INTRODUCTION

Urethral stricture is a partial or complete narrowing of the urethra, caused by damage to the urethral epithelium. This condition leads to a persistent urination dysfunction, the elimination of which is a difficult task. Until the 20th century, two main types of urethral strictures were mostly discussed – infectious and traumatic. Currently, the main cause of urethral damage is considered to be iatrogenic trauma [1]. The problem of stricture disease treatment remains extremely relevant in the past and present.

Because of iatrogenic injuries, as well as distraction defects, first of all, the membranous part and the bulbomembranous junction are damaged [1, 2, 3]. To define the proximal part of the bulb and membranous parts of the urethra, the authors use the term ‘bulbomembranous urethra’ (BMU).

Knowledge of the surgical anatomy of the BMU and the structures surrounding it helps to minimize intraoperative injuries. Adverse damage to the muscles of the perineum or the distal urinary sphincter can lead to urinary incontinence [4]. Desvascularization and denervation of the urethra can lead to...
Although there is much awareness about the likelihood of the negative effects of urethroplasty, little attention is paid to the development of methods for their prevention. Researchers are focused on finding methods for subsequent treatment, rather than preventing the occurrence of negative conditions. Currently, patients at risk for postoperative incontinence, shortening of the penis or impotence are warned about the possible need for subsequent implantation of an artificial urinary sphincter, penile prosthesis or further complex surgical correction. Based on the literature analysis of the results of the currently used BMU lesions treatment methods, a number of conclusions can be made. Firstly, DVIU is an ineffective and dangerous operation that can aggravate the course of the disease and worsen the results of subsequent treatment. Secondly, there is a significant group of patients for whom the anastomotic or replacement plastic surgery can lead to negative consequences due to damage to the anatomical structures of the perineum (perineal muscles, urethral sphincter mechanism, vessels and nerves of the urethra and penis). Thirdly, the methods of existing substitutional urethroplasty are inferior in efficiency to anastomotic operations or are not available in everyday urological practice due to technical reasons (regenerative surgery).

Damage in the proximal part of BMU is relatively rare, but this is a severe pathology that determines the subsequent development of a number of complications such as chronic urinary retention, urinary infection, uremia, and even death. The use of some existing methods of surgical treatment of this pathology can lead to a number of complications such as shortening of the penis, urinary incontinence, and erectile dysfunction.

Thus, there is an urgent need to improve existing methods and develop new more effective methods of treatment for patients with narrowing of the proximal part of the bulbar and membranous parts of the urethra. The authors have developed and implemented an alternative method of magnifying plastic surgery of the BMU, which has demonstrated comparable effectiveness with less risk of complications [25].

The aim of this study was a comparative analysis of the immediate and long-term results of the treatment of patients with narrowing of the proximal part of the bulbar and membranous parts of the urethra using the author’s magnifying and anastomotic methods of plastic surgery.

**MATERIAL AND METHODS**

The clinical research was approved by the local ethics committees of The Ministry of Health of the Rus-
sian Federation “Irkutsk State Medical University” and the Regional State Autonomous Healthcare Institution “Irkutsk City Clinical Hospital No. 1”.

A prospective, blind, randomized, single-center study was performed in the urological hospital at Irkutsk City Clinical Hospital No. 1.

The clinical part of the study includes an analysis of the examination and treatment results of patients who underwent surgical procedures for strictures (narrowing) of the bulbomembranous urethral part from April 2012 to February 2018.

Plastic surgeries were performed by the method of urethral anastomosis after excision of the affected area (EPA) or by the developed method of magnification substitutional intraurethral grafting (BMG) with a buccal graft [16]. The proposed method relates to methods of replacement and magnifying urethroplasty using autotransplants [25].

**Study participation criteria**

The criteria for inclusion in the study were:

- The patient is scheduled for plastic surgery for urethral stricture;
- Urethral stricture is localized in the proximal part of the bulbar and / or membranous parts of the urethra;
- Patients are older than 18 years old;
- The patient signed a voluntary informed agreement to participate in the study;
- The patient is deliberately planning to perform urethroplasty using a method determined randomly until the day of operation

**Exclusion Criteria:**

- Strictures of the anterior urethra;
- The patient did not sign a voluntary informed agreement to participate in the study;
- The presence of benign prostatic hyperplasia (BPH), significantly affecting urodynamics;
- Complete distraction defect of the urethra;
- The patient refused to participate at any stage of the study;
- Due to any reason, the patient has not undergone a demanding operation or performed another operation that does not fit the criteria of the group.

**Study groups characteristics**

The selection of patients for the study who fit the inclusion criteria was carried out prospectively by the continuous sampling method until the desired quantity was achieved. Over the specified period of time, 272 patients were diagnosed with urethral stricture. Among them, 102 patients fit the criteria for inclusion in the study. All included patients were randomly divided into two groups according to the approved study protocol. EPA was performed in patients of the first group, and BMG for the second group.

Of 102 patients initially included in both groups, 39 were subsequently excluded from the study. Out of the group of patients excluded from the study, 23 dropped out due to deviations from the study protocol, and 16 – due to personal reasons.

During the postoperative period, 10 patients from Group I (26.3%) and 6 patients from Group II (14.6%) refused to participate in the study. The completeness of clinical observation for Group I was 73.6%, and for Group II – 85.3%. The analysis of the effectiveness of postoperative observation demonstrated its comparability in both groups (p = 0.293). The clinical case was assessed as lost for observation when the patient missed the examination within three months from the time of operation – the first checkpoint. If the patient refused to continue the study after this checkpoint, he was considered to have completed the study.

