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Publication Date

2022-12-01

DOI

10.1016/j.urology.2022.09.006

Peer reviewed



The Outcomes of Pelvic Fracture Urethral Injuries Stratified by Urethral Injury Severity: A Prospective Multi-institutional Genitourinary Trauma Study (MiGUTS)

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OBJECTIVE

To determine patient outcomes across a range of pelvic fracture urethral injury (PFUI) severity. PFUI is a devastating consequence of a pelvic fracture. No study has stratified PFUI outcomes based on severity of the urethral distraction injury.

METHODS

Adult male patients with blunt-trauma-related PFUI were followed prospectively for a minimum of six months at 27 US medical centers from 2015-2020. Patients underwent retrograde cystourethroscopy and retrograde urethrography to determine injury severity and were categorized into three groups: (1) major urethral distraction, (2) minor urethral distraction, and (3) partial urethral injury. Major distraction vs minor distraction was determined by the ability to pass a cystoscope retrograde into the bladder. Simple statistics summarized differences between groups. Multi-variable analyses determined odds ratios for obstruction and urethroplasty controlling for urethral injury type, age, and Injury Severity Score.

RESULTS

There were 99 patients included, 72(72%) patients had major, 13(13%) had minor, and 14(14%) had partial urethral injuries. The rate of urethral obstruction differed in patients with major (95.8%), minor (84.6%), and partial injuries (50%) ($P < 0.001$). Urethroplasty was performed in 90% of major, 66.7% of minor, and 35.7% of partial injuries ($P < 0.001$).

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In conjunction with the Trauma and Urologic Reconstruction Network of Surgeons.

Funding Support: This study was supported by the American Association for Surgery of Trauma Multi-institutional Trials Committee. Support included critical review of trial design, central database design and implementation, and advertisement on the AAST website.

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Submitted: May 6, 2022, accepted (with revisions): September 8, 2022

Traumatic genitourinary injuries are observed in approximately 0.5 % of all trauma patients and considerably increase trauma-related morbidity and mortality.^{1,2} While urethral injury is relatively rare, comprising only 4% of all urologic trauma, it is present in up to 10% of patients with traumatic pelvic fractures.^{3,4} Pelvic fracture urethral injury (PFUI) occurs most commonly at the bulbomembranous junction, and is the result of the forceful sheering of the prostate and bulbomembranous urethra.^{5,6} Male patients are at a much higher risk for PFUIs due to a longer and less mobile urethra.⁷ Many patients with PFUI will subsequently develop urethral obstruction, erectile dysfunction, and urinary incontinence, which markedly reduce patient quality of life and increase burden on health care systems.⁸

Within PFUI there exists a wide spectrum of severity. The urethra can be partially or circumferentially transected, and the distance between to the two ends of the fully transected urethra can vary greatly among patients.⁹ Partial injuries consist of full thickness tears without complete circumferential disassociation of the mucosa.¹⁰ Complete urethral transection is defined as circumferential disassociation of the mucosa and adventitia of the urethra without any remaining continuity between the two severed urethral ends. Complete and partial injuries are commonly distinguished with a combination of retrograde urethrography (RUG), cystourethroscopy, and simple retrograde catheter placement. Partial urethral injuries often exhibit passage of radiological contrast into the bladder during RUG, will show at least some mucosal continuity on cystourethroscopy, and will often allow for successful blind urethral catheterization.⁵ Complete circumferential urethral injuries, on the other hand, infrequently allow passage of radiologic contrast into the bladder during RUG, and successful retrograde catheterization is often impossible even with the aid of a cystoscope. For minor distraction injuries, even though contrast material may not fill the bladder, it is often possible to navigate a retrograde placed cystoscope into the bladder, passing through the hematoma intervening between the urethral ends.

PFUI patients are affected with a wide spectrum of injury severities meriting different management strategies based on the severity level of the genitourinary damage. This is comparable to renal trauma patients who are categorized using severity scales to receive optimized treatments ranging from conservative management to immediate surgical interventions.^{11,12} The Committee on Organ Injury Scaling of the American Association for the Surgery of Trauma (AAST) introduced a scaling system for urethral injuries. According to AAST injury scale, major distraction roughly corresponds to grade 5, minor

distraction to grade 4, and partial injury to grade 3 injury scales.¹³ However, no effort has as of yet been made to more carefully categorize PFUI outcomes and management based on severity of urethral distraction.

