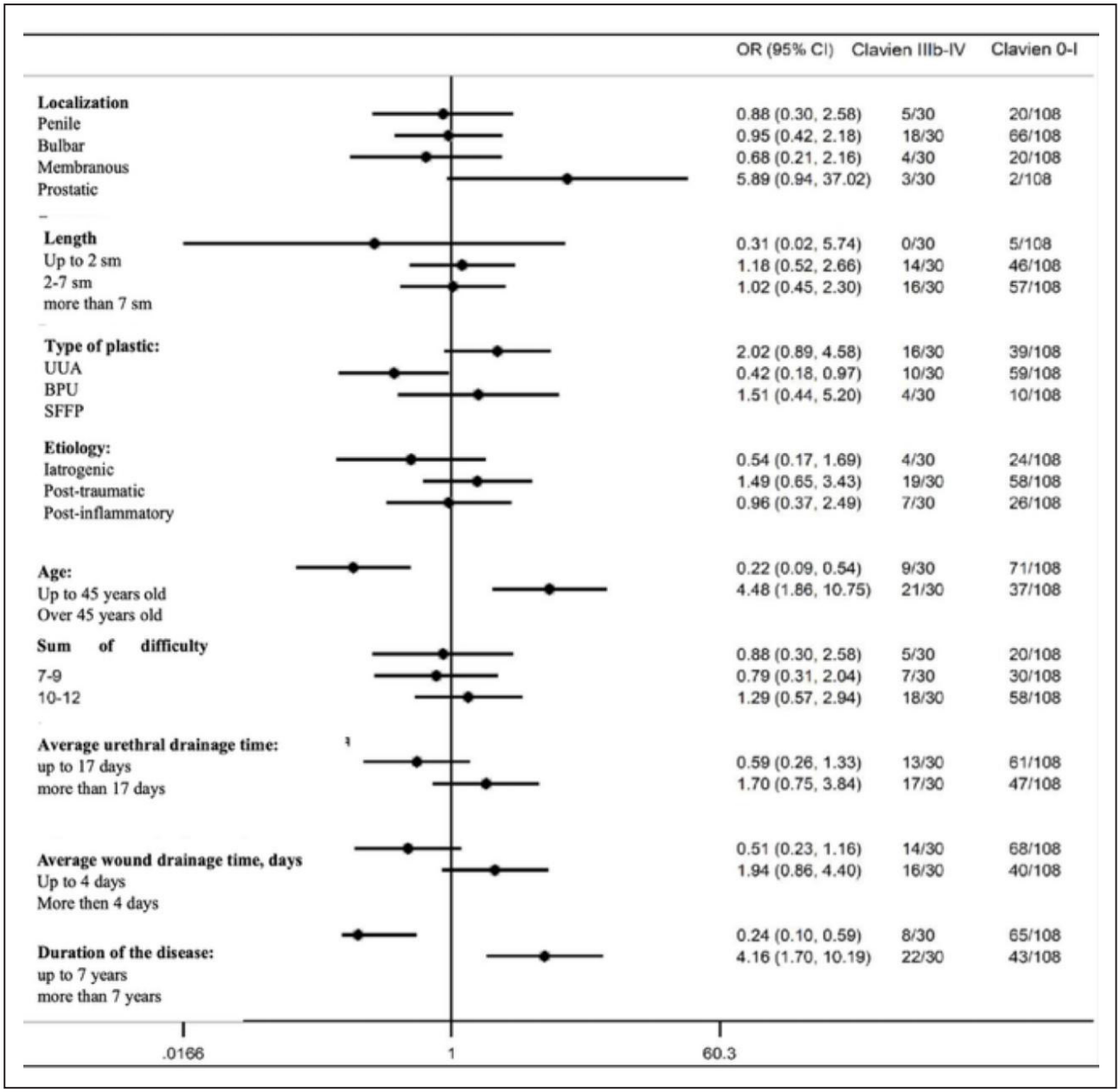

Figure 1. Prognostic assessment of individual clinical parameters for the risk of developing Clavien IIIb-IV compared with Clavien 0-I (OR and 95% confidence interval).

a tendency to increase the risk of Clavien-Dindo IIIb–IV complications compared to the risk of Clavien-Dindo 0–I complications by 1.18 and 1.02 times, respectively. And with the length of the SU up to 2 cm, on the contrary, there is a tendency to reduce the risk of Clavien-Dindo IIIb–IV complications by 69% compared to the risk of Clavien-Dindo 0–I complications.