Thus, 63 patients who fit all of the study criteria were included in the final clinical analysis. Two groups of patients were formed. Patients who underwent EPA were assigned to Group 1 (n = 28) and patients who underwent BMG were assigned to Group 2 (n = 35).

Table 1 presents the comparative data on the initial parameters of patients in the study groups.

**Analysis / Diagnostic methods**

During the examination, anamnestic (in order to establish a possible cause and duration of the disease), clinical, biochemical, radiological, ultrasound, magnetic resonance, and endoscopic research methods were used.

Evaluation of the quality of life, erectile function, the lower urinary tract symptoms and the severity of pain was carried out by patients independently using standard questionnaires and the visual analogue scale.

To clarify the nature and extent of pathological changes in the urethra, uroflowmetry, urethrography, urethrocystoscopy, or urethral calibration were performed for all patients. In doubtful cases, additional multislice computed tomography (MSCT) or magnetic resonance imaging (MRI) urethrography with 3D image reconstruction was performed for the final verification of the diagnosis.

In the three-month period after the operation, at least once every six months or once a year all patients passed the standard assessment established by the
protocol of the study: urological consultation, clinical blood and urine tests, urethrography, urethroscopy, uroflowmetry, and ultrasound. The patients’ subjective conditions were also assessed using the international prostate symptom score (IPSS), quality of life (QoL), and international index of erectile function (IIEF-5) scales. Patient complaints were recorded.

The treatment effectiveness was evaluated according to several criteria: the maximum urine flow rate (by uroflowmetry), the diameter of the urethral lumen in the operating zone (urethrography), the volume of residual urine (ultrasound), and rating scale indicators (IPSS, QoL and IIEF-5).

The treatment results were evaluated based on a comprehensive analysis of the parameters of all primary and secondary endpoints. Absence of relapse and adequate urination do not give an accurate image of the patient’s quality of life after surgery. Therefore, the interpretation of the results requires consideration of all factors. The treatment results were divided into three groups, the scheme is presented in Table 2.
Data analysis

The initial data and the results of surgical treatment were analyzed using the STATISTIKA software for Windows version 10.0 (Statsoft Inc, USA), SPSS Statistics version 23.0 (IBM, USA) and Stata version 14.2 (StataCorp, USA).

A comparative analysis of the examination results and surgical treatment was performed in two groups, conventionally designated: Group I (EPA) and Group II (BMG). The comparison was performed using the combined endpoint method.

Intraurethral plastic surgery technique

The intraoperative urethrocystoscopy or urethral catheter helped to determine the distal end of urethral narrowing. The spongious body and urethra were dissected in stages in the bulbomembranous physiological bend projection, but distal to the urethral lumen narrowing. The length of urethrotomic access was 2–3 cm (Figure 1).

The narrowed part of the urethra was dissected ventrally with little penetration beyond the urethra into the muscle thickness. Then, the scar-modified urethral tissue was excised in the ventral semicircle between five to seven o’clock (according to the standard dial). A graft site was formed within the excised scar tissue of the urethra. The proximal and distal borders of the formed site were 10 mm within the unchanged urethral tissues (Figure 2).

The adequacy of the urethral lumen was checked by inserting a 24 Fr catheter into the bladder. An oral mucosa graft was used as replacement material, and was harvested according to the standard method. The shape and size of the graft correlates to the parameters of the bed formed for its transplantation.

The oral graft was fixed without tension in the urethra bed by successive sewing with separate nodal sutures (absorbable suture material 4/0). After the proximal part graft fixation with triangular vertexes (the tab method), it was sewn through the center to the underlying structures, which allows the exclusion of the formation of a pathological cavity (Figure 3). The intraoperative urethroscopy and magnifying optics helped to control the quality of the surgical suture.

Then, a 16–18 Fr Foley urethral catheter was inserted into the bladder and its balloon inflated to 5–10 ml. In some cases, additional suprapubic drainage was used. The distal part of the graft was pierced and fixed with Onlay method (Figure 4).

To exclude the formation of a pathological cavity, separate nodal sutures with suturing of the sub-mucosal graft base closed the urethrotomic access (Figure 5) were performed.

Postoperative period

During the operation, in order to facilitate the subsequent mobilization of the urethra, urethrocystoscopy with a flexible conductor or urethral catheter was performed. To control the quality of the surgical suture during the transplant fixation, urethroscopy was used.

After the operation, patients remained in the intensive care unit for 3–6 hours. Infusion therapy was carried out during the first 24-48 hours. Antibacterial therapy, analgesia (non-steroidal or narcotic analgesics), prophylaxis of thromboembolic complications (low molecular weight heparins), protection against stress ulcers (proton pump inhibitors) was administered, and to eliminate the discomfort of urethral drainage, alpha-blockers were used ad-

Figure 1. Urethrotomic access.

Figure 2. The scar tissue excision, formation of a bed for buccal graft transplantation.
On the first day after surgical treatment, the severity of postoperative pain was assessed according to the visual analogue scale (VAS). During the postoperative period, in the absence of contraindications from the second or third day after the operation, 5–10 sessions of hyperbaric oxygenation were performed in a mode of 1–1.5 atmosphere for 40–45 minutes. Hyperbaric oxygenation helped to improve the probability of BMG engraftment and improve reparative processes. Drugs that improve microcirculation (Trental), wound healing (Solcoseryl), and also fibrinolytic therapy (Longidase) were prescribed.

Bladder drainage was performed with a 16–18 Fr silicone urethral catheter. The urethral catheter was removed 10–14 days after surgery for patients in Group II, and after 14–21 days – for patients in Group I.