In this multi-institutional prospective study, we aimed to compare the outcomes of major distraction, minor distraction, and partial injury PFUIs. We hypothesized that obstruction rates and the need for urethroplasty are higher in major and minor complete distraction injuries compared to partial urethral injuries.

MATERIALS AND METHODS

Study Design

This study was a prospective observational cohort study and was conducted in conjunction with the American Association for Surgery of Trauma Multi-institutional Trials Committee and the Trauma and Urologic Reconstruction Network of Surgeons. The study design and primary *a priori* hypotheses have been previously published.¹⁴ In brief, the main aim of the study was to establish the impact of endoscopic urethral realignment (EUR) vs suprapubic cystostomy tube (SPT) alone in major distraction injuries. Forty-two US medical centers joined the study from 2015 to 2020. Institutional review board approval was obtained by each participating site; 27 centers ultimately entered data included in the study. Data were managed using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at University of Utah. REDCap is a secure, web-based software platform designed to support data capture for research studies.¹⁵

Patient Cohort and Variables

Adult male patients presenting to a participating center with blunt-trauma-related PFUI were included. Included patients underwent retrograde cystourethroscopy as well as many who underwent RUG to determine injury severity, and they were categorized into three groups: (1) major distraction injury, (2) minor distraction injury, and (3) partial urethral injury. Major distraction injury was defined as a circumferential urethral injury combined with the inability to navigate a cystoscope retrograde into the bladder. Minor distraction injuries were defined as those with circumferential disruption, but the injury allowed for passage of a cystoscope retrograde into the bladder. Partial urethral injuries were defined as incomplete urethral disruption as seen on cystourethroscopy and RUG. Mechanism of injury (motor vehicle accident vs other), concomitant injury other than pelvic fracture (solid organ, gastrointestinal, spinal cord, major vascular, and bladder injuries), Injury severity score (ISS), and medical comorbidities were recorded and evaluated. Medical comorbidities were defined by those recorded within the National Trauma Databank and included: history of diabetes, stroke, peripheral vascular disease, cirrhosis, drug abuse, alcoholism, current smoking, myocardial infarction within the last six months, congestive heart failure, chronic obstructive pulmonary disease, and end stage renal disease.

Management and Outcomes Measures

Major distraction injuries were managed with either SPT alone or with SPT with early endoscopic urethral realignment within seven days of their injury depending upon the primary study design. The primary study showed no difference in outcomes between these treatment arms for either development of obstruction or need for urethroplasty, and for this reason major distraction injuries, regardless of their acute management, were pooled into one group. Minor distraction and partial injury patients were managed with Foley catheter and/or SPT placement depending upon surgeon preference.

The primary outcome was development of urethral obstruction which was identified by cystourethroscopy, urethrography, or failed passage of a catheter. The secondary outcome was the need for urethroplasty. Patients were followed for a period of at least six months after their injury for development of urethral obstruction, unless they were diagnosed with urethral obstruction prior to six months. Urethral obstruction during the follow-up period was diagnosed by cystourethroscopy, urethrography, or failed passage of a catheter.

Statistical Analysis

We performed statistical analysis using the Statistical Package for the Social Sciences (SPSS; version 28.0.1.0, SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were generated for covariates of interest, the results were expressed as the mean \pm standard deviation (SD) or median (Interquartile range (IQR): Q1-Q3 (25th percentile-75th percentile)) for continuous variables, and as frequencies for the categorical variables. The differences

between the outcomes for the groups with different injury types were analyzed using Fisher's exact test for continuous variables, and one-way analysis of variance (ANOVA) for categorical variables. Multi-variable analyses were carried out using a logistic model to determine the odds ratios (OR) and 95% confidence intervals (95% CI) for obstruction and need for urethroplasty controlling for injury types, age, and ISS. The level of significance was defined as P -value < 0.05 .

RESULTS

There were 136 patients enrolled in the study from 27 participating centers, of which 99 patients met inclusion criteria. 37 patients were excluded either because they were lost to follow-up (22), were not evaluated by cystourethroscopy (11), died from their injuries (2), or had penetrating mechanism of injury (2). Of the included patients, 72 (72%) patients suffered major distraction injuries, 13 (13%) patients had minor distraction injuries, and 14 (14%) patients had partial urethral injuries. Mean age was 40.3 (SD: 16.3) years for the whole cohort, 37.1 (SD: 16.1) years for the major distraction group, 48.3 (SD: 13.4) years for the minor distraction group, and 49.1 (SD: 15.2) years for the partial injury group ($P = 0.006$). Motor vehicle-associated trauma was the most common mechanism of injury and was observed in 65 (66.3%) patients. Nearly half of the patients (48.5%) were diagnosed with at least one major injury other than pelvic fracture, and 18.2% of patients had more than one other major injury. Medical comorbidities were observed in 28 (28.2%) of all patients (Table 1).

