



Major management of urethroplasty after trauma: a systematic review

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Abstract

Introduction: In the context of urethroplasty, epidemiological data show that urethral trauma accounts for approximately 4.5% of all genitourinary traumas. Most urethral traumas, both blunt and penetrating, result in complete urethral rupture, while the remaining 1/3 result in at least a partial urethral laceration. Urethroplasty remains a significant challenge in urethral and penile reconstruction, and the use of robotics and artificial intelligence is a significant tool for improving urethroplasty. **Objective:** This study aimed to present the main surgical approaches for urethroplasty after trauma or subsequent comorbidities, highlighting the use of robotic surgery and artificial intelligence to optimize surgical techniques. **Methods:** The PRISMA Platform systematic review rules were followed. The research was carried out from February to April 2026 in the Scopus, Embase, PubMed, Science Direct, SciELO, and Google Scholar databases. The quality of the studies was based on the GRADE instrument, and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** A total of 117 articles were found, and 35 articles were evaluated in full, and 12 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 25 studies with a high risk of bias and 27 studies that did not meet GRADE and AMSTAR-2. Most studies showed homogeneity in their results, with $X^2=81.1\%>50\%$. It was concluded that, regardless of the urethral injury pattern and treatment options, well-planned, rigorous follow-up with a urologist is of utmost importance for accurate assessment of outcomes and proper management of complications. Patient characteristics and needs should be considered before

developing a surgical plan. The tube-in-tube technique is the first choice for single-stage penile and urethral reconstruction for thinner patients. For other patients, a different flap can be used as a substitute for urethral reconstruction. Superficial circumflex iliac artery, pudendal-thigh, and pedicled scrotal flaps can be used to reconstruct the urethra. The tubularized superficial circumflex iliac artery flap and the pudendal-thigh flap are reliable, simple, and suitable for revision urethroplasty. Finally, buccal mucosal grafts with auxiliary maneuvers, such as flap interposition or transfer of adjacent tissue, in robotic reconstruction of the lower urinary tract are durable, safe, and comparable to open surgical approaches, especially when aided by the use of artificial intelligence to enhance urethroplasty.

Keywords: Urethral trauma. Urethroplasty. Surgical approaches. Robotic surgery. Artificial intelligence.

Introduction

In the context of urethroplasty, epidemiological data show that urethral trauma accounts for approximately 4.5% of all genitourinary traumas [1,2]. Furthermore, urethral rupture occurs in around 10.3% of blunt pelvic traumas and in up to 40% of penetrating penile traumas [3,4]. Most urethral traumas, both blunt and penetrating, result in complete urethral rupture, while the remaining 1/3 result in at least a partial urethral laceration [1].

Most urethral traumas are caused by blunt trauma, penetrating trauma, and/or iatrogenic injury. Most severe urethral injuries are due to blunt trauma caused by mechanisms such as motor vehicle collisions, kicks,

or falls [5]. Penetrating trauma accounts for about 10% of urethral injuries and results mainly from mechanisms such as gunshot wounds, stab wounds, or insertion of foreign bodies [4]. Iatrogenic urethral trauma accounts for less than 1% of urethral injuries and usually results from difficult urethral catheterization or transurethral procedures, such as prostate or tumor resection [4,6].

Most anterior urethral injuries (AUE) are caused by trauma that causes easy rupture of the epithelium and results in adverse effects such as hematuria and erectile dysfunction. However, most posterior urethral injuries (PUE) are caused by pelvic fracture and blunt trauma resulting from massive deceleration events or pelvic crush injuries. These injuries are often referred to as pelvic fracture urethral injuries (PFUE) because they are most commonly associated with a pelvic fracture [5-7].