**Treatment results evaluation**

There were several criteria to evaluate the treatment effectiveness: the maximum rate of urine flow (by uroflowmetry), the diameter of the urethral lumen in the operation zone (urethrography and urethral calibration), the volume of residual urine (ultrasound), evaluation scales indicators (IPSS, QoL and IIEF-5). After 3 months or more after surgery, the following treatment results were considered successful: Qmax of more than 12 ml/sec; absence of residual urine or signs of relapse according to urethrography (the normal diameter of the urethral lumen 5 mm or more); absence of severe symptoms of the lower urinary tract, satisfactory quality of life.
RESULTS

Preoperative parameters

The average age of patients in groups I and II were 55.5 ± 17.02 and 58.17 ± 12.2 years, respectively (p = 0.329). All patients were male. The median index of disease duration in groups I and II were 2.0 (0.9; 8.25) and 5 (1.3; 13) years, respectively, and did not differ significantly (p = 0.154).

Among the concomitant diseases, the most common pathology was a urinary tract infection, noted in 71.4% and 82% of cases in groups I and II, respectively (p = 0.7). The frequency of other concomitant diseases occurrence, as well as other baseline indicators in both groups, did not differ statistically (p >0.05).

The subjective condition of patients and their functional status are presented in Table 3.

An analysis of anamnestic data revealed 13 possible etiological factors for the urethral stricture formation for 13 patients of the first group (46.4%) and 21 patients of the second group (60%) (p = 0.554). Previous surgical treatment of urethral stricture had 18 patients of the first group (64.2%) and 28 patients of the second group (80%) (p = 0.579).

According to the complaints analysis, medical records and uroflowmetry, all patients in the first and second groups had urination disorders (Qmax less than 12 ml/sec), and in some cases, there was no independent urination. In the first group, the absence of independent urination was reported by 4 patients (14.2%), in the second – by 7 (20%) patients (p = 0.617). In this case, symptoms of the lower urinary tract (LUTS) were evaluated with a maximum rate (35 points) to avoid confusion in the statistical analysis.

Table 4 presents the comparative data of the objective examination results in both groups.

Analysis of the obtained data showed that urethral stricture in patients of both comparison groups was characterized by extended, subtotal and total obliteration of the lumen with the development of a significant volume of residual postvoid urine, a critical decrease in the maximum urine flow rate and a mixed component of obstruction.

Thus, the comparability of the main characteristics of patients in both groups was established (p >0.05).

Treatment results

For a comparative assessment of the immediate results of urethral stricture disease surgical treatment after anastomotic operations (group I) and intra-urethral substitutional operations (group II), a comparative analysis of the postoperative parameters of the patients’ condition and the final results of the study was performed.

An intergroup analysis of the surgical access sizes showed that its average linear sizes in Group I was 8.4 ± 0.9 cm, which significantly (p <0.001) exceeds the measurement results (3.9 ± 0.7 cm) in Group II. In the early and late postoperative period, there were no cases of mortality in both groups. Chronometric analysis of the operating period and the intensive care unit (ICU) period was performed. The average length of stay in the ICU was 3.3 ± 0.8 and 3.0 ± 0.0 hours for groups I and II, respectively (p = 0.017). The average duration of surgical intervention in groups I and II were 1.4 ± 0.41 hours and 1.7 ± 0.49 hours, respectively (p = 0.354).

In the early postoperative period, there were no complications from the anesthesiologic procedure or deterioration in general somatic status.

Table 3. Assessment of the subjective condition of patients

| Parameter | Group I (n = 28) | Group II (n = 35) | P |
|-----------|-----------------|-----------------|---|
| Erection-suppressing medications, n (%) | 11 (39.2) | 17 (38.3) | 0.646 |
| Treatment with a-blockers, n (%) | 12 (42.8) | 8 (22.8) | 0.225 |
| IPSS, points, Me (IR 25; 75) | 28 (24; 30) | 33 (24; 31) | 0.564 |
| QoL, points, Me (IR 25; 75) | 5 (4; 5) | 5 (4; 5) | 0.658 |
| IIEF-5, points, Me (IR 25; 75) | 12 (7; 14) | 14 (8; 16) | 0.595 |

IPSS – international prostate symptom score; QoL – the quality of life scale; IIEF-5 – international index of erectile functioning; IR – interquartile range

Table 4. The results of an objective examination of patients in comparison groups

| Indicator | Group I (n = 28) | Group II (n = 35) | P |
|-----------|-----------------|-----------------|---|
| BMU stricture length, mm | 10 (10; 15) | 15 (10; 15) | 0.267 |
| The smallest diameter of the lumen of the urethral stricture, mm | 1 (0.75; 2) | 1 (1; 2) | 0.906 |
| Complete obliteration of the urethral lumen, n (%) | 7 (25%) | 7 (20%) | 0.705 |
| Prostate volume, cm³ | 24.5 (20; 28.1) | 25 (20; 30) | 0.871 |
| The volume of residual urine, ml | 200 (80; 262) | 300 (124; 545) | 0.051 |
| The volume of residual urine more than 100 ml, n (%) | 20 (71.4%) | 28 (80%) | 0.769 |
| Qmax, ml/sec | 4 (2.9; 5) | 3 (1.8; 4.9) | 0.391 |
| V average, ml/sec | 2.85 (2; 4) | 2 (1; 3) | 0.108 |
| Lack of urination, n (%) | 4 (14.2%) | 7 (20%) | 0.617 |
| Diverticula and false urethral passages, n (%) | 2 (7.1%) | 6 (17.1%) | 0.294 |