Table 1. Demographics and injury characteristics in PFUI patients with different injury severity including major distraction, minor distraction, and partial injuries.

	Total 99 (100%)	Major Distraction 72 (72.3%)	Minor Distraction 13 (13.1%)	Partial Injury 14 (14.1%)	<i>P</i> -value *
Age mean (SD)	40.3 (16.3)	37.2 (16.1)	48.3 (13.4)	49.1 (15.2)	0.006
BMI mean (SD)	27.5 (5.4)	27.0 (5.2)	26.8 (5.9)	30.3 (5.8)	0.107
Medical comorbidities ≥ 1 n (%)	28 (28.3)	19 (19.2)	5 (38.5)	4 (28.6)	0.672
ISS mean (SD)	28.8 (12.6)	29.4 (12.7)	23.3 (11)	30.9 (12.8)	0.251
Mechanism of injury-MVC n (%)	65 (66.3)	51 (70.8)	4 (33.3)	10 (71.4)	0.05
Concomitant injuries other than pelvic fracture – any n (%) ¹	48 (48.5)	35 (48.6)	6 (46.2)	7 (50)	1
Concomitant injuries other than pelvic fracture > 1 n (%) ¹	18 (18.2)	14 (19.4)	3 (23.1)	1 (7.1)	0.490
Solid organ injury n (%)	31 (31.3)	25 (34.7)	1 (7.7)	5 (35.7)	0.137
GI injury n (%)	13 (13.1)	8 (11.1)	4 (30.8)	1 (7.1)	0.135
Spinal cord injury n (%)	7 (7.1)	6 (8.3)	1 (7.7)	0 (0)	0.682
Major vascular injury n (%)	21 (21.2)	17 (23.6)	2 (15.4)	2 (14.3)	0.787
Bladder injury n (%)	23 (23.2)	19 (26.4)	4 (30.8)	0 (0)	0.059
Mean follow-up days median (IQR)	404 (234-725)	407.5 (244.5-665)	573 (202.5-825.5)	298.5 (231.25-752.5)	0.438

Abbreviations: SD: standard deviation; BMI: body mass index; ISS, injury severity score; MVC: motor vehicle collision; GI: gastrointestinal; IQR: interquartile range (Q1-Q3 (25th percentile-75th percentile)).

* Comparisons made between major distraction, minor distraction, and partial injury groups; Values that are significant at the 0.05 level are bolded.

¹ Defined as presence of any concomitant injury, including: solid organ, gastrointestinal, spinal cord, major vascular, and bladder injury.

Primary and Secondary Outcomes

According to the study protocol, patients in major distraction group were initially managed by EUR (37) or SPT placement (35). SPT was placed in ten minor distraction and nine partial injury patients. The remaining minor distraction (3) and partial injury (5) patients received a Foley catheter as their only initial treatment. Obstruction and urethroplasty rates were significantly different among the three groups. The rate of urethral obstruction was higher in patients with major distraction (95.8%) and minor distraction (84.6%) compared to partial injury (50%) patients ($P < 0.001$). Urethroplasty was performed in 90% of major distraction patients, 66.7% of minor distraction patients, and 35.7% of partial injury patients ($P < 0.001$) (Supplementary Figure 1). Eleven patients were diagnosed with urethral obstruction during the study period but did not undergo urethroplasty (6 major distraction, 3 minor distraction, and 2 partial injuries). Treatment of these patients included multiple dilations without urethroplasty in the study period in one patient in the major distraction group, one patient in the minor distraction group, and two patients in the partial injury group. One patient with a major distraction injury elected to keep the SPT and did not receive any further interventions. Six patients were lost to follow-up after they were diagnosed with urethral obstruction (4 major distraction and 2 minor distraction) (Supplementary Figure 2).

Mean follow-up time for the total cohort was 404 (IQR:234-725) days; 407.5 (IQR:244.5-665) days for major distraction, 573 (IQR:202.5-825.5) days for minor distraction, and 298.5 (IQR:231.3-752.5) days for partial injury ($P = 0.438$). Mean time to diagnosis of obstruction was 97 (IQR:57.5-124.5) days for major distraction injuries, 89 (IQR:47-173) days for minor distraction, and 48 (IQR:37-199) days for partial injury ($P = 0.669$). Mean time to urethroplasty was 125 (IQR:107-204) days for major distraction injuries, 233 (IQR:164.3-399.8) for minor distraction, and 153 (IQR:107-412) days for partial injury patients ($P = 0.014$) (Table 2).