Given this, urethroplasty remains a significant challenge in urethral and penile reconstruction. Currently, there is no recognized ideal method. Urethral reconstruction with an anterolateral thigh pedicle flap stands out, using modified techniques and alternative flaps. The characteristics and needs of patients must be considered before developing a surgical plan. Furthermore, the tube-in-tube technique is the first choice for penile and urethral reconstruction in a single stage for thinner patients. For other patients, a different flap can be used as a substitute for urethral reconstruction. In addition, the use of buccal mucosal grafts in robotic reconstruction of the lower urinary tract has been evidenced, as well as the use of artificial intelligence (AI) to improve urethroplasty [8,9].

Therefore, the present study aimed to identify the main surgical approaches for urethroplasty after trauma or subsequent comorbidities of this condition, highlighting the use of robotic surgery and artificial intelligence to optimize surgical techniques.

Methods

Study Design

This study followed the international systematic review model, following the PRISMA (preferred reporting items for systematic reviews and meta-analysis) guidelines. Available at: <http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1>. Accessed on: March 21, 2026. The AMSTAR-2 (Assessing the methodological quality of systematic reviews) methodological quality standards were also followed. Available at: <https://amstar.ca/>. Accessed on: March 21, 2026.

Data Sources and Search Strategy

The bibliographic search process was conducted from February to April 2026 and developed based on the Scopus, Embase, PubMed, Lilacs, Ebsco, Scielo, and Google Scholar databases, covering scientific articles from various periods up to the present day. The following descriptors (DeCS/MeSH Terms) were used: "Urethral trauma. Urethroplasty. Surgical approaches. Robotic surgery. Artificial intelligence", using the Boolean "and" between MeSH terms and "or" between historical findings.

Study Quality and Risk of Bias

Quality was classified as high, moderate, low, or very low based on the risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized controlled trials, followed by randomized clinical trials. Low-quality evidence was assigned to case reports, editorials, and brief communications, according to the GRADE instrument. Risk of bias was analyzed according to the Cochrane instrument by analyzing the funnel plot (sample size versus effect size) using Cohen's d test.

Data Analysis

A database was created in a Microsoft Excel spreadsheet, which was exported to the statistical programs Stata 18 and Minitab 18®. Common descriptive statistical analysis was performed using mean, standard deviation, and minimum/maximum values of general numerical clinical data. The Chi-square X^2 test was used to analyze the heterogeneity of the studies, with $X^2 > 50\%$ as homogeneous studies, and Cohen's d test was used to analyze the risk of bias, with $p < 0.05$ considered significant in the 95% CI.

Results

Summary of Findings

As a corollary to the literature search system, 117 studies were analyzed and submitted to eligibility analysis, and 12 of the final 35 studies were subsequently selected for this systematic review. The selected studies were of medium to high quality (Figure 1), considering, first, the level of scientific evidence of studies of meta-analysis, consensus, randomized clinical, prospective, and observational types. Biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies presented homogeneous results, with $X^2 = 81.1\% > 50\%$. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 25 studies with a high risk of bias and 27 studies that did not meet GRADE and AMSTAR-2.

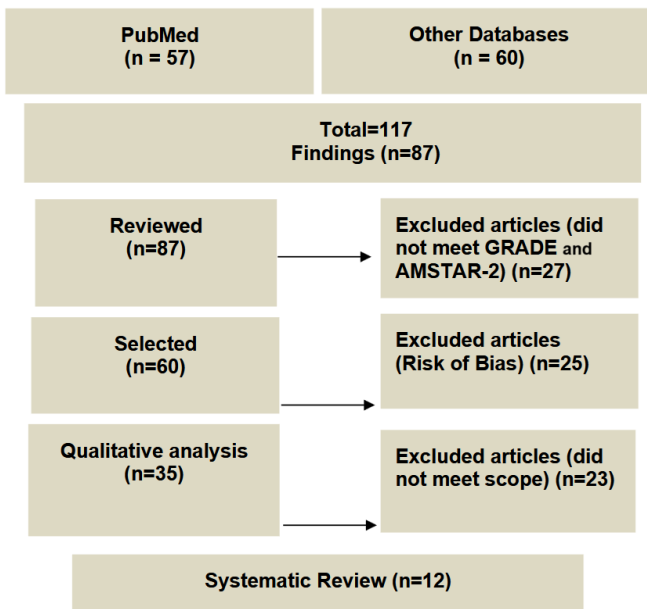


Figure 1. Flowchart showing the article selection process. Source: Own Authorship.

Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using Cohen's d Test. Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph showed symmetrical behavior, suggesting no significant risk of bias, either among studies with small sample sizes (lower precision), which are shown at the bottom of the graph, or among studies with large sample sizes, which are presented in the upper region.

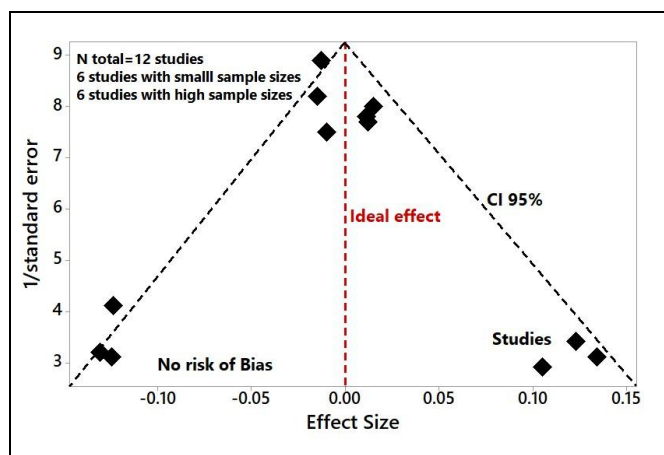


Figure 2. The symmetrical funnel plot suggests no risk of bias among the small-sample-size studies shown at the bottom of the graph. High-confidence and high-recommendation studies are shown above the graph (n=12 clinical studies). Source: Own Authorship.

Major Findings

In the field of urological trauma, retrograde urethrography remains the recommended initial diagnostic modality for assessing urethral injury. Iatrogenic urethral injury is frequently caused by

traumatic catheterization and is best treated with a catheterization attempt [1-3]. Penetrating trauma can cause anterior and/or posterior urethral injury and is best treated with early surgical repair. Blunt trauma, most commonly associated with injuries, can be treated with early primary endoscopic realignment or late urethroplasty after suprapubic cystostomy [10].

The authors Erickson et al. (2025) [11] validated a staging system for anterior urethral stenosis (AUS) based on the previously validated classification system of Length (C), Urethral Segment (S), and Etiology (E; LSE). The prospective database of the Urologic Trauma and Reconstructive Surgeons Network (TURNS) was used to create and validate the staging system. Five stages of mid-urethral stricture (aUSD), with a total of 10 substages, were finally created: stage I - short bulbar, stage II - long bulbar, stage III - penile/fossa of favorable etiology, stage IV - penile/fossa of adverse pathology, and stage V - panurethral (3 segments). The mean Urethroplasty Triad score decreased (increasing severity) at each substage, with the linear trend being validated both in the separate validation cohort and within the individual TURNS studies. LSE staging was superior to LSE score and U score in predicting the need for multiple stages or a non-orthotopic meatus and was similar in predicting surgical outcomes.

Also, the authors Jamil et al. (2023) [12] described the characteristics, management, and functional outcomes of patients with synchronous urethral stricture (EUS) using a multi-institutional cohort. Patients undergoing anterior urethroplasty for the treatment of urethral stricture (US) were included and stratified by the presence or absence of USE. A total of 1,983 patients were identified, of whom 137 (6.9%) presented with USE. The mean length of the primary stricture in patients with USE was 3.5 cm and 2.6 cm for secondary stricture. Twelve combinations of anterior urethroplasty techniques were used in the treatment of 27 different combinations of unilateral unicompartamental urethrocystitis (SUSD). Functional failure was observed in 18/137 (13.1%) patients with SUSD versus 192/1846 (10.4%) patients with isolated unicompartamental urethrocystitis (SUSD), p = 0.3. SUSD was not associated with an increased probability of functional failure. The S classifications: S1b (p = 0.003), S2a (p = 0.001), S2b (p = 0.01) and S2c (p = 0.02), and the E classifications: E3a (p = 0.004) and E6 (p = 0.03) were associated with an increased probability of functional failure.