BMU – the proximal part of the bulbar and membranous parts of urethra; Qmax – maximum urine flow rate; V – average flow rate
Table 5. Comparative data of the immediate results in both groups

| Indicator                                                                 | Group I (n = 28) | Group II (n = 35) | P     |
|---------------------------------------------------------------------------|-----------------|------------------|-------|
| Stay in the intensive care unit, n (%)                                    | 1 (3.5%)        | 1 (2.8%)         | 0.876 |
| Wound failure, n (%)                                                      | 0               | 0                |       |
| Hematoma in the area of operation, n (%)                                  | 0               | 0                |       |
| Urethrorrhagia, n (%)                                                     | 1 (3.5%)        | 0                |       |
| Subfebrile condition in the early postoperative period, n (%)             | 21 (75%)        | 29 (82%)         | 0.794 |
| Infectious complications, n (%)                                           | 0               | 0                |       |
| Urethral suture failure, n (%)                                            | 2 (7.1%)        | 0                | 0.120 |
| Severe pain syndrome (more than 7 points) in the first day after surgery, n (%) | 13 (46.4%)      | 2 (5.7%)         | 0.0033|
| Average length of hospital stay, days                                    | 16.0 ±3.8       | 12.27 ±3.5       | 0.0002|
| Postoperative incontinence, n (%)                                         | 5 (17.8%)       | 0                | 0.016 |
| Recovery of urine retention after surgery, n (%)                          | 0               | 3 (8.5%)         | 0.128 |
| Total continent patients after surgery, n (%)                             | 21 (75%)        | 29 (82.8%)       | 0.794 |

Table 5 presents a comparative description of the postoperative condition factors. Analysis of the study results showed that postoperative complications in the early and late postoperative periods developed extremely rarely. To determine the predictors of postoperative complications, univariate and multivariate logistic regression analysis was performed. The selection of predictor variables was carried out according to the initial parameters. Data concerning predictor factors for the occurrence of postoperative complications (univariate and multivariate logistic regression analysis) is presented in Table 6.

The results were used to build a predictive model for significant pain syndrome in multivariate regression analysis (selection of predictor factors with significance level p <0.05). The anastomotic urethroplasty (BP 15.1; 95% CI 1.3–164.5; p = 0.026) became a significant predictor of severe pain syndrome, and the remaining factors were not significant (p >0.05). An odds ratio of less than one indicates a protective effect, and more than one indicates a provocative effect of the revealed predictor variables. Based on this correlation, the degree of influence of the predictor on the development of complications was calculated.

Table 6. Predictors of postoperative complications

| Complications in the early postoperative period | Factor                                      | Univariate analysis | Multivariate analysis |
|------------------------------------------------|---------------------------------------------|---------------------|-----------------------|
|                                                |                                             | χ²     | BP (95% CI) | P     | BP (95% CI) | P     |
| Severe postoperative pain syndrome              | Age                                         | 4.38   | 0.9 (0.9–0.9) | 0.042 | 0.9 (0.8–1.0) | 0.182 |
|                                                | Disease duration                            | 1.5    | 1.0 (0.9–1.1) | 0.215 | –             | –     |
|                                                | Iatrogenic injury                           | 1.91   | 0.4 (0.1–1.4) | 0.164 | –             | –     |
|                                                | BPH                                         | 2.76   | 0.3 (0.06–1.3) | 0.111 | –             | –     |
|                                                | Perineal injury                             | 2.9    | 2.9 (0.8–10.7) | 0.094 | –             | –     |
|                                                | Pelvic injury                               | 9.34   | 8.1 (2.1–37.2) | 0.003 | 62.2 (0.9–4153) | 0.054 |
|                                                | Cystostomy drainage                         | 5.57   | 7.8 (0.9–65.9) | 0.058 | –             | –     |
|                                                | STI                                         | 3.72   | 3.75 (0.9–14.2) | 0.052 | –             | –     |
|                                                | Atherosclerosis                             | 5.12   | 0.2 (0.05–0.8) | 0.035 | 6.4 (0.1–387.5) | 0.371 |
|                                                | TU operations                               | 2.87   | 0.2 (0.05–1.4) | 0.123 | –             | –     |
|                                                | Significant residual urine volume           | 7.34   | 0.9 (0.9–0.9) | 0.033 | 0.9 (0.9–1.0) | 0.117 |
|                                                | Urethral stricture                          | 0.03   | 0.9 (0.9–1.0) | 0.864 | –             | –     |
|                                                | Operation duration                          | 0.23   | 1.3 (0.3–4.4) | 0.636 | –             | –     |
|                                                | EPA                                         | 13.76  | 14.2 (2.7–73.7) | 0.002 | 15.1 (1.3–164.5) | 0.026 |
|                                                | BMG                                         | 13.76  | 0.07 (0.01–0.36) | 0.002 | –             | –     |
|                                                | Delayed urethroplasty                       | 1.65   | 1.7 (0.7–4.1) | 0.193 | –             | –     |
| Incontinence                                  | Age                                         | 1.24   | 1.0 (0.9–1.1) | 0.312 | –             | –     |
|                                                | Severe LUTS                                 | 3.33   | 0.8 (0.7–1.0) | 0.082 | 1.7 (0.9–3.2) | 0.084 |
|                                                | ED before surgery                           | 0.83   | 3.9 (0.2–67.5) | 0.348 | –             | –     |
|                                                | Pelvic injury                               | 1.73   | 4.2 (0.5–33.5) | 0.176 | –             | –     |
|                                                | AMI                                         | 1.38   | 5.4 (0.4–69.4) | 0.192 | –             | –     |
|                                                | CVI                                         | 2.02   | 4.7 (0.5–38.5) | 0.142 | 0.4 (0.0–20.2) | 0.680 |
|                                                | Pathology of the spine                      | 1.68   | 4.1 (0.5–32.7) | 0.183 | –             | –     |
|                                                | TU operations                               | 4.36   | 1.3 (1.0–1.8) | 0.034 | 1.6 (0.7–3.9) | 0.229 |
|                                                | Prostate surgery                            | 2.51   | 5.6 (0.5–58.4) | 0.145 | 11.8 (0.3–412) | 0.173 |
|                                                | Prostate volume                             | 1.62   | 1.0 (0.9–1.0) | 0.187 | –             | –     |