Adjusted Analysis

In the adjusted multivariable analysis with the outcome of urethral obstruction, partial urethral injury had an OR of 0.06 (95% CI 0.01-0.36, $P = 0.002$) compared to major distraction injury. Increased age was also associated with decreased odds of urethral obstruction (OR 0.92, 95% CI 0.87-0.97, $P = 0.007$) (Table 3). The analysis for urethroplasty demonstrated OR of 0.09 in partial injury patients (95% CI 0.02-0.38, $P = 0.001$), and OR of 0.96 for increased age (95% CI 0.92-1, $P = 0.04$) again compared to major distraction injury (Table 4).

DISCUSSION

In this prospective multi-institutional observational cohort study, we found higher rates of urethral obstruction and urethroplasty in patients with complete circumferential urethral disruptions, including major and minor distraction injuries, in comparison with patients with partial PFUIs. Our findings demonstrate that there is a spectrum of severity in PFUI, with a clear delineation in rates of urethral obstruction and need for urethroplasty between the three injury categories. PFUI is similar to many traumatic injuries in that severity dictates management and outcomes.

The incidence rate of partial and complete urethral injuries broadly varies in previous published studies ranging from 3% to 94% for partial injuries among all PFUIs.¹⁶ Webster et al reviewed urethral injuries reported between 1964 to 1981 and determined an incidence rate of approximately 35% for partial urethral injuries.⁹ Mouraviev et al retrospectively reviewed records of PFUI patients from 1984 to 2001, and concluded 37% incidence rate for partial injuries. In a more recent study, Chung et al reported 13% incidence rate for partial urethral injuries among PFUIs. However, their study only included four

Table 2. PFUI management, primary (obstruction) and secondary (urethroplasty rates) outcomes.

	Total 99 (100%)	Major Distraction 72 (72.7)	Minor Distraction 13 (13.1)	Partial Injury 14 (14.1%)	P-value*
Pelvic angioembolization n (%)	20 (20.2)	16 (22.2)	1 (7.7)	3 (21.4)	0.611
Total dilations n (%)	10 (10.3)	6 (8.6)	1 (7.7)	3 (21.4)	0.306
SPT n (%)	91 (91.2)	72 (100)	10 (76.9)	9 (64.3)	0.000
Primary outcome					
Obstruction n (%)	87 (87.9)	69 (95.8)	11 (84.6)	7 (50)	0.000
Days to obstruction median (IQR)	91 (55-128)	97 (57.5-124.5)	89 (47-173)	48 (37-199)	0.669
Secondary outcome					
Urethroplasty n (%)	76 (79.2)	63 (90)	8 (66.7)	5 (35.7)	0.000
Days to urethroplasty median (IQR)	140.5 (109-210.25)	125 (107-204)	233 (164.25-399.75)	153 (107-412)	0.014
Why no urethroplasty?	6 Lost F/U 4 Dilations 1 SPT	4 Lost F/U 1 Dilatation 1 only SPT	2 Lost F/U 1 Dilatation	2 Dilations	Why no urethroplasty?

Abbreviations: SPT: suprapubic cystostomy tube; IQR: interquartile range (Q1-Q3 (25th percentile-75th percentile)); F/U: follow-up.

* Comparisons made between major distraction, minor distraction, and partial injury groups; Values that are significant at the 0.05 level are bolded.

Table 3. Adjusted multivariable analysis demonstrating OR for primary outcome, urethral obstruction.

Variable	Odds ratio for obstruction	Low 95 CI	High 95 CI	P value
Major distraction (Intercept)	-	-	-	-
Minor distraction	0.29	0.03	2.32	0.24
Partial injury	0.06	0.01	0.36	0.002
Age (years)	0.92	0.87	0.97	0.007
ISS	0.95	0.89	1.02	0.182

Abbreviation: ISS: injury severity score.