The authors Patel et al. (2024) [13] evaluated through a retrospective study the impact of social deprivation, a measure of disadvantage at the area level, on the recurrence of urethral stricture after urethroplasty. The median age was 46.0 years, with a

median follow-up of 367 days for the 1452 men included in the study. Patients in the fourth quartile of the Social Deprivation Index (SDI) (worst social deprivation) were more likely to be active smokers with traumatic and infectious strictures compared to the first quartile of the SDI. Patients in the fourth quartile of the IPS had a 1.64-fold higher unadjusted risk of functional stenosis recurrence compared to patients in the first quartile of the IPS (95% CI 1.04-2.59). Compared with anastomosis ± excision, replacement-only repair had a 1.90-fold higher unadjusted risk of recurrence. The adjusted risk of recurrence was 1.08 per 10-point increase in the IPS (95% CI 1.01-1.15, $p = 0.027$).

Furthermore, the authors Wu et al. (2022) [14] share our experience in urethral reconstruction with an anterolateral thigh pedicle flap, using modified techniques and alternative flaps. A total of 49 patients underwent penile reconstruction with an anterolateral thigh pedicle flap; 17 patients had micropenis, 3 had iatrogenic defects, and 29 had post-traumatic penile defects. Different urethroplasty methods, complications, and revision methods were described separately. The tube-in-tube technique was used in 6 cases; the superficial circumflex iliac artery perforator flap (SCIAP) and the pudendal-thigh flap were used in 26 and 11 cases, respectively, and the scrotal pedicle flap was used in 6 cases. In 13 cases, revision urethroplasties were performed due to postoperative necrosis ($n = 3$), stenosis ($n = 8$), and fistula ($n = 2$). The urethral complications (flap necrosis, urinary fistula, and stenosis) were as follows: tube-in-tube flap, 66.7%; SCIAP flap, 46.2%; pudendal-thigh flap, 38.5%; and scrotal septum flap, 50%. After the revision procedures, all patients were able to urinate standing up.

A retrospective study conducted by the authors Pandher et al. (2025) [15] analyzed medical malpractice lawsuits arising from urethroplasty interventions in patients with urethral stenosis. After manual analysis of 128 cases in the LexisNexis and Westlaw databases, 12 met the inclusion criteria. Five (42%) cases were brought for genital deformity after urethroplasty, two (17%) for lack of informed consent, two (17%) for erectile dysfunction, one (8%) for postoperative venous thrombosis, one (8%) for postoperative infection, and one (8%) for negligence in treatment. Six (50%) cases resulted in compensation for the plaintiffs; three of them were settled before the final verdict. Compensation ranged from US\$72,500 to US\$810,000. Of the 12 cases, two (17%) occurred in California and two (17%) in Illinois; the rest occurred in isolated locations.

In advances in robotic surgery, the authors Liu et al. (2022) [16] describe through a retrospective study the technique, feasibility, and short-term results of