BP – the probability of risk; CI – confidence interval; STI – sexually transmitted infections; BPH – benign prostatic hyperplasia; TU – transurethral; EPA – anastomotic surgery; BMG – substitutional intraurethral plastic; LUTS – symptoms of the lower urinary tract; ED – erectile dysfunction; AMI – acute myocardial infarction; CVI – chronic venous insufficiency
Therefore, the anastomotic method increases the likelihood of severe pain in the postoperative period by 15.1 times.

After the analysis of incontinence predictors after the anastomatic operation, the significance of previously performed transurethral (TU) operations (BP 1.3; 95% CI 1.0–1.8; p = 0.034) was revealed.

Postoperative indicators of urodynamics and functional status (IPSS, QoL, IIEF-5) for both groups are presented in Table 7.

A comparative intergroup analysis of these indicators was performed. A significant (p = 0.013) intergroup difference in the state of erectile function was noted: in Group II, this parameter was better than in Group I. Deterioration of the state of erectile function in Group I was reported for 13 (46.4%) patients; in the second group, no such complications were recorded (p = 0.003).

The Qmax intergroup analysis one month after the operation revealed no superiority of this urodynamic indicator in any of the groups [22.4 (19.8; 25.7) ml/sec for Group I; 22.1 (19.7; 24.3) ml/sec for Group II; p = 0.266].

The Qmax results demonstrate comparable effectiveness [18.9 (17.8; 22.6) ml/sec for Group 1 versus 19.8 (18.3; 21.2) ml/sec for Group 2] three months after the operation (p = 0.596). However, the final results [18.45 (15.5; 22.1) ml/s for Group I; 16.4 (13.7; 17.6) ml/s for Group II] showed superiority (p = 0.023) of this parameter (Qmax) in Group I.

The long-term results of stricture surgical treatment were evaluated according to the protocol check-points. The average clinical observation was from 736 days with a 95% CI of 613–860 days, to 1904 days maximum. The completeness of clinical observation of a total of 79 discharged patients (Group I and Group II) was 63 patients (79.7%).

For Group I patients, the average observation period was 686 days with 95% CI of 480–892 days (maximum period of 1850 days). For Group II patients – 778 days with 95% CI 621–935 days (maximum period 1904 days).

Figures 6 and 7 show a clinical example of retrograde urethrography in a patient before intraurethral urethroplasty and 2 years after surgery.

Remote results

In the distant postoperative period, a single episode of mortality in Group II was noted, however this was not connected with urethroplasty.

In the distant postoperative period, a number of significant complications were noted. In 5 (14.2%) cases from Group II and in 1 case (3.5%) from Group I, a severe inflammatory process of the urinary tract was observed in the period from 3 to 6 months, which required the administration of antibacterial therapy (p = 0.187). A logistic regression analysis of these complications did not reveal predictors of its occurrence.

Complaints about the shortening of the penis during an active survey 3 months after the operation were reported by 4 (14.2%) patients from Group I. In Group II, no such complaints were reported. It was surely estimated (p = 0.031) that there is a higher risk of shortening of the penis after anastomotic method (Group I), in comparison to the BMG method (Group II) with an initial length of urethral strictures of more than 2 cm.

Table 7. Postoperative indicators of urodynamics and functional status (IPSS, QoL, IIEF-5)

| Parameter                      | Group I (n = 28) | Group II (n = 35) | P     |
|-------------------------------|-----------------|-------------------|-------|
| IPSS, points                  | 7.5 (5; 12)     | 10 (8; 14)        | 0.080 |
| IIEF-5, points                | 10.5 (6.5; 14)  | 16 (12; 18)       | 0.013 |
| QoL, points                   | 1 (1; 3)        | 1 (1; 2)          | 0.970 |
| Qmax, ml/sec                  | 18.45 (15.5; 22.1) | 16.4 (13.7; 17.6) | 0.023 |
| Residual urine volume, ml     | 0 (0; 0)        | 0 (0; 0)          | 0.852 |
| The achieved diameter of the lumen of the urethra in the area of operation, mm | 7 (6; 8) | 6 (5; 7) | 0.064 |

IPSS – international prostate symptom score; IIEF-5 – international index of erectile functioning; QoL – the quality of life scale; Qmax – maximum urine flow rate

Table 8. Predictors of postoperative complications

| Complications in the early postoperative period | Factor            | Univariate analysis | Multivariate analysis |
|------------------------------------------------|-------------------|---------------------|-----------------------|
|                                                |                   | χ²                  | BP (95% CI)          | P        | BP (95% CI) | P        |
| Penis shortening                               | Age               | 0.52                | 0.9 (0.9–1.0)        | 0.464    | –          | –        |
|                                                | Disease duration  | 2.03                | 1.0 (0.9–1.1)        | 0.142    | –          | –        |
| Multivariate logit regression χ² = 10.25; p = 0.0059 | Pelvic injury     | 3.04                | 8.6 (7.9–104)        | 0.091    | –          | –        |
|                                                | Fistula of the US | 1.94                | 8.3 (5.0–120)        | 0.119    | –          | –        |
|                                                | EPA               | 4.63                | 3.9 (1.1–13.8)       | 0.031    | 36.4 (1.1–1116) | 0.039 |
|                                                | Failed EPA        | 5.26                | 19.2 (1.4–251.1)     | 0.024    | 5.36 (1.1–25.9) | 0.037 |