Odds ratios that are significant at the 0.05 level are bolded.

patients with partial urethral injuries.¹⁷ The rarity of PFUI patients, even at tertiary referral centers, is a considerable limitation in this field of study. A substantial number of investigations reported only few partial urethral injury patients.¹⁷⁻¹⁹ Variability in the rate of partial PFUI may arise from different injury mechanisms or severity of injury. For instance, it has been demonstrated that the rate of PFUI is declining in the US but perhaps injuries are more severe when they occur.²⁰ Another explanation is that some minor distraction defects may have been categorized by some studies as partial urethral injuries because placement of a catheter was feasible in a retrograde fashion. The AAST scaling system for urethral injuries utilized data of patients who were evaluated by RUG on admission. However, RUG can be associated with low diagnostic value to distinguish between complete and partial defects due to the contraction of the external sphincter that may prevent the passage of contrast dye into the bladder.¹³ PFUI patients included in the present study were evaluated by cystourethroscopy, as well as many who underwent RUG, to provide precise anatomic assessment of the defects.

According to the American Urological Association (AUA) Urotrauma Guidelines, prompt urinary drainage in the setting of PFUI is the urologist's first priority.¹¹ Full transection injuries require immediate placement of an SPT in nearly all cases to provide urinary drainage unless a urethral realignment procedure is performed promptly. The European Association of Urology (EAU) guidelines indicate that partial urethral injuries can be conservatively managed by SPT placement or urethral catheterization.¹² Although guidelines suggest that partial PFUIs can be managed with simple urethral catheterization without subsequent urethral fibrosis or obstruction,²¹ some studies reported that indeed urethral obstruction occur in almost all partial urethral injuries.^{5,22,23} In this study, we found that up to half of partial PFUIs developed urethral obstruction and required further urological interventions.

The results of our study and the others mentioned, emphasizes that this group of patients should be closely monitored for development of stricture and requirement of further urological interventions.

It is novel to consider minor distraction defect category in PFUI. These defects were considered as a separate group due to the primary aim of this prospective study, reported elsewhere, which was to evaluate the difference in outcomes between urethral realignment vs SPT placement alone for major distraction defects. In order to accomplish this goal, and to minimize inclusion bias of less severe injuries we aimed to compare major distraction defects that necessitated combined antegrade – retrograde realignment only. Thus, we needed to exclude urethral injuries where a catheter was placed with the aid of a retrograde cystoscope. The logic in excluding these patients, other than avoiding inclusion bias, is that most urologists would agree that placement of a retrograde catheter if feasible with a simple cystourethroscopy may benefit patients and simplify management in some cases in the immediate post trauma period. We found that altogether, minor distraction injuries had a more benign behavior in comparison with major distraction defects, given that obstruction and urethroplasty rates were lower. Also, our results demonstrated that older PFUI patients were less prone to urethral obstruction and need for urethroplasty. We think this could be due to a protective effect of increased prostate size in older patients. This is an intriguing finding and merits further evaluation in future investigations.

The key strengths of this study were its prospective design and very robust inclusion and exclusion criteria. However, the study has limitations. Although this is a national study with 27 US centers contributing for over five years, this study is still limited by the low number of patients with partial and minor distraction injuries. Additionally, a follow-up period of only six months may be insufficient to demonstrate obstruction, especially in patients with partial injury treated with a Foley catheter.

Table 4. Adjusted multivariable analysis demonstrating OR for secondary outcome, urethroplasty rates.

Variable	Odds ratio for urethroplasty	Low 95 CI	High 95 CI	P value
Major distraction (Intercept)	-	-	-	-
Minor distraction	0.26	0.05	1.25	0.09
Partial injury	0.09	0.02	0.38	0.001
Age (years)	0.96	0.92	1	0.04
ISS	0.97	0.92	1.02	0.27

Odds ratios that are significant at the 0.05 level are bolded.

We were also unable to determine minor distraction and partial injury incidence rates as some of the participating center excluded these patients. Additionally, we were unable to evaluate the outcomes of urethroplasty due to variability in surgical management and follow-up after the surgery, considering the on-going debate about the optimal follow-up methods.²⁴ Also, we did not compare sexual function and measurement of urinary incontinence between the groups as we were unable to collect patient-reported outcome measures (PROMs) with any consistency. Partial urethral injury management was left to the treating surgeon leading to management variability. Therefore, we were not able to compare differences in management of partial injuries.

CONCLUSION

There is a spectrum of severity in PFUI, with a clear delineation in rates of obstruction and need for urethroplasty. Partial PFUIs are associated with lower risks of developing urethral obstruction and need for further urological interventions compared to complete circumferential urethral injuries of any severity. However, patients with partial PFUI still need to be carefully monitored for development of obstruction.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.urology.2022.09.006>.

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