buccal mucosal grafts in robotic reconstruction of the lower urinary tract. Nine patient records of those who underwent single-port robotic posterior urethroplasty with buccal mucosal graft were reviewed. The mean age was 65.4 years. Robotic urethroplasty with buccal mucosal graft was performed to treat vesicourethral anastomotic strictures ($n=7$), urethral strictures ($n=4$), pubic fistula after robotic posterior urethroplasty ($n=1$), and anastomotic distraction ($n=1$). The strictures occurred after treatments for prostate cancer ($n=8$) and trauma ($n=1$). All patients had undergone previous unsuccessful endoscopic interventions: balloon dilation, bladder neck resection/incision, internal urethrotomy under direct vision, urethral stent placement, and posterior urethroplasty. The mean defect length was 3.9 cm. Five of the nine patients underwent ancillary procedures, including harvesting of rectus abdominis muscle flaps ($n=3$) and omental or gracilis muscle flaps (both $n=1$). No intraoperative complications occurred. The median operative time was 377 minutes, the blood loss was 200 mL, and the length of hospital stay was 2 days. Postoperative complications at 30 days included urinary tract infection, epididymitis, anemia, recurrent stenosis, and small bowel obstruction requiring surgery (all cases $n=1$). The median follow-up time was 11.7 months.

Given the results mentioned above, it is also worth noting that anterior urethral stenosis is increasingly treated with replacement urethroplasty, but the choice between graft and flap remains complex in varied phenotypes. Contemporary practice has turned to the oral mucosa, and new evidence emphasizes results that go beyond patency. Tissue-engineered oral mucosa and selected non-oral graft sources represent evolving options, particularly when the oral mucosa is limited [17].

Finally, recently, the authors Davis et al. (2026) [18] evaluated the complications of artificial urinary sphincter insertion after urethroplasty in a multi-institutional cohort. 178 cases performed by 17 surgeons (range 4 to 40) in 15 institutions were identified, with a median follow-up of 33.5 (interquartile range of 46) months. Complications related to the artificial urinary sphincter requiring explantation, including infection, erosion, and mechanical failure after transectant urethroplasty, occurred in 56.2% of cases, compared to 23.5% after non-transectant urethroplasty ($p<0.001$). The transectant urethroplasty technique correlated with a higher risk of device explantation, both due to erosion ($p=0.004$) and atrophy ($p=0.008$). Radiotherapy (HR, 0.46; 95% CI: 0.28-0.76; $p=0.002$), hypertension (HR, 0.44; 95% CI: 0.27-0.73; $P = 0.0008$), and patient age (> 68 years; HR, 0.5; 95% CI: 0.3-0.81; $p=0.004$) were also correlated with the risk of device explantation.

Limitations

There is a lack of randomized clinical trials with sufficient sample sizes, as well as more detailed methodological designs for techniques that employ artificial intelligence and robotics in urethroplasty. There are also information gaps regarding buccal mucosal grafts in urethroplasty, as well as a lack of scientific evidence for new urethral reconstruction techniques.

Conclusion

It was concluded that, regardless of the urethral injury pattern and treatment options, well-planned, rigorous follow-up with a urologist is of utmost importance for accurate assessment of outcomes and proper management of complications. Patient characteristics and needs should be considered before developing a surgical plan. The tube-in-tube technique is the first choice for single-stage penile and urethral reconstruction for thinner patients. For other patients, a different flap can be used as a substitute for urethral reconstruction. Superficial circumflex iliac artery, pudendal-thigh, and pedicled scrotal flaps can be used to reconstruct the urethra. The tubularized superficial circumflex iliac artery flap and the pudendal-thigh flap are reliable, simple, and suitable for revision urethroplasty. Finally, buccal mucosal grafts with auxiliary maneuvers, such as flap interposition or transfer of adjacent tissue, in robotic reconstruction of the lower urinary tract are durable, safe, and comparable to open surgical approaches, especially when aided by the use of artificial intelligence to enhance urethroplasty.

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Author contributions: Conceptualization; Data curation; Formal Analysis; Investigation; Methodology; Project administration; Supervision; Writing - original draft; Writing-review & editing- Fagner Henrique Costa, Heitor Brazil Ferlini Vidal, Rodolfo Brazil Ferlini Vidal.

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Conflict of Interest

The authors declare no conflict of interest.

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It was applied by Ithenticate®.

Application of Artificial Intelligence (AI)

Not applicable.

Peer Review Process

It was performed.

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