BP – the probability of risk; CI – confidence interval; US – urinary system; EPA – anastomotic surgery
To determine the predictors of the complication’s development, a univariate and multivariate logistic regression analysis was performed. The selection of predictor variables was carried out according to the initial parameters. Data concerning predictor factors for the occurrence of postoperative complications (univariate and multivariate logistic regression analysis) is presented in Table 8. The results were used to build a predictive model for penile shortening in multivariate regression analysis (choice of factors $p < 0.05$). Significant predictors of the occurrence of this complication were anastomotic plastic surgery ($BP = 36.4; 95\% CI 1.1–1116; p = 0.039$) and anastomotic insufficiency after EPA ($BP = 5.36; 95\% CI 1.1–25.9; p = 0.037$).

Table 9. The long-term comparative data on the success of urethroplasty

| Indicator                        | Group I (n = 28) | Group II (n = 35) | $p$  |
|----------------------------------|-----------------|-------------------|------|
| Successful primary, n (%)        | 24 (85.7%)      | 33 (94.2%)        | 0.796|
| Relapse, n (%)                   | 4 (14.2%)       | 2 (5.5%)          | 0.297|

Table 10. Cox proportional risk regression model

| Variable                        | Wald test | Cox Univariate Analysis | Cox Multivariate Analysis, $\chi^2 = 1.65; p = 0.033$ |
|---------------------------------|-----------|-------------------------|-----------------------------------------------------|
|                                 | $\chi^2$  | BP (95\% CI)            | $p$                                                   | BP (95\% CI) | $p$ |
| Age                             | 0.21      | 1.0 (0.9–1.0)           | 0.647                                                | –            | –   |
| Urethritis                      | 0.38      | 2.1 (0.1–25.5)          | 0.535                                                | –            | –   |
| Neurogenic disorders of urination| 4.27    | 6.3 (0.8–46.9)          | 0.038                                                | 1.6 (0.6–4.3) | 0.293|
| Pelvic injury                   | 1.96      | 4.9 (0.4–59)            | 0.161                                                | –            | –   |
| Permanent urethral catheter     | 1.99      | 6.2 (0.3–113)           | 0.158                                                | –            | –   |
| Purulent process of the US      | 1.69      | 3.6 (0.4–28.4)          | 0.193                                                | –            | –   |
| Prostate cancer                 | 2.06      | 6.2 (0.3–108)           | 0.151                                                | –            | –   |
| Contact with harmful substances | 5.04      | 9.3 (0.8–101)           | 0.024                                                | 1.1 (0.4–3.1) | 0.718|
| Pathology of the spine          | 6.19      | 11.9 (0.9–143)          | 0.012                                                | 1.0 (0.5–2.3) | 0.819|
| Hyperbaric oxygenation          | 2.67      | 0.2 (0.03–1.5)          | 0.102                                                | –            | –   |
| Late complications              | 5.5       | 6.9 (1.0–45.1)          | 0.019                                                | 0.5 (0.1–1.6) | 0.257|

US – urinary system; BP – the probability of risk; CI – confidence interval
DISCUSSION

The analysis of the effectiveness of existing treatment methods showed the feasibility of developing and introducing an alternative minimally invasive method of substitutional plastic surgery in case of narrowing the proximal part of the bulbar and membranous parts of the urethra. The new method should be comparable in effectiveness, have a lower risk of developing postoperative complications and fit several important criteria. Firstly, to minimize the risk of damage to the anatomical structures of the perineum, which are responsible for erectile function, the length of the erect penis and retention of urine. Secondly, to achieve comparable effectiveness in comparison to anastomotic methods, the technique of transplantation of autologous transplants should be optimized.

The prototypes for creating the BMG technique were the methods of urethral replacement with autologous grafts [26, 27], intraurethral methods of replacement of the bulbar urethra [28]. In addition, the experience of using other existing surgical methods was taken into account. As a result, it was possible to develop a new method for treating narrowing of BMU.

Other things being equal, such as group homogeneity and a single operation correction algorithm, restoration of normal urethral patency was achieved in both study groups. This result was evaluated on a number of parameters.

Analyzing the comparative intergroup effectiveness of the treatment based on the criteria established in the study, good treatment results were obtained in 6 (21.4%) patients from Group I and in 21 (60%) patients from Group II (p = 0.046). Satisfactory results were obtained in 18 (64.2%) patients from Group I and in 12 (34.2%) patients from Group II (p = 0.160). Unsatisfactory results were recorded in 4 (14.2%) patients of group I and in 2 (5.7%) patients of group II (p = 0.297).

It should be noted that the use of the developed method of BMG allows you to get better treatment results than the use of anastomotic methods. Both methods of urethroplasty are characterized by zero operating and hospital mortality and a low incidence of postoperative general and urinary system (US) related complications. Both methods are highly effective and safe when performing urethroplasty for strictures of the proximal part of the bulbar and membranous sections. However, the performance of anastomotic operations is associated with a risk of deterioration in the quality of life and sexual function.