When comparing the risks for the respective type of urethroplasty performed, it was found that the risk of Clavien-Dindo IIIb–IV complications is 58% lower than that of Clavien-Dindo 0–I complications when performing BMGUP (the result is probable, 95% CI: 0.18–0.97). And when performing UUA and SFUP, there is a tendency to increase the risk of Clavien-Dindo IIIb–IV complications by 2.02 (95% CI: 0.89–4.58) and 1.51 times, respectively (95% CI: 0.44–5.2).

When considering the etiological factor, there is only a tendency to reduce the risk of Clavien-Dindo class IIIb–IV complications, compared with class 0–I complications by 46% and 4% for iatrogenic (95% CI: 0.17–1.69) and post-inflammatory SU (95% CI: 0.37–2.49), respectively. On the contrary, it was found that for such a clinical parameter as "post-traumatic SU" there is a tendency to increase the risk of Clavien IIIb–IV complications by 1.49 times (95% CI: 0.65–3.43).

The risk of class IIIb–IV complications is statistically significantly increased by 4.48 times when the patient is over 45 years old (95% CI: 1.86–10.75) and significantly decreased by 78% when the patient with SU is under 45 years old (95% CI: 0.09–0.54), compared to the group of patients without complications (Table 5 and Figure 1).

To determine the optimal period of urethral drainage, a clinical criterion such as "average urethral drainage time" was evaluated. At the same time, for its ranges "up to 17 days" and "more than 17 days" no significant difference in the risk of Clavien-Dindo IIIb–IV complications was found compared to the group of patients with class 0–I complications.

There was only a tendency to reduce the risk of complications IIIb–IV by 41% when the urethral drainage was up to 17 days and a 1.7-fold increase in the risk of complications IIIb–IV class, when the urethra was drained for longer than 17 days (95% CI: 0.26–1.33, 0.75–3.84), respectively.

Similar to the existing significant difference in the age of patients for the risk of developing complications of Clavien-Dindo IIIb–IV, there is the same significant difference in the duration of the disease in the patients of the studied groups. With a duration of the disease up to 7 years, the risk of complications of Clavien-Dindo IIIb–IV, compared with complications of Clavien-Dindo 0–I, is significantly reduced by 76% (95% CI: 0.1–0.59). Whereas, with a disease duration of more than 7 years, the risk of Clavien IIIb–IV complications significantly increases by 4.16 times (95% CI: 1.7–10.19).

Conclusions

It was found that patients who underwent BMGUP and SFUP, compared with UUA, had significantly greater length and complexity of strictures, namely 5.9 ± 4.2 cm and 8.4 ± 1.5 points for BMGUP, 5.3 ± 3.9 cm and 8.0 ± 1.6 points for SFUP versus 1.9 ± 1.9 cm and 6.3 ± 2.4 points for UUA ($P = 0.001$).

The success rate of BMGUP (group 2) is statistically significantly higher compared with UUA (group 1) and SFUP (group 3) by 12.4% and 17.1%, respectively ($P = 0.039$). Postoperative complications of class IIIb–IV occur significantly more often by 7.7% in patients after SFUP ($P = 0.026$).

Localization of SU in the prostatic region on average significantly causes 5.89 times more severe complications (Class IIIb–IV according to Clavien-Dindo) (95% CI: 0.94–37.02), and with penile localization of SU such complications occur 72% less often (95% CI: 0.09–0.9).

Performing BMGUP causes a 58% reduction in the risk of developing Clavien-Dindo IIIb–IV complications (95% CI: 0.18–0.97). The following risk factors for complications of surgical treatment of strictures and obliterations are the duration of the disease for more than 7 years (4.16 times, 95% CI: 1.7–10.19).

The results obtained in the retrospective analysis of clinical data can be considered a basic assessment of risk factors (pilot result), therefore, to eliminate the concordance of factors and determine the independence of the relationship, it is advisable to conduct further analysis by conducting prospective clinical studies with a clear program and registration of certain stratification features, time intervals and sequence of detection of individual complications in patients.

Declarations

Availability of data and materials: Not applicable.

Financial support and sponsorship: None.

Conflicts of interest: Not applicable.

Ethical approval and informed consent: This retrospective study was conducted in accordance with the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Ethics Committee of the State Institution "Academician O.F. Vozianov Institute of Urology NAMS of Ukraine" (Kyiv, Ukraine). All patients provided written informed consent for treatment (primary medical record form No. 003-6/o).

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Cite this article as: Shamrayev S, Ridchenko M, & Shamraieva D. Comparative evaluation of results, frequency of complications and identification of risk factors for their development of different types of urethroplasty in patients with urethral strictures. *Uro-Technology Journal*, 2026, 10(2): 36-46. doi: 10.31491/UTJ.2026.06.058