The revealed statistical difference in the Qmax indicators analysis is due to the methodology of the op-
eration and does not affect the effectiveness of surgical treatment since the achieved result meets the most stringent assessment criteria (Qmax > 15 ml/s; achieved urethral lumen diameter of more than 5 mm) in both groups. According to subjective parameters (IPSS, QoL) and the volume of residual urine, no significant intergroup difference was found (p < 0.05). According to the final data analysis, 4 patients from Group I (14.2%) and 2 patients from Group II (5.7%) had a relapse (p = 0.297). The lack of statistical significance can be explained by the low recurrence rate and the relatively small sample size. The absence of relapse was equal in both groups (p = 0.190) during the entire observation period and after 2 years was 83.0 ± 7.9% (95% CI 60.1–93.4%) in Group I and 92.5 ± 5.1% (95% CI 72.7–98.1%) – in Group II. Based on complications analysis in the early postoperative period, a more pronounced pain syndrome was noted on the first day after the anastomotic operation (p = 0.0033). Multivariate regression analysis confirmed the data on the effect of the anastomotic method on the occurrence of significant pain syndrome (BP 15.1; 95% CI 1.3–164.5; p = 0.026). The theoretical justification for the difference may be greater operational injuries (larger wound size, mobilization, and dissection of perineal structures). Analysis of incontinence cases in Group I (n = 5; 17.8%) proved the provocative effect of previously performed TU operations (BP 1.3; 95% CI 1.0–1.8) (p = 0.034). These results are consistent with the findings of other researchers about the risks of urinary incontinence after previous transurethral operations and interventions on the prostate gland with the destruction of one or more elements of the sphincter. Performing anastomotic plastic surgery with a length of narrowing of more than 3 cm resulted in a shortening of the penis in 4 (14.2%) cases in Group I. In Group II, no such complaints were noted. Consequently, a negative effect of anastomosing urethroplasty on the postoperative parameters of the length of the penis was established reliably (p = 0.031) in comparison to those after BMG. Significant predictors of such a complication based on multivariate regression analysis are anastomotic plastic surgery (OS 36.4; 95% CI 1.1–1116; p = 0.039) and anastomotic insufficiency after EPA (BP 5.36; 95% CI 1.1; 25.9; p = 0.037), which confirms the conclusion.

The decrease in erectile function is moderate – none of the patients in Group I noted the development of impotence. However, erectile dysfunction (ED) reduces the quality of life and serves as an important marker of impaired blood supply to the spongy body of the urethra, which is important to consider in subsequent interventions on the urethra.

A comparative analysis of our results with previously published studies [6, 29–36] was carried out. It revealed that the work of these authors have several limitations: retrospective analysis (level 2b) or case-control studies (level 3b); lack of randomization; small sample size; lack of presentation of long-term clinical outcomes; lack of regular monitoring through the entire necessary set of studies (ultrasound, urethrography, urethroscopy). In almost all of these studies, an assessment of a decrease in erectile function was not performed, but only its persistent disappearance was recorded. The largest studies [5, 6] indicate a significant risk of ED and urinary incontinence after urethroplasty. In this case, no statistically significant difference in the risk of ED development was demonstrated between EPA methods and BMG substitutional surgery in general. Our findings are consistent with the literature, confirming the negative impact of common surgical techniques for performing urethroplasty on erectile function and urinary retention. Distinctive features of our study are: a prospective set of patients, the distribution into groups by randomization; a relatively large sample size for this pathology (102 patients included, and 63 patients completed the study in groups I and II) calculated when planning the study; homogeneity of groups according to initial characteristics, similar functional characteristics of patients; obligatory diagnostic algorithm before surgery and postoperative control for all patients; unified algorithm of surgical correction; presentation of immediate and distant clinical outcomes.

This study has a limitation - the average follow-up is less than 5 years. With continued observation, the results will be presented separately. Recruitment of patients for the study is ongoing. Currently, it includes 112 patients.

CONCLUSIONS

In both groups, the desired result was achieved – adequate independent urination was restored. The anastomotic method of urethroplasty should be used with caution in patients from risk groups, as well as with the presence of predictors of complications: previous transurethral surgeries on the urethra and prostate, anastomotic urethroplasty, radical prostatectomy. The developed minimally invasive substitution technique has a similar effectiveness with a lower risk of complications.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.
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DATA AVAILABILITY
Data will be available on request.

References

1. Palminteri E, Berdondini E, Verze P, De Nunzio C, Vitarelli A, Carmignani L. Contemporary urethral stricture characteristics in the developed world. Urolgy. 2013; 1: 191-196.

2. Buddha S. Complication of urethral catheterisation. Lancet. 2005; 9462: 909-913.

3. Davis NF, Quinlan MR, Bhatt NR, et al. Incidence, Cost, Complications and Clinical Outcomes of iatrogenic Urethral Catheterization Injuries: A Prospective Multi-Institutional Study. J Urol. 2016; 5: 1473-1477.

4. Chung PH, Esposito P, Wessells H, Voelzke BB. Incidence of Stress Urinary Incontinence After Posterior Urethroplasty for Radiation-induced Urethral Strictures. Urology. 2018; 114: 188-192.

5. Blaschko SD, Sanford MT, Schlomer BJ, et al. The incidence of erectile dysfunction after pelvic fracture urethral injury: A systematic review and meta-analysis. Arab J Urol. 2015; 1: 68-74.

6. Feng C, Xu YM, Barbagli G, et al. The relationship between erectile dysfunction and open urethral stricture: a systematic review and meta-analysis. J Sex Med. 2013; 8: 2060-2068.

7. Hosseini J, Soleimanzadeh Ardebili F, Fadavi B, Haghighatkhah H. Effects of Anastomotic Posterior Urethroplasty (Simple or Complex) on Erectile Function: a Prospective Study. Urol J. 2018; 2: 33-37.

8. Mundy AR, Andrich DE. Urethral trauma. Part II: Types of injury and their management. BJU Int. 2011; 5: 630-650.

9. Ignjatovic I, Stojkovic I, Basic D, Stankovic J, Potic M, Dinic L. Reconstruction of urethral strictures in patients with a long history of blind urethral dilatation. Urol J. 2014; 3: 1660-1665.

10. Leddy LS, Vanni AJ, Wessells H, Voelzke BB. Outcomes of endoscopic realignment of pelvic fracture associated urethral injuries at a level 1 trauma center. J Urol. 2012; 1: 174-178.

11. Pal DK, Kumar S, Ghosh B. Direct visual internal urethrotomy: Is it a durable treatment option? Urol Ann. 2017; 1: 18-22.

12. Wong SSW, Aboumarzouk OM, Narahari R, O’Riordan A, Pickard R. Simple urethral dilatation, endoscopic urethrotomy, and urethrolasty for urethral stricture disease in adult men. Cochrane Database Syst Rev. 2012; 12: CD006934.

13. Levine J, Wessells H. Comparison of open and endoscopic treatment of posttraumatic posterior urethral strictures. World J Surg. 2001; 12: 1597-1601.

14. Hudak SJ, Atkinson TH, Morey AF. Repeat transurethral manipulation of bulbar urethral strictures is associated with increased stricture complexity and prolonged disease duration. J Urol. 2012; 5: 1691-1695.

15. Wessells H, Agermeier KW, Elliott S, et al. Male Urethral Stricture: American Urological Association Guideline. J Urol. 2017; 1: 182-190.

16. Brant WO, Martins FE. Artificial urinary sphincter. Transl Androl Urol. 2017; 4: 682-694.

17. Zhu L, Zhou ZB, Shen D, Chen AM. Ipsilateral S2 nerve root transfer to pudendal nerve for restoration of external anal and urethral sphincter function: an anatomical study. Sci Rep. 2019; 1: 13993.

18. Yumashev AV, Utyuzh AS, Volchkova IR, Mikhailova MV, Kristal EA. The influence of mesodiencephalic modulation on the course of postoperative period and osseointegration quality in case of intraosseus dental implantation. Ind J Sci Tech. 2016; 9: 1-8

19. Andrich DE, Mundy AR. Non-transecting anastomotic bulbar urethroplasty: a preliminary report. BJU Int. 2012; 7: 1090-1094.

20. Jordan GH, Eltahawy EA, Virasoro R. The technique of vessel sparing excision and primary anastomosis for proximal bulbous urethral reconstruction. J Urol. 2007; 5: 1799-1802.

21. Tang S-H, Kao CC, Wu ST, Meng E, Cha TL. Inlay buccal mucosal graft for reoperative posterior urethroplasty. Kaohsiung J Med Sci. 2012; 4: 220-224.

22. Dabernig J, Shelley OP, Cuccia G, Schaff J. Urethral reconstruction using the radial forearm free flap: experience in oncologic cases and gender reassignment. Eur Urol. 2007; 2: 547-553.

23. Osman NI, Hillary C, Bullock AJ, MacNeil S, Chapple CR. Tissue engineered buccal mucosa for urethroplasty: progress and future directions. Adv Drug Deliv Rev. 2015; 82-83: 69-76.

24. Gomez-Iturriaga A, Crook J, Evans W, Saibishkumar EP, Jezioranski J. The efficacy of hyperbaric oxygen therapy in the treatment of medically refractory soft tissue necrosis after penile brachytherapy. Brachytherapy. 2011; 6: 491-497.

25. Vorobyev VA, Beloborodov VA. Mini-invasive reconstruction technique of the bulbomembranous urethra. Acta Biomedica Scientifica. 2018; 2: 91-96.

26. Gimbernat H, Arance I, Redondo C, Meilán E, Andrés G, Angulo JC. Treatment for long bulbular urethral strictures with membranous involvement using urethroplasty with oral mucosa graft. Actas Urol Esp. 2014; 8: 544-551.

27. Joshi P, Kaya C, Kulkarni S. Approach to bulbular urethral strictures: Which technique and when? Turk J Urol. 2016; 2: 53-59.

28. Welk BK, Kodama RT. The augmented nontransected anastomotic urethroplasty for the treatment of bulbular urethral strictures. Urology. 2012; 4: 917-921.

29. Al-Ba’adani TH, Al-Asbahi W, Al-Towaity M, et al. Urethral stricture Yemen experience. Int Urol Nephrol. 2010; 3: 703-708.

30. Corriere JN, Rudy DC, Benson GS. Voiding and erectile function after delayed one-stage repair of posterior urethral disruptions in 50 men with a fractured pelvis. J Trauma. 1994; 4: 587-590.

31. Feng C, Xu YM, Yu JJ, Fei XF, Chen L. Risk factors for erectile dysfunction in patients with urethral strictures secondary to blunt trauma. J Sex Med. 2008; 11: 2656-2661.
32. Fu Q, Zhang J, Sa YL, Jin SB, Xu YM. Recurrence and complications after transperineal bulboprostatic anastomosis for posterior urethral strictures resulting from pelvic fracture: a retrospective study from a urethral referral centre. BJU Int. 2013; 4: 358-363.

33. Koraitim MM. Predictors of erectile dysfunction post pelvic fracture.

34. Popken G, Sommerkamp H, Schulte-Seemann W, Wetterauer U, Katzenwadel A. Anastomotic stricture after radical prostatectomy. Incidence, findings and treatment. Eur Urol. 1998; 4: 382-386.

35. Santucci RA, Mario LA, McAninch JW. Anastomotic urethroplasty for bulbar urethral stricture: analysis of 168 patients. J Urol. 2002; 4: 1715-1719.

36. Shenfeld OZ, Kiselgorf D, Gofrit ON, et al. The incidence and causes of erectile dysfunction after pelvic fractures associated with posterior urethral disruption. J Urol. 2003; 6: 2173-2176.